Relationships between soil properties, erodibility and hillslope features in Central Apennines, Southern Italy

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Abstract

Soil erosion is one of the main environmental problems in the Mediterranean area. This problem is becoming even more important especially in the central Apennines, where several erosive processes, frequently favoured by intensive land use, occur due to the action of concentrated running water in few hours. To investigate on the relationships between soil characteristics and local morphologic-topographical features, a study was carried out in the southern part of Italy which is located in Molise region within the middle little valley (Trigno River). In the study area, a systematic sampling of topsoil was performed to evaluate by means of geostatistical techniques the relationships between soil erodibility and superficial soil structure, texture and organic matter content. The results show clear evidence about the relation between the topsoil characteristics and morphometric indexes. In particular, the differences in topsoil erodibilty appear to be directly related to slope morphology and to the specific morphodynamic features. The observed relationships reflect the possibility to better evaluate both the soil erodibility factor (K) used within the USLE equation and the spatial variability of physical and chemical soil characteristics on the basis of digital terrain analyses, and so better predict soil loss rates.

Key Words

Rainfall erosion, USLE Equation, soil erodibility factor.

Introduction

The progressively increasing exploitation of agricultural areas and the ongoing climate changes are largely favouring soil loss related on particular to the action of running water. As the susceptibility of soils to erosion depends on the complex interactions between geologic-environmental parameters and soil features, (which are also affected by modifications just due to the acting erosive processes), it appears particular important to ascertain their spatial variability in relation to slope features and local relief. Predictive methods to reliably estimate soil erodibility are generally based on the analysis of spatial variability of a few soil properties, such as soil structure, soil texture and organic matter content (Wischmeier and Smith 1978). Statistical methods such as kriging interpolation have been widely used in spatial prediction of physical and chemical soil parameters (Castrignanò *et al.* 1998; Diodato and Ceccarelli 2004). The effects of erosive processes on soil features and their consequent spatial distribution in relation to local morphologic and morphometric slope features, can be observed along a soil "catena" located along the slope profile (Birkeland 1999). On the basis of such considerations, to estimate on particular the relationships between soil features and erodibility, type and distribution of erosive processes and local slope features, a large-scaled analysis was carried out in a small test area located in southern of Italy (Molise) which is drained by the Rivo torrent. Within the test area, two soil "catena" have been developed to determine the main soil characters along an alignment crossing different morphologic slope units which are distinguished with reference to specific dominant erosive phenomena. Then, spatial statistical procedures were applied for spatial prediction of soil erodibility factor K (Wischmeier and Smith 1978) using the K topsoil sample values.

Methods

The studied area

The selected test area (about 2.67 km^2) has a test plot station for soil erosion measuring several climatic parameters, as well as soil erosion rates and liquid discharges in relation to different land cover (Aucelli *et al.* 2006a, 2006b). The geological substrate is made of clayey and marly-arenaceous rocks characterized by low permeability, above which mainly Vertisols and Inceptisols showing outstanding vertic characteristics have developed. Climate is characterized by mean annual rainfall and temperatures ranging respectively between 650 mm and 800 mm and 5° and 30°. Agriculture and pasture are the main economic activities. From a geomorphological point of view the study area shows a remarkable variety of hillslope forms and erosive processes, resumed on a map which classifies the whole territory into seven morphodinamic unit.

Pedological sampling

Ten soil profiles were samples along a 1.7 km long transect which defines two soil catenae extending from the valley. For each profile a detailed fact sheet was compiled. Moreover, soil samples taken from the main diagnostic horizons were subjected to physical and chemical laboratory analyses to the aim to classify the sampled soils according to FAO (2006). Systematic topsoil sampling was carried out on the basis of a net of sampling points (located at regular distances of about 300 m each one from another) in order to characterize the upper, about 20 cm thick, soil portion. Furthermore, also the spatial distribution of superficial bulk density and calcium carbonate content was analysed, as they can be considered good indicators of accelerated topsoil erosion.

