SOIL ORGANIC MATTER PATTERNS IN RELATION TO SOIL REDISTRIBUTION IN A CULTIVATED FIELD

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Introduction

Mediterranean agroecosystems are particularly sensitive to soil degradation mainly due to climatic characteristics (scarce and irregular precipitations and drought summer) and undeveloped and shallow soils with low soil organic matter content (<2%) (Quijano *et al*. 2014b).

Soil degradation is related to the decline of soil quality affecting soil fertility of cultivated soils (Lal 1991). The depletion of soil organic matter can be related to soil erosion (Quijano *et al*. 2014a) and may be a reliable tool for a quantitative assessment of soil degradation (Navas *et al*., 2011).

Soil organic matter (SOM) is an important soil quality indicator related to soil structure and aggregate stability which are important soil characteristics to soil productivity and agricultural sustainability.

Caesium-137 (^{137}Cs) has been used as an effective tracer of soil erosion in Mediterranean soils (Navas *et al*. 2007). ^{137}Cs is an artificial radionuclide (half-life 30.2 yr) produced by nuclear testing which occurred from the mid-1950s until mid 1970s. After deposition at the soil surface, ^{137}Cs is rapidly and strongly adsorbed by clay and SOM (Walling *et al*. 1995). In cultivated soils ^{137}Cs is homogeneously distributed throughout the plough layer by tillage and its spatial redistribution is essentially controlled by soil erosion and deposition processes.

Objective: to examine the effect of soil redistribution processes on the distribution of soil organic matter using ^{137}Cs to identify eroded and depositional areas in a Mediterranean cultivated field.

Materials and Methods

The study field is a representative rainfed Mediterranean agroecosystem located in the central part of the Ebro river basin (42˚25´37´´N, 1˚13´12´´W)(**Fig. 1**). The climate is continental Mediterranean

- Mean elevation 630 m a.s.l
- Mean annual temperature 13.4 ˚C (ranging from 5 ˚C in January to 24 ˚C in June)
- Mean annual rainfall 500 mm mainly occurring in spring (April and May) and autumn (September and October).

Figure 1 Location of the study area

The study field (1.6 ha) is under cultivation since the last 150 years with winter cereal crops as wheat (*Triticum aestivum*) and barley (*Hordeum vulgare*) (**Figs. 2a and b**).

Soils in the study area are Calcisols developed on Quaternary deposits mainly formed by silt, sand and gravel.

Figure 2 a) 3D view of the study area b) Photo of the cultivated field

- **SOM, ^{137}Cs massic activity and grain size** were measured on the <2 mm (**Fig. 3**). SOM (%) was determined by a Mettler Toledo titrimeter and electrode. The ^{137}Cs massic activity (Bq/kg) was measured using high resolution, low background, low energy, hyperpure coaxial gamma-ray germanium detector coupled to an amplifier and multichannel analyzer. Particle size fractions were analyzed using a Beckman Coulter LS 13 320 laser diffraction particle size analyzer.
- The assessment of **^{137}Cs redistribution** was based on the comparison of measured inventories at each sampling point with the reference inventory of the study area which was established by sampling stable sites (not affected by erosion or deposition.) If sample inventories are lower than the reference inventory, loss of soil and therefore erosion may be inferred. Sample inventories higher than the reference inventory indicate soil deposition.
- The **spline interpolation** method was used to perform the spatial variability of the soil properties into a continuous map using ArcGIS 10.2.1.

Figure 3 Sampling points (n=156) on a 10x10 grid

Results

1. Soil properties

SOM and coarse fraction (>2 mm) contents were low (**Table 1**). Most of the soil samples (81%) had a silt-loam texture: silt ranging from 50 to 71.9%.

