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# PROCESSES, FACTORS AND CONSEQUENCES OF GULLY EROSION; INVESTIGATIONS IN THE IBERIAN PENINSULA

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## I. INTRODUCTION

Gully erosion can be defined as the displacement of soil or soft rock particles by a flow of water that forms narrow incisions that are larger and deeper than rills and that usually carry water only during and immediately after heavy storms. In this paper a complete revision of some aspects of gully erosion is presented. The article is directed to researchers, teachers and PhD students who want to go into greater depth in this topic. The processes of gully initiation and development are analyzed as well as the factors influencing process intensity. In addition, the on-site and off-site consequences of gully erosion are evaluated. Finally, a summary of studies carried out in the Iberian Peninsula presenting gully erosion rates is included.

A wide collection of gully taxonomies is gathered in literature. Traditionally, ephemeral and permanent gullies have been distinguished in literature, but also, several kinds of permanent gullies have been described, such as discontinuous permanent gullies, bank gullies, etc. The most relevant taxonomies of gullies are presented in the paper.

## II. GULLYING PROCESSES

Gullying is a process governed by concentrated flow characteristics and frequently is focused as a threshold process. Several hydraulic indicators have been used to express and quantify the intensity of the process such as total discharge, unitary discharge, flow shear stress, stream power or unit stream power. All those parameters, and others not cited here, have been applied to predict gully initiation and development. During the last years, a new set of models including stochastic components have been developed. The threshold for gully initiation and gully development can be extrinsic (e.g. climatic, anthropogenic, etc.) or intrinsic and inherent to the own channel (as a consequence of geomorphological and

sedimentological natural processes within the gully). The possible genesis and dynamic of a gully or a gully system is widely discussed in the extended paper, analyzing the effects of land use changes, climatic fluctuations, individual extreme events, etc. Also the role of subsurface flow and soil moisture content is discussed.

Three processes can contribute to increase the size of a permanent gully; headcut upstream retreat, channel widening and channel deepening. Headcut retreat can represent an important source of sediments, being able to produce approximately the same amount of sediments than the contributing area. On the other hand, bank erosion has also been highlighted in several works. Channel widening and deepening have been related to variability in soil water pressure. Channel widening is mainly supported by banks collapse, usually presenting a seasonal trend. In addition, the role of vegetation in the channel and bank material properties is discussed.

## III. FACTORS CONDITIONING GULLYING PROCESSES

Soil loss related to gully erosion ($E_c$) can be described as a multivariate function expressed as follows:

$$E_C = f(G,S,U,C,T),$$

where G represents gully type, S represents soil and bedrock properties, U is the land use and vegetation cover, C represents the climate and T represents topographical characteristics of the land surface. All of these terms and their relationships with gully erosion processes are analyzed and discussed in the paper.

## IV. CONSEQUENCES OF GULLYING PROCESSES

Gully erosion processes have been related to soil degradation due to soil and water loss. On the other hand, gully contribution to overall sediment production means between 10 and 94%. This contribution can provoke flow contamination and reduction of reservoirs lifetime and channel capacity, increasing the risk of floods. There is a wide variety of methods and materials to control gullying processes and to reduce their negative consequences (e.g. diverting flow from headcuts, transforming headcuts and banks slopes, revegetation within the catchment and/or within the channel, installing dams, etc.).

## V. GULLY EROSION IN THE IBERIAN PENINSULA

Since the 1990, several works have contributed to increase our knowledge with rates of soil losses due to gully erosion in the Iberian Peninsula. All these data are synthesized and presented in the extended version of the paper, including specific references to methods and techniques used to estimate soil losses due to gully erosion. There are several evidences of the increasing concern about gully erosion in Spain during the last years: the IV International

Symposium on Gully erosion was held in Pamplona in 2008 and a special issue of the journal *Earth Surface Processes and Landforms* was published with the most relevant works presented there and recently, a double monograph of the Spanish journal *Cuadernos de Investigación Geográfica* dealing with gully erosion studies in Spain has been published.

## VI. CONCLUSIONS

Gullying is a complex and relatively frequent process. The genesis and development of the process is sometimes related to human activities. Negative consequences are well-known including those affecting flow and those happening in depositional areas. In spite of this, some aspects of the process are still unknown, mainly, the consequences of future climate fluctuations. In Spain, initial works took place in the 80s although rates of soil losses due to gully erosion were not published up to the 90s. During the last years, research activities about gully erosion have increased as a response to a growing concern. In the near future, researchers and institutions should predict and prevent the consequences of climatic transformations in land use and gullying process.