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Soil erosion processes and soil quality variability evaluated using fallout radionuclides

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This study reports on the use of geostatistics coupled with a geographic information system (GIS) to assess soil redistribution, as indicated by ^{137}Cs measurements, and its spatial relationship with soil quality parameters such as soil texture and soil organic carbon (SOC).

The spatial correlation of ^{137}Cs (Bq m^{-2}), soil texture, SOC (%) and soil erosion-sedimentation patterns was estimated in a 2.16 ha field in the southern part of the Boyer River watershed, in Eastern Canada. The slope did not exceed 2%. The soil was a sandy loam, with an average composition of 54% sand, 33% silt and 13% clay. Some 42 soil samples were collected along seven parallel transects laid down the dominant slope.

The spatial variability of the parameters was characterized through geostatistical concept, which considers the randomized and structured nature of spatial variables and the spatial distribution of the samples. Semivariograms were produced to take into account the spatial structure present in the data. A significant autocorrelation and reliable variograms were found for each parameter tested ($0.87 \leq R^2 \leq 0.95$ and $0.7 \leq$ Scale/Sill ≤ 0.96).

The SOC ranged from 2.3 to 7.3% with an average of 4.3 ± 0.4%. The mean value of the ^{137}Cs reference sites was estimated at 2970 ± 110 Bq m^{-2} with a coefficient of

variation of 4 % (n = 9). The ^{137}Cs activity in the agricultural field varied from 531 to 4180 Bq m^{-2} with a mean value of 2034 $\pm$ 745 Bq m^{-2}. After conversion of the ^{137}Cs activity into soil movement using the Mass Balance Model 2 (MBM2) a soil movement budget was calculated using Ordinary Kriging. Around 85 % of the field is affected by a high erosion rate in excess of 6 t ha^{-1} yr^{-1}. A significant relationship between SOC and ^{137}Cs surface inventory for the first 20 cm was found:

$$\boldsymbol{y = 0.0867\, x^{0.5487}}\ (n = 42;\ r^2 = 0.63;\ p < 0.001)$$

Where y is the SOC (%) and x the ^{137}Cs areal activity (Bq m^{-2}).

Similar results were found in a 180 ha watershed located in northern France 100 km north-east of Paris. At that site 30 samples were selected on the basis of their topographic location: 10 on flat upslope positions (not affected by erosion and sedimentation processes), 10 on mid-slope (affected by erosion) and 10 below the slope (depositional areas).

Fifteen chemical parameters was measured (Mehlich 3 extractible elements, pH, SOC content, total ammonium, nitrate nitrogen, ^{137}Cs) but only a significant positive correlation was found between the ^{137}Cs activity and SOC contents. Eroded areas with low ^{137}Cs activities had low SOC and sedimentation areas identified by high ^{137}Cs level had high SOC accumulation. The simple linear relationship found could be expressed by the following equation:

$$\boldsymbol{y = 0.0002\, x + 0.9626}\ (n = 30;\ r^2 = 0.62;\ p < 0.001)$$

Where y is the SOC (%) and x the ^{137}Cs areal activity (Bq m^{-2}).

Soil erosion is a selective process and thus the spatial redistribution of soil should be translated into soil quality depletion in eroding areas, and into enrichment in sedimentation areas. The correlation found for the soil subsurface between ^{137}Cs and SOC highlights the relationship between soil erosion and spatial redistribution of organic carbon. The variability of ^{137}Cs redistribution is comparable to other indicators of soil quality such as SOC as reported in China and USA.

Therefore, physical degradation of soils through erosion is coupled with a soil quality degradation that will decrease crop productivity. The spatialisation of soil movement and SOC variability is a first step towards an efficient resource management policy and towards implementing conservation actions successfully.

Key Words: ^{137}Cs, soil organic carbon (SOC), geostatistics, soil erosion, soil quality.