Preliminary results of ^{137}cs activity in a soil erosion toposequence in cuenca (castilla-la mancha, central spain)

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INTRODUCTION

The soil redistribution due to the conventional tillage practices represents a very severe process of soil erosion and degradation in Mediterranean agricultural lands. The existing methods for soil erosion assessment can be grouped into two main categories: erosion modelling and prediction methods and erosion measurement methods. The use of environmental radionuclides, in particular ^{137}Cs, overcomes many of the limitations associated with traditional approaches and has been shown as an effective way of studying erosion and deposition. Its determination and the study of the characters of soils in a sequence permits know the control of the erosion. The pioneer work on this method was developed by Ritchie and McHenry in the United States (McHenry et al 1973, Ritchie et al. 1973). The technique has been intensively applied and improved in many countries during the last several decades (Walling and Quine 1990, Navas 2007, etc.). Zapata et al. (2003) presented the recent advancements and future developments related to the technique.

The distribution of ^{137}Cs, in the environment began with atmospheric testing of thermonuclear weapons, primarily in the period from 1954 to mid 1970s. The objective of this study was to determine the soil erosion rates using ^{137}Cs activities concentrations in a typical Mediterranean environment: the Chillaron basin (Cuenca, Castilla-La Mancha, Spain).

MATERIALS AND METHODS

The study area, located in the province of Cuenca in Castilla-La Mancha (Central region of the Iberian Peninsula), is part of the Chillarón basin. Geological formations which extend throughout the stratigraphy: from marls, conglomerates, gypsums, sands more or less clayies, clays, silts, and gravels. The climate is temperate mediterranean modified by continental condictions. This is a typical continental mediterranean climate, with 507 mm average annual precipitations and 12.6ºC average mean annual temperature, with hot summers and cold winters (data of Cuenca meterological station situated on 956 m., period 1971-2000). The potential climax vegetation is a *Quercus ilex* forest, but in the region over half of the soils are occupied by crops. The actual vegetation is the result of a complex interactive networks of a large number of various factors (floristic, climatic, pedologic and antropic impacts).

The transect are situated under forest (Quercus ilex and Pinus nigra) and cultivated land use (cereals mainly). Transect were chosen along the valley bottom from the head towards the basin's outlet. The altitudes range between 923 and 892 m. above the sea level. The basin is characterised by slopes varying around 2 to 20%. Lithology, tillage erosion and sedimentation have been taken into consideration. Common tillage practices consist of passing a duckfoot chisel plough by a tracker tractor weeds and to enhance infiltration.

The cross-sections and thalweg profiles were sampled. Samples soil transect extending downslope and perpendicular to the direction of stream flow. We have selected ten soil samples, based on the slope position, soil types and its variety of properties (table 1). Each sample included a total of 4 sampling sites to a depth of 0 to 0.15 m. The sampling sites were chosen to represent all landform types including primitive forest areas, deteriorated forest, and agricultural soils. An extensive reforestation programme was carried out during the 1960s to prevent soil erosion processes.

Table 1. General description and macromorphological characteristics of soil samples

Soil Sample	**Location/ Coordinates**	**Horizon Type**	**Vegetation/ use**	**Topography**	**Altitude (m)**	**Colour**	**Stoniness (%)**
1	40º 03’ 25,1” 2º 12’ 14”	A_h	Forest	Flat	923	10YR 4/3	1
2	40º 03’ 28,3” 2º 12’ 19,9”	A_h	Forest	Flat	919	10YR 4/3	1
3	40º 03’ 29,3” 2º 12’ 24,4”	A_h	Forest/ reforestation	Flat	920	10YR 5/6	10
4	40º 03’ 25,6” 2º 12’ 12,6”	A_h	Scrub/ pasture	Flat	920	5YR 4/4	10
5	40º 03’ 25,8” 2º 12’ 12,3”	A_p	Dry farming	Slope	919	5YR 5/7	5
6	40º 03’ 26,1” 2º 12’ 10,3”	A_p	Dry farming	Slope	914	5YR 5/6	5
7	40º 03’ 26,6” 2º 12’ 5,4”	A_p	Dry farming	Slope	908	5YR 4/6	
8	40º 03’ 27,9” 2º 11’ 56,5”	A_p	Dry farming	Ridge	899	5YR 5/8	5
9	40º 03’ 29” 2º 11’ 55”	A_p	Dry farming	Terrace	897	5YR 4/8	5
10	40º 03’ 29,7” 2º 11’ 49,6”	A_p	Dry farming	Valley botton	892	10YR 3/3	10

Once in the laboratory, the samples have been dried to the air, later sieved by 2 mm. Each aliquot was divided into two parts; one was used to determine soil properties. The radiochemical analyses were performed using the other part. In the soil samples we measured: pH (in H_2O and KCl, in relation s/w 1:2,5); electrical conductivity (relation s/w 1:5); particle size (by sedimetology); calcium carbonate (valoration acid-base); organic matter content (Wackley Black).