Soil erodibility factor estimation

The values of the soil erodibility factor K of the topsoil samples were calculated using the following formula of Wischmeier and Smith (1978):

$$Ks = 2.1*10^{-4}\ (12\text{-}OM)\ M^{1.14}*3.25(S-2) +(2.5(P-3)/7.59*100 \qquad (1)$$

where K is expressed in $t•ha•h/h•MJ^{1.14}•mm$, OM represents the organic matter content (%), M defines the relations between percentages of silt, very fine sand and clay content (% silt + % very fine sand) (100 - % clay), S represents the soil structure code and P the permeability class. Spatial variability of the five examined parameters was evaluated by means of a geo-statistical analysis. The results were then compared to the spatial distribution of soil types and that of the morphodynamic units and, at last, to several morphometric parameters which were automatically extracted by a high resolution (5 m) Digital Terrain Model (DTM).

Results

The study area is characterized by ten different soil types. Figure 1 shows the pedological section, some basic soil characteristics are detailed in Table 1. The dominant soil types are Grumic Vertisols (some Calcaric) which represent about 60-70% of the test area.

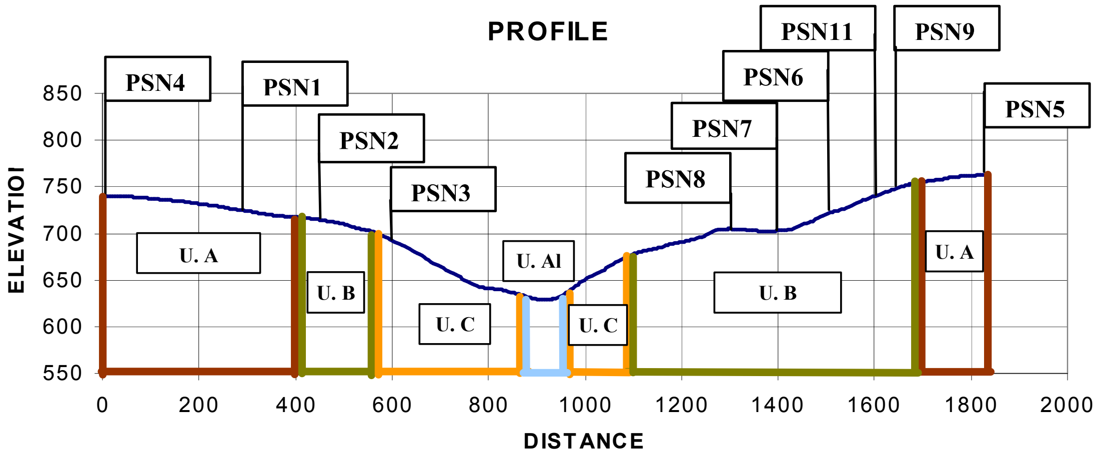

Figure 1. Topographic profile along the catena with indications about the location of soil profiles. Distances and elevations are expressed in meters. PSNx: soil profile code; Ux: morpho-dynamic unit.

All soil types have an organic matter content of less than 5.7% and most of them are poorly drained. Field and laboratory analyses showed that the soils along the transect can be classified as Grumic Mollic Vertisols (clayey and up to 1.5–2 metres thick, well structured, deeply fissured and characterised by a moderately deep calcic horizon), Vertic Calcisols (about 1 metre thick, with a superficial calcic horizon) and Leptosols (very thin soils with a massive structure and a strong sandy texture). Analyses of soil profiles along the catena have shown very clearly that the position of the profile on the slope, as well as type and intensity of local dominant hillslope processes acting there, are crucial for the development of diagnostic physical and chemical characteristics of soils. Spatial variability of the five examined parameters was evaluated by means of a geo-statistical analysis. The results show important correlation between their spatial distribution, soil types and he morphodynamic units. The soil erodibility map derived using a kriging interpolation is shown in Figures 2a and b.

Table 1. Some basic physical and chemical characteristics of soil profiles.

