Geomorphology 318 (2018) 162–171

Contents lists available at ScienceDirect

Geomorphology

journal homepage: www.elsevier.com/locate/geomorph

Effects of agricultural drainage systems on sediment connectivity in a small Mediterranean lowland catchment

A. Calsamiglia [a,b,*,1], J. García-Comendador [a,b,1], J. Fortesa [a,b,1], J.A. López-Tarazón [a,b,c,d,1], S. Crema [e], M. Cavalli [e], A. Calvo-Cases [f], J. Estrany [a,b,1]

[a] Department of Geography, University of the Balearic Islands, E-07122 Palma de Mallorca, Balearic Islands, Spain
[b] Institute of Agro-Environmental and Water Economy Research – INAGEA, University of the Balearic Islands, E-07122 Palma, Mallorca, Balearic Islands, Spain
[c] Institute of Earth and Environmental Science, University of Potsdam, Germany
[d] Fluvial Dynamics Research Group, University of Lleida, Lleida, Catalonia, Spain
[e] CNR-IRPI, National Research Council of Italy - Research Institute for Geo-Hydrological Protection, Padova, Italy
[f] Department of Geography, University of Valencia, Av. Blasco Ibáñez 28, 46010 Valencia, Spain

ARTICLE INFO

Article history:
Received 19 December 2017
Received in revised form 24 April 2018
Accepted 16 June 2018
Available online 22 June 2018

Keywords:
Sediment connectivity
Traditional drainage systems
Catchment management
Soil erosion
LiDAR

ABSTRACT

Traditional drainage systems combining man-made channels and subsurface tile drains have been used since Roman times to control water excess in Mediterranean lowland regions, favouring adequate soil water regime for agriculture purposes. However, mechanization of agriculture, abandonment or land use changes lead to a progressive deterioration of these drains in the last decades. The effects of these structures on hydrological and sediment dynamics have been previously analyzed in a small Mediterranean lowland catchment (Can Revull, Mallorca, Spain, 1.4 km^2) by establishing an integrated sediment budget with a multi-technique approach. Moreover, the recent advances in morphometric techniques enable the completion of this analysis by the accurate identification of active areas (i.e. sources, pathway links, and sinks) and improve the understanding of (de-)coupling mechanisms of water and sediment linkages. In this study, the Borselli's index of connectivity (IC; Cavalli et al. (2013)'s version) derived from a LiDAR-based high resolution DEM (>1 pt m^{-2}; RMSE < 0.2 m) was used to evaluate the spatial patterns of sediment connectivity of the catchment under two different scenarios: (1) the current scenario, including an accurate representation of the 3800 m of artificial channels and levees (CS - Channelled Scenario), and (2) a hypothetical scenario in which these anthropogenic features were removed (US - Unchannelled Scenario). Design and configuration of the drainage system in Can Revull generated changes favouring lateral decoupling between different compartments, with hillslopes-floodplain and floodplain-channels relationships, showing a general decrease of IC values, and high longitudinal connectivity along the artificial channel network. Field observations corroborated these results: structures enabled rapid drainage of the water excess also promoting low surface runoff within the field crops, proving to be an effective management practice for erosion control in agricultural Mediterranean lowland catchments. By contrast, US demonstrated that the abandonment of the current agricultural practices and the subsequent destruction of the drainage system could lead the higher soil loss rates owning to more intense/effective processes of sediment connectivity.

© 2018 Elsevier B.V. All rights reserved.

1. Introduction

The study of sediment flows in fluvial systems is a key aspect for Earth Sciences due to its great influence on ecosystems, water resources management, agriculture and landscape evolution (Milliman and Meade, 1983; Pelletier, 2012). The need to understand sedimentary dynamics has led to the emergence, during the last decades, of numerous studies examining the internal processes of sediment supply, transport and storage in catchments under the influence of different human disturbances (Syvitski et al., 2005; Hooke, 2006; Davis, 2009). Notwithstanding important assumptions of the effectiveness of local measures on inferring catchment related erosion rates, monitoring sediment delivery at a river section can provide an order of magnitude of erosion and depositional processes within a catchment (Parsons et al., 2006; Girolamo et al., 2015). However, only a fraction of the eroded sediment reaches the catchment outlet, which was called the 'sediment delivery problem' (Walling, 1983; de Vente et al., 2007). The presence and spatial configuration of different linkages and blockages, as well as

