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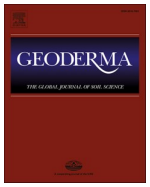

# Land use effects on surface runoff and soil erosion in a southern Alpine valley

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ABSTRACT

In mountain regions, soil landscapes are highly vulnerable against soil loss. Moreover, these environments are particularly affected by land use changes, which influence soil properties and related processes like surface runoff generation and soil erosion. These processes are in turn amplified by extreme climatic events and intensive geomorphological dynamics. The objective of this study is to quantitatively assess the effects of land use changes on surface runoff and soil erosion in a southern Alpine valley (Onsernone valley, Switzerland) characterized by a former intense land use followed by a progressive abandonment in the last decades. Surface runoff and related sediment transport has been analysed under controlled and reproducible conditions using a portable rainfall simulator device (1 $m^2$). The results show a statistically significant increase in surface runoff when the soil gets water repellent reducing the surface infiltration capacity and generating preferential flow paths, which prevent a homogeneous wetting of the soil. However, the documented high sensitivity of surface runoff to land use changes does not result in an equally high sensitivity to soil erosion processes. Instead, soils display a high aggregate stability leading to very low sediment transports except for abandoned and reforested agricultural terraces. There, the lack of maintenance and progressive collapse of terrace dry walls locally increase slope angles and directly exposes the soil to atmospheric agents and surface runoff, which causes soil erosion rates beyond the customary natural level.

## 1. Introduction

Steep mountain slopes combined with episodically intense and high erosive rainfall confer to the Alpine soil landscape a high vulnerability against erosion-induced soil loss. In such circumstances, land use has a specific influence on soil properties and the related sensitivity to surface runoff and soil erosion (Bettoni et al., 2022; Gordon et al., 2001; Panagos et al., 2015). As a consequence, land use changes are one of the most important causes for accelerated soil erosion (Borrelli et al., 2017; Zema et al., 2012), generally coming along with a loss of fertile topsoil (Bayramin et al., 2008). According to Panagos et al. (2015), in the Alps soil loss rates may exceed 5 t $ha^{-1}$ $yr^{-1}$. In turn, soil erosion affects soil productivity and existing options for a sustainable soil management, eventually leading to a decrease in crop production, an overall decline of arable land, and subsequently to socio-economic problems (Bruce et al., 1995; Märker et al., 2008; Pelacani et al., 2008; Rasoulzadeh et al., 2019).

Specific and distinct influences of land use changes on soil properties

*Abbreviations:* SWR, Soil Water Repellence; SOC, Soil Organic Carbon; SOM, Soil Organic Matter; $K_{sat}$, Saturated Hydraulic Conductivity; PARS, Portable Automated Rainfall Simulator; TDR, Time domain reflectometry; MED test, Molarity of Ethanol Droplet test; RLF, Rising Limb Factor; $FS_S$, South-facing forested slopes; $DT_S$, South-facing deforested, cultivated terraces; $FT_S$, South-facing (re-)forested, abandoned terraces; $FS_N$, North-facing forested slopes; PS, Pastures on slopes; $MS_N$, North-facing meadows on slopes; LCTUs, Land cover-topography units.

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concern saturated hydraulic conductivity, aggregate stability (Bettoni et al., 2022; Cantón et al., 2009; Cerdà, 1998), and soil water repellence (Doerr et al., 2003; Lemmnitz et al., 2008; Miyata et al., 2007). Aggregate stability is strongly influenced by the amount of soil organic carbon (SOC) (Haynes and Swift, 1990; Le Bissonnais and Arrouays, 1997; Smith et al., 2015), which is often higher under forest vegetation, where a low biodegradability of soil organic matter (SOM) favours the accumulation of SOC (Guo and Gifford, 2002). However, under agricultural use, SOC is generally lower due to regular tillage and biomass harvesting (Guo and Gifford, 2002; Rehfuess, 1990; Vogel and Conedera, 2020). The amount of SOC together with the quality and composition of SOM (Doerr et al., 2000; Fu et al., 2021; Lozano et al., 2013) eventually influence soil water repellence, which may have a large effect on infiltration processes and surface runoff (Miyata et al., 2007; Ritsema et al., 1993; Ritsema and Dekker,1994; Ritsema and Dekker, 1995; Witter et al., 1991; Wang et al., 2000).

Despite such evident influence on soil properties, land use changes do not necessarily have a direct impact on the stability of the soil landscape and specific investigations are needed for understanding this relationship. One of the methodological approaches to assess these relationships consists of using controlled and reproducible precipitation simulations. As shown by several authors in the past, rainfall simulators have proved to be reliable instruments for the identification and quantification of hydrological processes and soil erosion rates (e.g. Iserloh et al., 2012; Iserloh et al., 2013a; Fister et al., 2012; Martínez-Murillo et al., 2013; Lassu et al., 2015; Prosdocimi et al., 2016; Mayerhofer et al., 2017). Iserloh et al. (2013c) compared 13 different typologies of portable automated rainfall simulators (PARS) and stated that rainfall simulators may differ for the area covered during simulation, the adjustable intensity of precipitation, the dimension of raindrops, and the homogeneity of coverage of the plot. However, the common criterion is that the kinetic energy reached by the simulator is lower compared to natural rainfall. This is explained by the much lower fall height provided by the rainfall simulator that does not allow to reach the terminal velocity of natural raindrops (Iserloh et al., 2013c). However, PARS allows the direct measurement of surface runoff and soil erosion under different land use conditions without any alteration of soil structure and surface. Moreover, it allows to measure the integrated effect of influencing factors such as slope steepness, surface roughness, soil permeability, soil water repellence, vegetation cover, aggregate stability, and soil moisture (Bowyer-Bower and Burt, 1989; Iserloh et al., 2013c). For the sake of simplicity and applicability, often a plot size of 1 $m^2$ is used as reported by Iserloh et al. (2013b). However, several experiments should be conducted due to varying site characteristics (Mayerhofer et al., 2017).