Table 1 Basic statistics of the soil properties for the soil samples (n=156).

	mean	median	s.d	CV %	min	max	range
>2 mm %	1.1	0.4	2.2	201.2	0.0	16.9	16.9
Clay %	19.0	18.9	6.0	31.5	5.3	56.5	51.2
Silt %	57.6	60.3	10.0	17.3	18.9	71.9	53.0
Sand %	23.4	20.5	13.3	56.8	3.5	74.3	70.8
SOM %	1.2	1.2	0.3	24.5	0.5	2.6	2.1
^{137}Cs Bq/kg	2.5	2.4	1.0	39.0	0.3	5.7	5.7
^{137}Cs Bq/m^2	1374.4	1279.5	668.5	48.6	0.0	4094.2	4094.2

s.d standard deviation; CV coefficient of variation

2. SOM correlations

SOM was positively and significantly correlated with the ^{137}Cs massic activity and with the fine soil fractions but inversely correlated with the coarse and sand fractions (**Table 2**).

Table 2 Pearson correlation coefficients between SOM and soil properties

n=156	>2 mm %	Clay %	Silt %	Sand %	^{137}Cs Bq/kg	^{137}Cs Bq/m^2
SOM %	**-0.307**	**0.455**	**0.349**	**-0.466**	**0.320**	0.084

Bold values are significant at p≤0.05

SOM, clay, silt and ^{137}Cs are clearly associated.

3. SOM and ^{137}Cs

The **SOM** mean for stable sites: **3.4%** → 3 times the mean of SOM in the study field

► A generalized loss of SOM in comparison with the reference site.

► SOM decline is clearly linked to tillage after forest was converted to cultivated land.

^{137}Cs stable sites: **1507** Bq/m^2 → In the field: 65% Eroded 35% Depositional sites

► There was a predominance of soil erosion over deposition.

► Slightly **lower mean SOM** content at eroded sites (1.14±0.3%) than at depositional ones (1.16±0.3%).