* Corresponding author at: Department of Geography, University of the Balearic Islands, E-07122 Palma de Mallorca, Balearic Islands, Spain.
E-mail address: a.calsamiglia@uib.cat (A. Calsamiglia).
[1] Mediterranean Ecogeomorphological and Hydrological Connectivity Research Team (http://medhycon.uib.cat).

https://doi.org/10.1016/j.geomorph.2018.06.011
0169-555X/© 2018 Elsevier B.V. All rights reserved.

their capacity to store or remove sediment within different time scales determines the efficiency of the sediment cascades (Fryirs et al., 2007). Internal sediment dynamics at a wide range of catchment scales can be effectively quantified using the 'sediment budget approach' (Walling, 1983). This conceptual model is based on the establishment of different compartments and the quantification of the sediment delivered from and stored in each one of them. However, the main gap is the significant 'spatial and temporal lumping' (sensu Walling, 1983) since the erosion-deposition at each compartment do not reflect either the processes involved or their spatiotemporal variability (Fryirs, 2013).

Human activities have a profound impact on water and sediment flow patterns and ratios (Hooke, 2006) because they alter the catchment 'sensitivity' by modifying the time-scale and storage or reworking capacity of landforms (Harvey, 2002; Fryirs, 2017). Changes in hydrological and sediment dynamics also depend on the position and extension of anthropogenic features which can act as buffers, barriers or blankets, depending on whether they (de-)couple lateral connectivity (i.e. slope-channel or channel- alluvial plain), longitudinal (i.e. along the channel) or vertical (i.e. surface-subsurface interactions), respectively (Fryirs et al., 2007). Buffers like agricultural terraces have been proved very effective in decoupling hillslopes and the main channel network, resulting in a significant decrease in runoff generation and sediment yield (Hooke and Sandercock, 2007; García-Comendador et al., 2017). On the contrary, the artificialization of river networks, with changes in the fluvial paths and channeling of riverbeds, may have impacts of different magnitude, in most cases associated with an increase in erosion due to enhanced longitudinal connectivity (Hooke, 2006). In lowland areas, the transformation of most catchments for agricultural use led to a complete remodeling of the drainage systems and the consequent alteration of their hydrological and sediment dynamics (Estrany et al., 2009; Van der Zanden et al., 2013). In Mediterranean environments, traditional drainage systems are suffering a progressive deterioration, accelerated during the last decades due to their abandonment and lack of maintenance or their destruction related to the mechanization of agriculture (Jover and Pons, 2012). Studies using the sediment budget approach showed that sediment contribution from surface and subsurface drainage systems in catchments slightly impacted by human influence can represent up to 10% (Walling et al., 2002) whereas in highly canalized catchments can reach 50% (Palmer et al., 2014). Energy disequilibrium caused by the alteration of the natural channel network can lead to morphological readjustments and increased sediment delivery (Landemaine et al., 2015). The construction of subsurface tile drains can increase peak flows and has been considered an important factor influencing the development of floodwaters (Wesström et al., 2000; Wiskow and van der Ploeg, 2003). Other studies recognized positive effects of these structures as an erosion control practice, reporting significantly reduced surface runoff and sediment losses in plots with subsurface tile drainages if compared with a more natural drainage situation (Istok and Kling, 1983; Bottcher et al., 1981; Schwab, 1976).

