Identification of the factors driving the spatial distribution and activity of gully network in a mediterranean semi-arid catchment

Houda Rebaï, Abir Ben Slimane, Damien Raclot, Radhouane Hamdi

IDENTIFICATION OF THE FACTORS DRIVING THE SPATIAL DISTRIBUTION AND ACTIVITY OF GULLY NETWORK IN A MEDITERRANEAN SEMI-ARID CATCHMENT

Houda Rebai[1], Abir Ben Slimane[2], Damien Raclot [3], Radhouane Hamdi [4]

[1] Institut Supérieur des Sciences Humaines Jendouba (ISSH), University of Jendouba ; [2] National Research Institute of Rural Engineering, Water and Forests (INRGREF), University of Carthage
[3] UMR LISAH, Université de Montpellier, INRAE, IRD, Institut Agro, Montpellier, France ; [4] Institut de recherche pour le développement, Tunis

Introduction

The gully erosion represents one of the most spectacular processes of land degradation, which constitutes a major concern strongly affecting the hydraulic infrastructures of surface water mobilization and interfering with socio-economic development. Although gully depends on a combination of factors that are the same everywhere (namely: climate, lithology, topography, and vegetation cover), the importance and role of one factor varies greatly from one catchment to another, depending on the characteristics of the environment and interactions with other factors, both biophysical and anthropogenic. The search for an effective strategy to control gully erosion cannot therefore be done without a study of the factors that prevail locally.

Aim

The main objective of this study is to evaluate gullying network evolution and to identify factors (physical or anthropogenic) that may explain the spatial distribution and dynamic of the gully network in a semi-arid Tunisian catchment (Fidh Ali, 2.4 km²) between 1952 and 2009.

Method

The proposed approach is based on i) the combination of field surveys carried out on the study site in 2009 to map the active gullying processes and a photo-interpretation of historical aerial imagery (1952-2009) to monitor the gully lengths evolution over nearly 57 years, and ii) a spatial correlations analysis between gully length evolution and a set of potential controlling factors of the presence and dynamics of gully network.

Study site

The Fidh Ali catchment (9°34'/9°35'E and 35° 42'/35°43'N) belongs to the Khit El Oued sector located 15 km northwest of the locality of Haffouz in the governorate of Kairouan (Fig 1). It has an area of about 240 ha. In 1991, a small reservoir with an initial capacity of around 135,000 m3 was built at its outlet.

The catchment is located in Mediterranean semi-arid climate, with an average annual rainfall of about 375 mm, and is characterized by calcimagnesic brown soils developed on gypsum mudstone interbedded with thin banks of sandstone limestone.

The morphological and land cover context is illustrated in the following figures: 1c and 1d,