Profile code	FAO soil classification (2006)	Depth (cm)	Elevation (m)	Slope (°)	Lithology	Cracks (cm)	SOM (30cm)	Clay 30cm (%)
PSN4	Grumic MollicVertisols	210	739	0.38	AC	> 10	2.5	65
PSN1	Grumic Vertisols	160	723	4.59	AC	> 10	1.8	61
PSN2	Grumic Vertisols	125	713	4.90	AC	> 10	2.1	60
PSN3	Grumic Vertisols	120	688	15.35	AC	> 10	2.1	58
PSN8	Vertic Calcisols	45	703	16.90	CMC	3-5	5.7	41
PSN7	Grumic Mollisols	260	702	6.50	APC	-	2.3	21
PSN6	Grumic Vertisols Calcaric	150	715	16.30	AC	6-10	3.1	45
PSN11	Haplic Cambisols Calcaric	160	740	11.50	APC	> 10	1.3	26
PSN10	Haplic Cambisols Calcaric	210	746	11.50	APC	> 10	1.4	21
PSN5	Haplic Leptosols Calcaric	45	763	3.90	APC	3-5	2.2	13

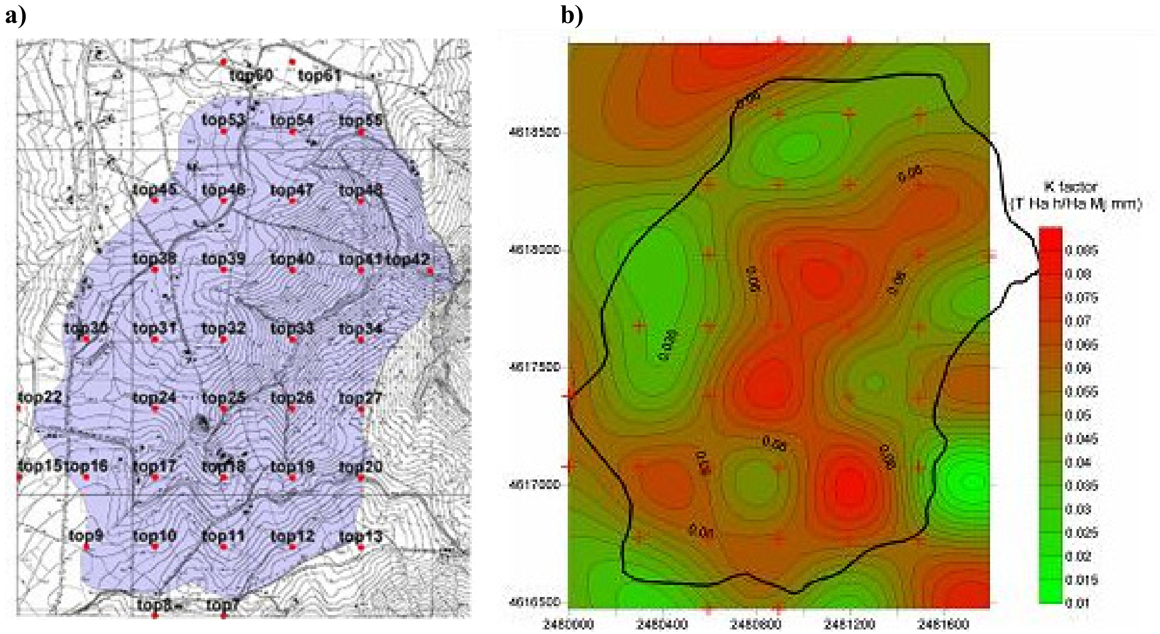

Figure 2. Location of topsoil samples within the test area a) and spatial interpolation of the K factor b), calculated by the formula of Wischmeier and Smith (1978).

The determined K values range from 0.01 to 0.085 t•ha•h/h•MJ•mm. The soil erodibility map shows significant differences of K values between the various examined soil profiles which depend on local soil variability. The spatial distribution of the K factor basically confirms that some of the chemical and physical properties of topsoils are clearly linked to the spatial distribution of certain morphometric indexes.

Conclusions

The results of the study encourage to develop methods and techniques to quickly and economically derive from DTMs some important soil characteristics whose estimate generally requires a lot of time and resources. The preliminary results will be useful for a more precise evaluation of the parameter K (soil erodibility factor) of the USLE equation and a better prediction of soil loss, and suggest important relationships between local geologic-environmental conditions, erosive phenomena, soil features and soil degradation.

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