Understanding the internal mechanisms that (de-)couple the water and sediment transfer in artificially-drained catchments and the effects of degradation processes related to their abandonment require new approaches for unraveling the spatiotemporal variability of geomorphic processes. The concept of 'sediment connectivity', understood as 'the continuity of sediment transfer from a source to a sink', has emerged as a new framework to unravel these spatio-temporal gaps, identifying provenance, pathways and fate of sediments, as well as timing and changes in erosion ratios within a catchment (Bracken et al., 2015). Recent advances in remote sensing techniques (i.e. LiDAR either aerial or terrestrial, automated digital photogrammetry) as well as in topographic modeling algorithms (e.g. Structure from Motion) have opened up great opportunities for the study of geomorphological processes under the connectivity framework. The rapid development of these technologies results in an increasing availability of high-resolution digital elevation models (HR-DEM) which accurately represent the catchment's morphology, allowing the identification of different landforms and their spatial distribution (Tarolli, 2014). The continuous monitoring of changes occurring on the Earth surface using morphometric techniques or increasingly realistic indices and models are revolutionizing the studies in geomorphology as they can provide a better understanding of geomorphic processes.

This paper aims to evaluate the effects of traditional drainage systems on the spatial patterns of sediment connectivity in a small agricultural catchment (Can Revull, Mallorca, Spain) by applying the index of connectivity (IC) proposed by Borselli et al. (2008) and improved by Cavalli et al. (2013). In order to understand the changes induced by the presence of these structures and to figure out the expected changes if structures are abandoned or obliterated, the index was calculated for two scenarios: (1) a scenario of the current situation, with an accurate representation of channels and levees from a LiDAR-based HR-DEM (CS - Channelled Scenario), and (2) a hypothetical scenario in which these structures were removed from the HR-DEM (US - Unchannelled Scenario). In this way, US was modelled to assess the hydro-sedimentary fluxes of the study catchment in the previous topographic conditions before the drainage system was built or how those fluxes would probably work in the event of a drastic land use change due to a modification in the agricultural exploitation system; e.g., by changing the current use to a more intensive and mechanized commercial agriculture (Binimelis and Ordinas, 2015). The spatial connectivity patterns derived from the two scenarios were analyzed and compared. The effects of channeling on the IC patterns in the CS were also assessed by field observations. The main aim is the comprehension of (de-)coupled internal mechanisms of water and sediment transfer through the combined analysis of IC and field observations in order to go beyond the previous works by Estrany et al. (2009, 2010, 2012), based on a multi-technique approach for establishing an integrated sediment budget.

2. Study area

Can Revull is a small catchment (1.4 km^2) placed in the headwaters of Na Borges River (Estrany et al., 2009), a lowland agricultural basin (319 km^2) located at the north-eastern part of Mallorca, Spain (Fig. 1). The catchment morphology is characterized by the structurally gentle alpine relief of the Central Ranges of the island, composed by Miocene materials and Quaternary materials, which rest discordantly over a deformed Mesozoic-Cenozoic substratum (IGME, 1983). Elevations range between 70 and 142 m a.s.l. and the mean gradient slope is 5%, exceeding 10% only in the 11% of the study area, at the headwaters of the catchment.

The climate is sub-dry Mediterranean according to the climatic classification by Thornthwaite (1948). The mean annual temperature is 16.5 °C and the mean annual precipitation is 517 mm with an interannual variability of 23% (1974–2006, data from *the Boscana Nou* meteorological station, located 1.5 km from Can Revull's catchment outlet). High-intensity rainstorms with a recurrence period of 25 years may reach 100 mm in 24 h. The flow regime is intermittent with baseflow from November–December to March or April. The mean daily specific discharge during the period 2004–2012, representative of the long-term records, was 5.9 l s^{-1} km^{-2} (López-Tarazón and Estrany, 2017) and the mean annual PET was estimated in 1010 mm yr^{-1} (Estrany et al., 2010).

The catchment substratum is constituted by limestones. The soils can be classified as Entisols in the catchment headwaters and Alfisols in the flat downstream areas, according to the USDA soil taxonomy classification. In the floodplain areas, soils are deep and well developed and are characterized by a "silty-clay-loam" texture. However, they overlay Quaternary alluvial sediments supported by an impervious lower-middle Miocene (Burdigalian) layer which prevent percolation into deep aquifers. A shallow unconfined aquifer exists in the soils characterized by a high field capacity >40% (Díaz-Palmer et al., 2006) and the

Download English Version:

https://daneshyari.com/en/article/8907939

Download Persian Version:

https://daneshyari.com/article/8907939

Daneshyari.com