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# Medium-term evolution of some ephemeral gullies in Sicily (Italy)

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ABSTRACT

In this study, the medium-term evolution of some erosion channels (ephemeral gullies, EGs) initiated in a wheat-cultivated area on silty-clay-loam soils in central Sicily (Italy) in 1995 was studied over 18 years. The studied EGs showed a cyclic behaviour. They appeared during the rainy season, were erased from July to October by soil infill from areas adjacent to the channel using ordinary tillage equipment, and, in most years, they reappeared in the same position during the following rainy season. Between 1995 and 2013, some field surveys were conducted to measure the channel dimensions (length, depth, width, surface area and volume). The channel size evolved over time. The depth and width increased from 76% to 90% in different EGs, reaching a depth greater than 1 m and an upper width greater than 2 m. These dimensions interfere with conventional tillage operations, and farmers suspend their efforts to fill in the channels. At the same time, the study showed that the EG length increased until almost 2006 and decreased in more recent years due to natural infilling beginning in the downstream area of the watersheds where the gradient is less. The average infilling rate ranged from 1.1 to 4.3 m year$^{-1}$. The results, on the whole, show how, once formed, EGs evolve towards permanent channels (gullies) and then can be naturally filled if the soil management system and precipitation regime are invariant.



## 1. Introduction

Gullies are relatively permanent, steep-sided water courses that experience ephemeral flows during rainstorms. They are characterised by headcuts and various steps or knickpoints along their course (Morgan, 2005). Gully erosion causes great damage both in-site and off-site (Poesen et al., 2003).

Different gully types have been described in the literature (Billi and Dramis, 2003; Ionita 2003, 2006; Poesen et al., 2003; Wu and Cheng, 2005). According to Poesen et al. (2003), three different gully types can be distinguished: permanent or classic, bank, and ephemeral gullies. Permanent gullies, or merely gullies, are landforms created through the incision of alluvial or colluvial deposits by overland or subsurface flow (Rustomji, 2006). They are channels resulting from erosion and are caused by the concentrated flow of water, usually during and immediately following heavy rains. These gullies are deep enough (usually >0.5 m) to interfere with, and not to be obliterated by, normal tillage operations (Soil Science Society of America, 2001). Bank gullies develop whenever concentrated runoff crosses an earth bank. Due to the very steep local slope gradient, bank gullies can rapidly develop by hydraulic erosion, piping, and eventually mass movement (Poesen et al., 2003). Once initiated, they retreat by headcut migration into the moderate-sloping soil surface and further into river or agricultural terraces (Poesen et al., 2002). According to Wu and Cheng (2005), bank gullies form over a long period of time and are difficult to control. An ephemeral gully (EG) is a concentrated type of flow erosion that is larger than a rill but smaller than a permanent gully (PG).

EG erosion has recently been recognized as a significant source of sediment from agricultural land contributing to total erosion from 20% to 100% (Capra, 2013). EG erosion generally occurs in cultivated soils during seedbed preparation and in planting and crop-establishment periods, when the soil is scarcely protected by vegetation. This type of erosion is a severe problem in many cultivated fields. Crops are washed out in areas where EGs develop and are submerged by the sediments at their lower end, and filling operations cause soil degradation (Liu et al., 2012; Tang et al., 2013) and reduce the long-term productivity of the farmland (Woodward, 1999). Furthermore, EGs constitute effective links for transferring runoff and sediment from uplands to valley bottoms (Valentin et al., 2005) and can rapidly evolve into permanent gullies (Vanwallaghem et al., 2005).

Different definitions of an EG have been given in the literature. According to the most common definition, EGs are channels that occur between two opposite slopes, which are typically masked but not completely obliterated by normal tillage (Casalí et al., 1999,

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2006; Foster, 1986; Soil Science Society of America, 2001; USDA, Soil Conservation Service, 1992). It is commonly accepted that rills are more common in the planar elements of watersheds, EGs on valley bottoms, or within swales (Casalí et al., 1999, 2006; Haan et al., 1994), but some authors (Capra et al., 2009; Poesen et al., 2003; Valcárcel et al., 2003) have highlighted that they have observed EGs not only in natural drainage lines but also along landscape linear elements. Capra et al. (2009) considered an EG a channel of varying size, mainly (but not only) located in swales and refilled by tillage equipment normally used on farms in the area where they are observed. Furthermore, the authors used the term EG system to indicate the entire main branch and the inter-connected tributaries of an EG.

Based on field observations, Casalí et al. (1999) described three main types of EGs: classical, drainage, and discontinuity. Classical EGs were formed by concentrated runoff flowing within the same field where the runoff started. Knickpoints (or headcut) due to flowering water migrated upstream, enlarging and deepening the channel. Drainage EGs were created by concentrated flow draining from areas upstream from the field. Drainage flows reached the upstream end of fields and eroded cultivated plots downstream. Discontinuity EGs were commonly found in places where management practices created a sudden change in slope, such as field boundaries adjacent to roads. EG headcuts, probably triggered by these slope discontinuities, later migrated upstream.