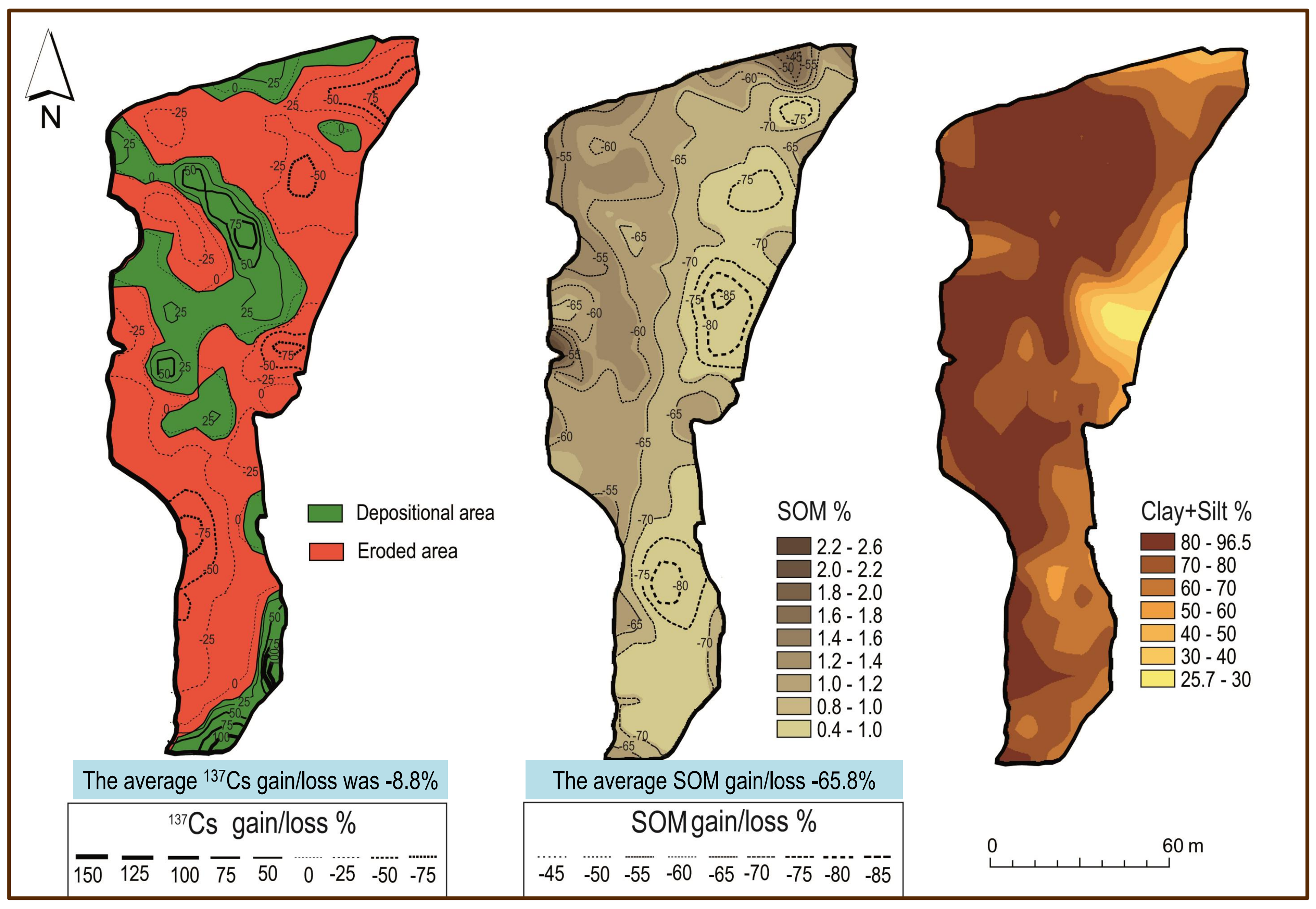

Figure 4 Spatial patterns of ^{137}Cs, SOM and fine particles and percentages of gain/loss of ^{137}Cs and SOM

► The lowest SOM content coincided with lowest percentage of fine particles at sites where there was a deposition of coarse fractions whereas fines were exported out (**Fig. 4**) → The decline of SOM likely related to soil erosion.

► The **spatial distribution of SOM, ^{137}Cs and fine soil fractions** takes place following similar soil processes.

► **Erosion** processes favor the **removal** of fine **particles and associated SOM and ^{137}Cs.**

Conclusions

I. Soil erosion contributes to the depletion of SOM.

II. ^{137}Cs and SOM are important proxies to assess soil degradation at field scale: Similar soil processes are involved in the spatial redistribution of SOM, fine soil particles and ^{137}Cs.

III. The knowledge of the spatial distribution of ^{137}Cs gain/loss and of SOM content is essential to identify where soil degradation and loss of soil fertility occurs.

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References

Lal R. (1991). Tillage and agricultural sustainability. *Soil and Tillage Research* 20:133-146.

Navas A. Walling D.E. Quine T. Machín J. Soto J. Domenech S. & López-Vicente, M. (2007). Variability in ^{137}Cs inventories and potential climatic and lithological controls in central Ebro valley. Spain. *Journal of Radioanalytical and Nuclear Chemistry* 274 (2):331-339.

Navas A. Gaspar L. Quijano L. López-Vicente & M. Machín J. (2011). Patterns of soil organic carbon and nitrogen in relation to soil movement under different land uses in mountain fields (South Central Pyrenees). *Catena* 94:43–52.

Quijano, L., Gaspar, L. & Navas, A. (2014a). Lateral and depth patterns of soil organic carbon fractions in a mountain Mediterranean agrosystem. *Journal of Agricultural Science. In Press*.

Quijano, L., Chaparro, M.A.E., Marié, D.C., Gaspar, L. & Navas, A. (2014b). Relevant magnetic and soil parameters as potential indicators of soil conservation status of Mediterranean agroecosystems. *Geophysical Journal International* 198:1805-1817.

Walling D.E. He Q. & Quine T.A. 1995. Use of caesium-137 and lead-210 as tracers in soil erosion investigations. Tracer Technologies for Hydrological Systems (Proceedings of a Boulder Symposium. IAHS Publ. 229.