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Redistribution of Soil Organic Carbon Triggered by Erosion at Field Scale Under Subhumid Climate, Hungary

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ABSTRACT

Soil organic carbon (SOC) has primary importance in terms of soil physics, soil fertility and even of climate change control. One hundred soil samples were taken from an intensively cultivated Cambisol to quantify SOC redistribution triggered by soil erosion under a subhumid climate, by the simultaneous application of diffuse reflectance (240–1 900 nm) and traditional physico-chemical methods. The representative sample points were collected from the solum along the slopes at the depth of 20–300 cm with a mean SOC content of 12 g kg^{-1}. Hierarchical cluster analyses were performed based on the determined SOC results. The spatial pattern of the groups created were similar, and even though the classifications were not the same, diffuse reflectance had proven to be a suitable method for soil/sediment classification even within a given arable field. Both organic and inorganic carbon distributions were found to be a proper tool for estimations of past soil erosion processes. The SOC enrichment was found on two sedimentary spots with different geomorphological positions. Soil organic matter composition also differed between the two spots due to selective deposition of the delivered organic matter. The components with low-molecular-weight reached the bottom of the slope where they could leach into the profile, while the more polymerised organic matter compositions were delivered and deposited even before on a higher segment of the slope in an aggregated form. This spatial difference appeared below the uppermost tilled soil layer as well, referring the lower efficiency of conventional ploughing tillage in soil spatial homogenisation.

Key Words: Cambisol, carbon sequestration, diffuse reflectance, selective erosion, soil organic matter composition

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INTRODUCTION

Soil organic carbon (SOC) content is one of the most important qualifying property in soil characterisation. Soil fertility is generally given as a function of SOC content. Increasing conservation of SOC content has become a symbol of sustainable agriculture. Since SOC has a pivotal role in structuring soil particles, it has primary importance in soil physical properties such as porosity, aggregate stability, and infiltration (Stavi and Lal, 2011). Lal (2004) estimated that global soils contain 2 500 Gt carbon (1 550 Gt SOC) in their uppermost 1 m thick horizon and hence there is the largest terrestrial carbon (C) pool second only to the geologic stock. In native soils SOC content generally decreases with depth, while tillage homogenises SOC content in the uppermost horizon (Lee J *et al*., 2009).

Among uniform climatic, vegetation, and land use conditions, SOC content does not change significantly. Tillage operations on a native land considerably reduce SOC content until it is stabilised at a lower value controlled by the new circumstances (Häring *et al*., 2013a). On intensively cultivated arable fields the oxidation caused by soil tillage is considered to be an effective factor reducing SOC (Häring *et al*., 2013b); however, data are also presented on SOC sequestration due to accelerated soil erosion and tillage-generated deposition (Lal, 2004). Although their effects are closely correlated, tillage triggers chemical degradation while soil erosion controls spatial distribution of SOC (Polyakov and Lal, 2008). Small soil particles are especially prone to erosion, while larger aggregates are less

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affected. Clay fraction and SOC-related colloid content in soil loss might be 2.5 times higher than those in the *in situ* tilled soil layer (Wang *et al.*, 2010; Farsang *et al.*, 2012; Nagy *et al.*, 2012). Additional report on the erosion of selective soil organic matter (SOM) proved the differences in organic matter between soil loss and the native soil (Jakab *et al.*, 2014). Even though soil erosion has already led to a C loss at 20–50 t C ha^{-1} (Lal, 2003), there are still ambiguities concerning the fate of eroded organic C whether it is sequestered or mineralized (Lal and Pimentel, 2008).

In general, SOC redistribution was investigated mainly by soil loss sampling and analysis of runoff plots at field or catena scale (Polyakov and Lal, 2008). Zhang *et al.* (2011, 2013) have reported the SOC erosion under simulated precipitation events at point scale, but the up- or down-scaling result is still a problematic issue (Chaplot and Poesen, 2012). Although there are estimations about C sequestration in the buried horizons of lakes and reservoirs, which exceed terrestrial C stocks by two orders of magnitude in Central Europe (Hoffmann *et al.*, 2013), still little is known about the deposition and burial processes at the field scale.

The SOM could be analysed by a simple way using indexes derived from ultraviolet (UV) and visible (VIS) absorbance spectra of SOM extractions (Chin *et al.*, 1994; Tan, 2003; Her *et al.*, 2008). The application of UV, VIS and near infrared (NIR) reflectance of soil is also a widespread method for the survey of soil properties by remote sensing (Aichi *et al.*, 2009; Conforti *et al.*, 2013). The remote sensing method is applicable only to establish the soil surface parameters (Gomez *et al.*, 2008). Diffuse reflectance is a suitable method for the study of buried horizons as well (Viscarra Rossel *et al.*, 2006). The UV-VIS-NIR spectra (200–2 500 nm wavelength) include all the information of the soil material and the measurement is simple and inexpensive. Numerous studies discussed the accuracy of predictions based on reflectance as for SOC, clay, carbonate, pH *etc.* (Lee K S *et al.*, 2009; Viscarra Rossel *et al.*, 2009; Brodský *et al.*, 2011). These studies compared many soil samples from various environmental conditions using partial least squares regression method and obtained relatively high R^2 values. However, it is not clear whether soil chemical properties would be determined based on diffuse reflectance with very similar soil samples at slope scale.

The aim of this study was to survey SOC redistribution triggered by soil erosion on an intensively cultivated arable land consisting of Cambisol under a subhumid climate. The main questions were whether the deposited part contained information about the origin of the sediment and whether the SOC enrichment measured in trapped soil losses in previous surveys (Wang *et al.*, 2010; Farsang *et al.*, 2012; Kuhn *et al.*, 2012) could be found in the *in situ* buried horizons. Additional goals were to compare the SOM composition of the tilled layer with those of the deposited and buried horizons in order to prove selective erosion processes and to test the prediction of soil physico-chemical properties based on diffuse reflectance with similar soil samples at slope scale.

MATERIALS AND METHODS

Study site

The investigated site was located at Ceglédbercel, southeast of Budapest, Hungary (Fig. 1). It was an intensively cultivated arable field on sandy loess parent material with an area of 3.2 ha. Soil cover varied among the differently eroded and deposited types of eutric calcaric loamic Cambisol and eutric calcaric ochric Regosol. The crest and the upper one third of the slope were occupied by an orchard and had an exceptionally shallow solum. This part was separated from the lower one by a road and a ditch, and therefore it was excluded from the investigation. The slope steepness of the lower studied part varied between 5% and 17% with the average value of 12%. This investigated part formed a valley with Regosol spots on the surface at the steepest points and 3 m deep deposition on the bottom. The elevation was between 154 and 170 m above sea level, mean annual temperature was 10.8 °C, while annual precipitation was around 600 mm in the study area (Dövényi, 2010). Prevalent crops for the last decades were winter wheat, maize and sunflower. Conventional tillage with autumn mouldboard ploughing was applied with northwest-southeast tillage direction (Fig. 1).

Field work

Topography of the study site was surveyed by a Trimble 3300DR laser total station (Trimble Navigation, USA). The surface was measured along the mesh at 10-m intervals. Boreholes were deepened using Edelman augers in order to reach the parent material along a net at 25-m intervals. Altogether 46 drillings (Fig. 1) were carried out during the summer of 2013 under the field of sunflower. Each drilling was described in details, and the depth of the parent material was recorded. Horizons were determined on the basis of field observations, such as colour, $CaCO_3$ (soil inorganic C, SIC) and moisture contents. All descriptions and predictions were performed according to the methods