The overall aim of this study is to assess the effects of land use changes on surface runoff, soil erosion, and sediment transport in a southern Alpine valley, thus, allowing also to evaluate the effects of these processes on soil landscape sensitivity. Therefore, we conduct surface runoff and soil erosion measurements under controlled and reproducible precipitation conditions using a small PARS on sites characterized by different land use-topography settings.

## 2. Material and methods

### 2.1. Study area

The study area covers approximately 6 $km^2$ in the Onsernone Valley (Canton Ticino, Southern Switzerland; Fig. 1) at altitudes ranging from 400 to 1000 m asl. Following the Köppen climate classification, the climate is considered as oceanic (Cfb) (Kottek et al., 2006). Dry winters are followed by rainy springs and autumns with a mean annual precipitation of roughly 2,000 mm and a mean annual temperature of about 12° (MeteoSwiss, 2020). Moreover, the study area is characterized by intense summer rainfall events, which may exceed 400 mm/day (MeteoSwiss, 2020).

The Onsernone valley is E-W oriented with morphological evidences

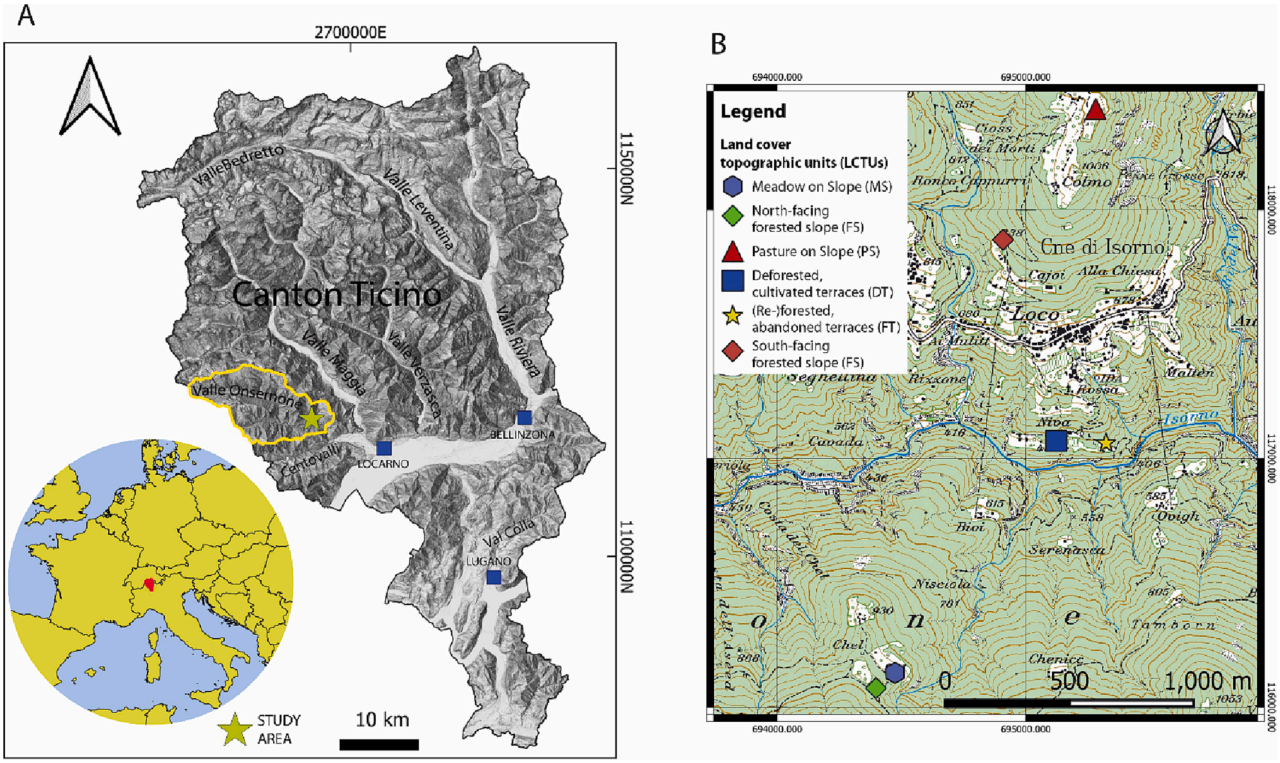


**Fig. 1.** A: Map of Canton Ticino with the location of the study area (Federal Office of Topography, swisstopo) after Bettoni et al. (2022), B: Land cover-topographic units (LCTUs). Based on Swiss Map Raster 10 (Federal office of Topography, Swisstopo) SR: CH1903/LV03.