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Carbon redistribution by erosion processes in an intensively disturbed catchment

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ABSTRACT

Understanding how organic carbon (OC) moves with sediments along the fluvial system is crucial to determining catchment scale carbon budgets and helps the proper management of fragile ecosystems. Especially challenging is the analysis of OC dynamics during fluvial transport in heterogeneous, fragile, and disturbed environments with ephemeral and intense hydrological pulses, typical of Mediterranean conditions. This paper explores the catchment scale OC redistribution by lateral flows in extreme Mediterranean environmental conditions, from a geomorphological perspective. The study area is a catchment (Cárcavo) in SE Spain with a semiarid climate, erodible lithologies, and shallow soils, which is highly disturbed by agricultural terraces, land levelling, reforestation, and construction of check-dams. To increase our understanding of catchment scale OC redistribution induced by erosion, we studied in detail the subcatchments of eight check-dams distributed along the catchments main channel. We determined ^{137}Cs, physicochemical characteristics, and the OC pools of the catchment soils and sediments deposited behind each check-dam, performed spatial analysis of catchment properties and buffer areas around the check-dams, and carried out geomorphological analysis of the slope-channel connections.

The soils showed very low total organic carbon (TOC) values, oscillating between 15.2 and 4.4 g kg^{-1} for forest and agricultural soils, respectively. Sediments mobilized by erosion were poor in TOC (6.6 ± 0.7 g kg^{-1}) compared to the eroded (forest) soils, and the redistribution of OC through the catchment, especially of the mineral associated organic carbon (MAC) pool, showed the same pattern as clay particles and ^{137}Cs. The TOC erosion rates estimated for the Cárcavo watershed are relatively low (0.031 ± 0.03 Mg ha^{-1} y^{-1}) but similar to those reported for subhumid Mediterranean catchments that are less fragile and more conducive to plant growth. The TOC erosion/total erosion ratio was lower (0.06%) than other estimates, although the average OC concentration of the sediments was higher than that of the agricultural soils of the catchment, underlining the problem of maintaining sustainable soil OC contents.

The OC in deposited sediments came not only from surface erosion processes, but also from deeper soil or sediment layers mobilized by concentrated erosion processes. Sediment richer in OC came from the surface soil of vegetated (reforested) areas close and well connected to the channels. Subcatchments dominated by laminar erosion processes showed a TOC erosion/total erosion ratio that was two times higher than that of subcatchments dominated by concentrated flow erosion processes. The lithology, soils, and geomorphology exert a more important control on OC redistribution than land use and vegetation cover in this geomorphologically very active catchment.

1. Introduction

Recently, fluvial sediments have been identified as important organic carbon (OC) sinks with potentially strong implications for catchment and regional carbon (C) budgets (Hoffmann et al., 2013; Ran et al., 2014; Boix-Fayos et al., 2015). However, the fluvial and geomorphological conditions and dynamics determine the quality and quantity of OC mobilized by sediments (Hoffmann et al., 2013), as well as the post-depositional processes that might affect OC fluxes and in turn the OC sink (Van Hemelryck et al., 2011; Berhe and Kleber, 2013). In semiarid and arid environments with episodic and intense hydrological events,

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alternating with small events and long drought periods, the OC redistribution due to lateral flows is complex and is not well defined. Better knowledge of the processes involved in the OC redistribution in semiarid, fragile environments would help their management, to at least maintain ecologically sustainable levels of OC in soils and sediments. This work explores the OC pools mobilized by lateral flows in a fragile, semiarid environment and tries to add to our knowledge of these processes.

Lateral flows of sediment are affected by agricultural management practices (Van Oost et al., 2007; Martinez-Mena et al., 2008; Quijano et al., 2016), which influence runoff production, soil stability, sediment detachment, and available soil organic carbon (SOC) in the soil surface - and thus the SOC detached and transported at the slope scale (Martínez-Mena et al., 2012; Nadeu et al., 2015; Quijano et al., 2016). Multiple experiments at the plot and field scales showed selective erosion of fine particles and enrichment of SOC in sediments, compared to the original soils (Avnimelech and McHenry, 1984; Starr et al., 2000; Jin et al., 2009; Martínez-Mena et al., 2012). However, the redistribution of OC by lateral flows at the watershed scale seems to be much more complex due to the interference of other ecogeomorphological processes (Boix-Fayos et al., 2015). Organic C redistribution through the fluvial system is affected not only by agricultural management but also by land use (Boix-Fayos et al., 2009), that partially determines the channel-slope connectivity by different erosion processes (Nadeu et al., 2011, 2012).

Furthermore, past studies have demonstrated the links between SOC yields in watersheds and the morphological properties of the drainage area, as well as relationships between land use and vegetation cover and the concentration of OC in sediments (Boix-Fayos et al., 2009; Nadeu et al., 2015). Also, the dominant erosion processes in a catchment influence the concentration and quality of the OC present in the eroded sediments (Nadeu et al., 2011).