Nachtergaele et al. (2002) and Capra et al. (2009) highlighted that the critical dimension that distinguishes an EG from a PG, depends on the possibility for the farmer to fill an EG, which in turn varies in space and time according to the equipment available on the farm. In areas where the pressure for land is high and modern farming techniques are available, farmers erase every EG during farming operations. Tillage restores the original swale and allowing erosion processes to be reactivated causing significant soil losses each year in response to runoff events. Nachtergaele et al. (2002) observed that as an EG develops towards a PG during subsequent runoff events when it forms in the same place year after year, in which case the farmers tend to suspend their efforts to infill the gullies.

It is not known whether annual EG infilling exacerbates or mitigates soil losses and degradation over long time periods. Gordon et al. (2008), using a numerical model, compared soil losses in two management conditions, e.g. EG infilling by annual tillage and no annual tillage where EGs formed. The results of 10-year simulation suggest that erosion rates could be 250–450% greater when gullies were tilled and reactivated annually as opposed to the no-till condition. Liu et al. (2012) showed that

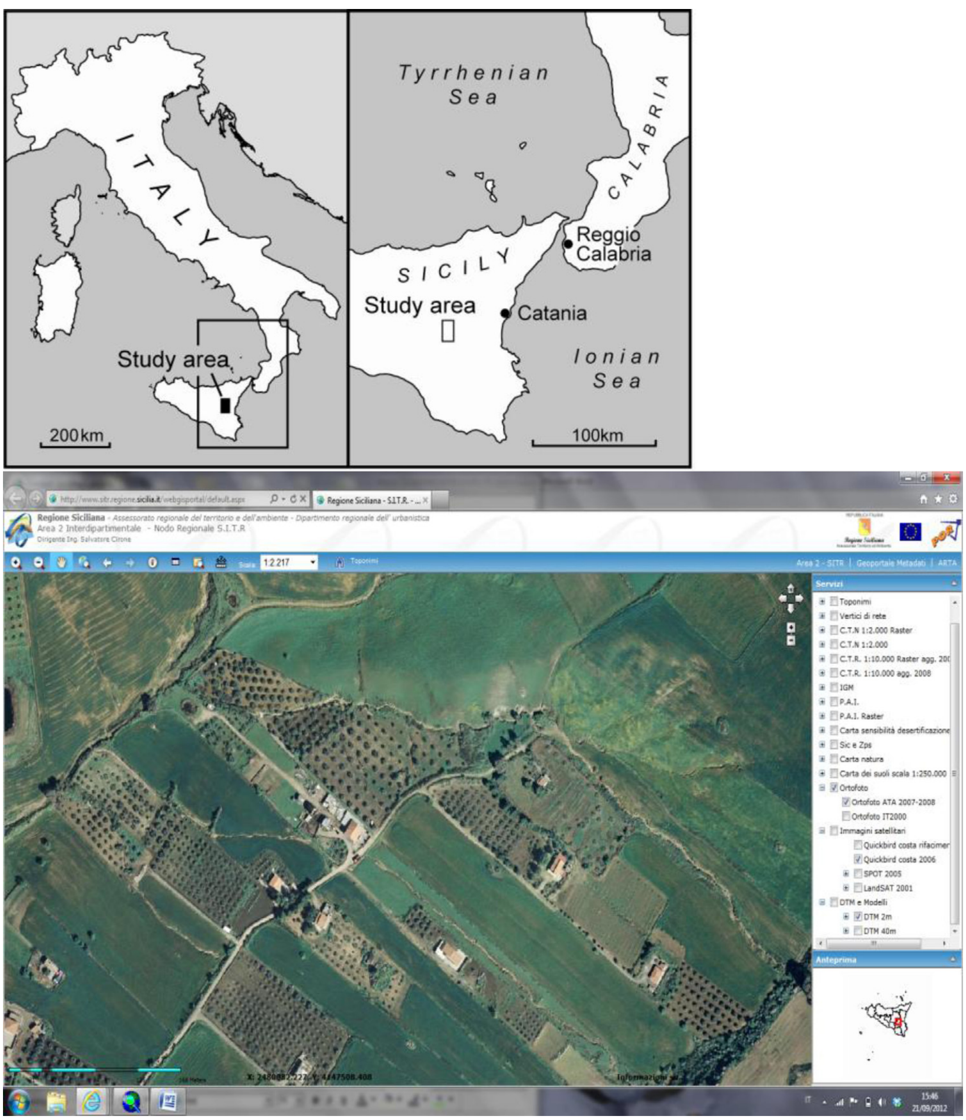


**Fig. 1.** Location and view of the study area.