The activity concentrations of ^{137}C isotope of the < 2 mm fraction in each sample were determined by gamma-spectrometry with semiconductor detector, using a germanium detector manufactured by Canberra linked to a standard electronic chain. The typical mass amount of every sample exceeded 400 g d.w. and 137Cs was measured at 661.6 keV. Counting times were typically about 28,800 s, providing a measurement accuracy of ca. ± 6% at the 95% level of confidence. The reference of experimental method is Hurtado et al (2004).

RESULTS AND DISCUSSION

The sand, clay and silt contents of the soil samples increase with depth valley (table 2). In the surface forest, coarser fractions are more abundant. The clay contents vary from 3% to 21%.

Clays might have been transported in suspension down the toposequence, but we cannot exclude the possibility that fine soil particles could have been removed from the soil surface in runoff. The sand fraction decreased with depth of sequence (84% to 58%). This pattern of particle-size distribution in all soil samples may facilitate water infiltration in the topsoil and transport ^{137}Cs through it to deeper levels where it can be adsorbed on finer particles.

Table 2: Chemical and physicochemical properties of soil samples

Sample	pH H_2O	pH KCl	10^{-3} dS/m	$CaCO_3$ %	O.M. %	Sand %	Silt %	Clay %
1	7,4	6,8	47,9	0	3,32	84	13	3
2	7,4	6,9	56,7	0	2,14	82	14	4
3	7,1	6,4	23,1	0	0,79	84	13	3
4	8,2	7,6	90,9	1,1	2,97	82	10	8
5	8,8	7,8	59,1	15,2	0,7	74	13	13
6	8,6	7,8	77,6	5,9	1,04	78	8	14
7	8,6	7,5	67,8	0	1,13	72	10	18
8	8,6	7,6	71,8	0	0,82	76	10	14
9	8,8	7,8	60,9	3,4	0,61	82	10	8
10	8,6	7,6	109,3	24,5	2,55	58	21	21

The organic matter content (table 2), was larger in soils of the forest (upper slope) that in valley bottom, By contrast, the pH and electrical conductivity ranges increased gradually from the upper surface to the deepest surface; reaction ranges from neutral to subalkaline, influenced by the high amounts of carbonates. Average carbonate contents differed among soil samples. Conde et al 2008, when analyzed a series of parameters of the soils that define their vulnerability, such as pH, electrical conductivity, carbonate content, texture, with emphasize the clay mineralogy, deduced that the soils of La Mancha have sufficient capacity of depuration.

Differences were found in radionuclide activities between samples (table 3). The interval of ^{137}C radioactivity was from 12.7 and 5.1 Bpkg^{-1}. It was concluded that not existing soils were affected with high levels of radiosotopes. Differences were found in radionuclide activities between transect. The smallest activities were on the valley botton and the largest ones under the forest.

Table 3. Bulk density, activity concentrations of ^{137}Cs and erosion rates.

Soil Sample	**Bulk density g cm^{-1}**	**^{137}C inventory Bpkg^{-1}**	**Erosion rate ^{137}C Jong et al. (1983) method Mg ha^{-1} year^{-1}**	**Erosion rate ^{137}C Zhang et al. (1990) method Mg ha^{-1} year^{-1}**
1	1,062	12,7	reference	Reference
2	1,233	10,1	reference	Reference
3	1,284	8,6	reference	Reference
4	1,435	4,2	28,66	19,68
5	1,452	2,8	33,64	27,19
6	1,303	2,9	35,00	27,91
7	1,314	3,4	33,83	25,33
8	1,284	3,6	29,95	21,91
9	1,464	2,7	38,08	31,22
10	1,422	5,1	26,79	16,94

For each sample ^{137}Cs inventories were converted into erosion rates using Jong et al. (1983) and Zhang et al. (1990) methods. Across the soil toposequence, soil erosion rates varied between 26,79 and 38,08 Mg ha^{-1} year^{-1}, (or between 16.94 and 31,22 according to applied method); with a mean of 29.4 Mg ha^{-1} year^{-1}. Accordingly, positive values of ^{137}Cs redistribution in the profile would represent points of sediment deposition. If the relationship between ^{137}Cs concentration and soil loss or gain be established, it would be possible to estimate soil erosion or deposition rates according to ^{137}Cs concentration measurements. Further detailed studies will be necessary to confirm the results.

CONCLUSIONS

^{137}Cs activity and derived soil erosion, distributed in the topsoil layer (0–0.15 m) from a soil toposequence was determined. The smallest ^{137}Cs activities were on the valley botton and the largest ones under the forest (2,7-12,7 Bpkg^{-1}). Soil erosions vary greatly in the entire sampled area, ranging from 26,79 to 38,08 Mg ha^{-1} year^{-1}, (or between 16.94 to 31.22 according to applied method); with a mean of 29.4 Mg ha^{-1} year^{-1}, which is a moderate to high rate of erosion. But further detailed studies will be necessary to confirm the results.

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