Therefore, to determine C budgets at the catchment scale, it is crucial to understand how OC moves with sediments along fluvial paths (Hoffmann et al., 2013). In particular, little is known of how OC is redistributed in fragile environments with a variety of lithologies, land uses, and ephemeral hydrological and sedimentological pulses, typical of Mediterranean conditions. The aim of this work was to characterize and analyze the OC redistribution by lateral flows in a Mediterranean catchment with erodible lithologies and shallow soils, and which is highly disturbed by agricultural terraces, land levelling for agriculture, reforestation, and construction of check-dams. The specific objectives were to: i) quantify the total OC mobilized by erosion at the catchment scale, ii) link the C redistribution to sediment properties and morphological characteristics of the drainage areas and channels, and iii) determine the factors controlling the quality and quantity of the mobilized OC.

We hypothesize that the abiotic characteristics of catchments (lithology, topography, geomorphology) impose a template for C redistribution by lateral flows. This template is more dominant than biological and ecological factors with regard to C redistribution by lateral processes in semiarid and fragile ecosystems.

2. Study area

The study was performed in the Cárcavo catchment, located in SE Spain, in the Region of Murcia (38°13′ N; 1°31′ W). It is a catchment of 2732 ha with a semiarid climate, an average annual precipitation of 279 mm, an average annual evapotranspiration of 848 mm (data from

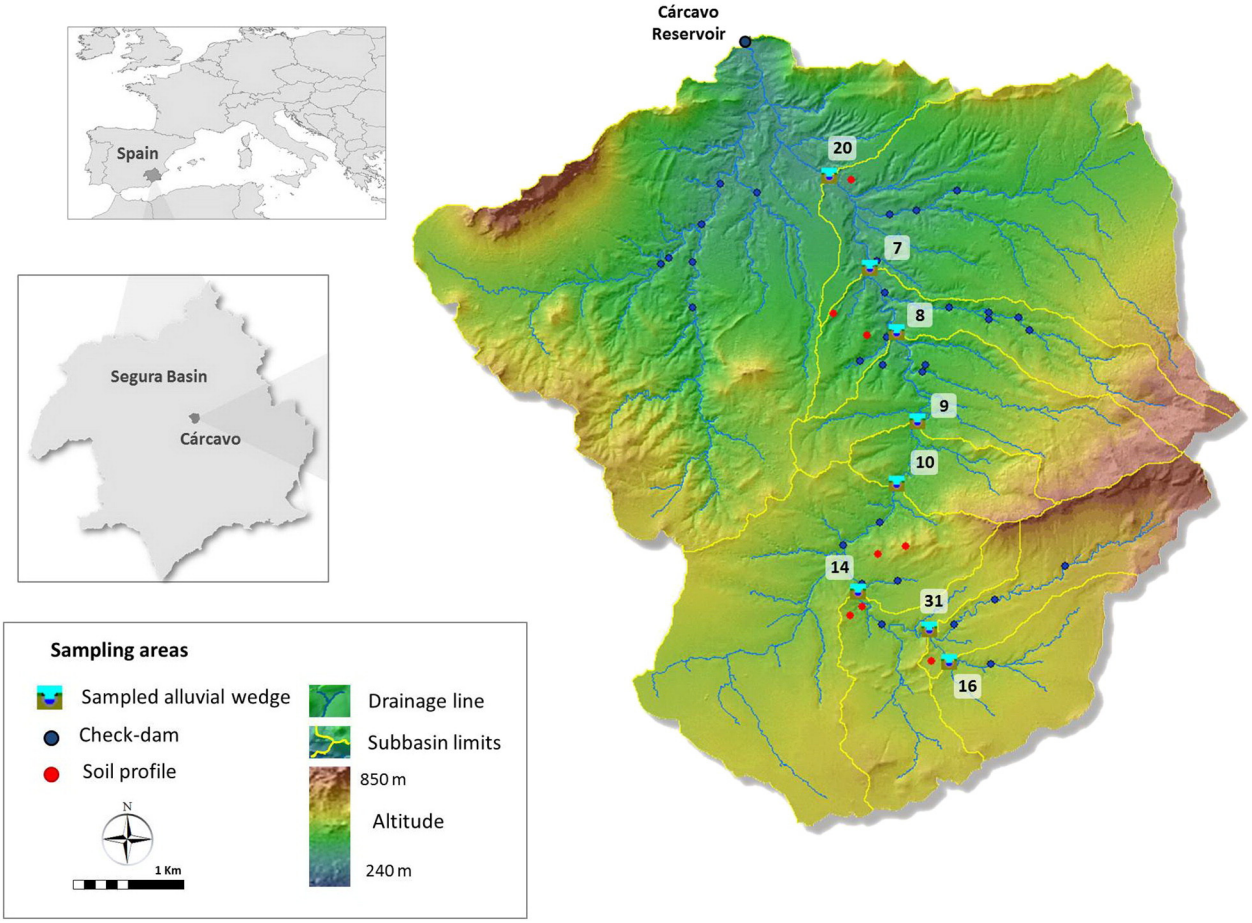

Fig. 1. Location map of the Cárcavo basin.

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