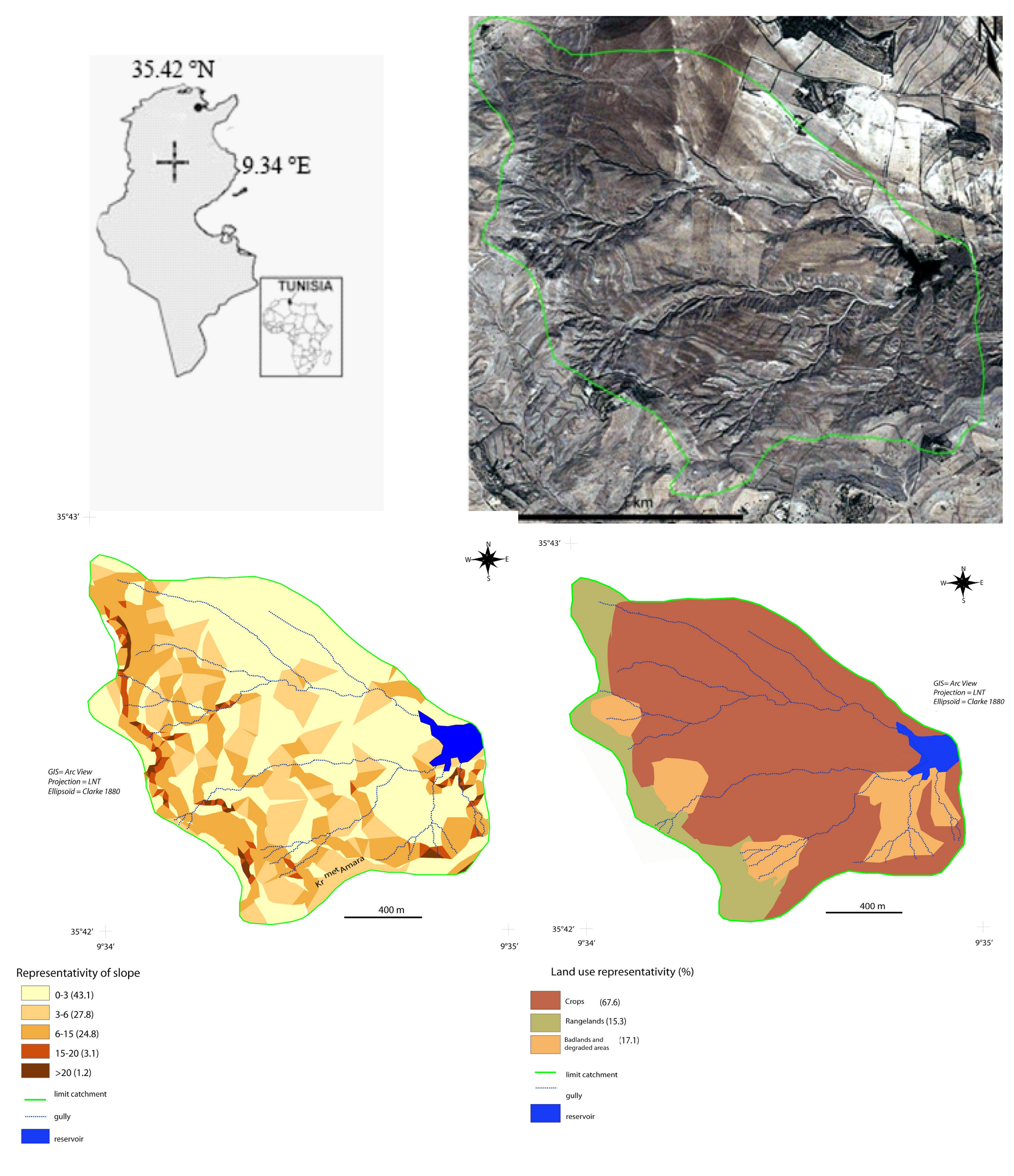

Figure 1: a) Location of the Fidh Ali catchment; b) Aerial view of the catchment (Google Earth © images, 2009); c) slope map; (d) Land cover map.

Results and discussion

The spatial distribution of erosion processes in 2009 shows a strong dynamic of bank and gully head retreat. The field monitoring shows the importance of tunnel erosion in triggering many of these patterns (Fig 2).

The catchment shows very strong spatial dynamics in the gully network, with the annual length of gullies increasing from 20.6 km in 1952 to 35.6 km in 2009, an average increase of 262 m/year. Most of this increase is due to the emergence of new gully sections on the sides of the main existing gullies (Fig 3).

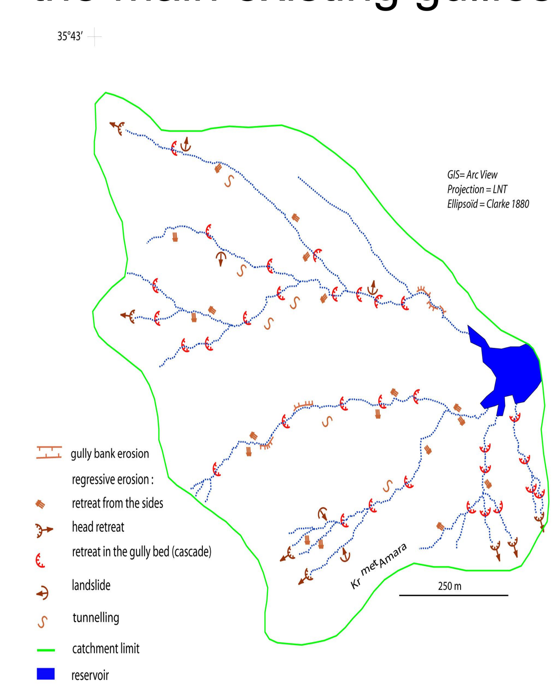

Figure 2: Mapping of active erosive processes in 2009 within the Fidh Ali gully network.

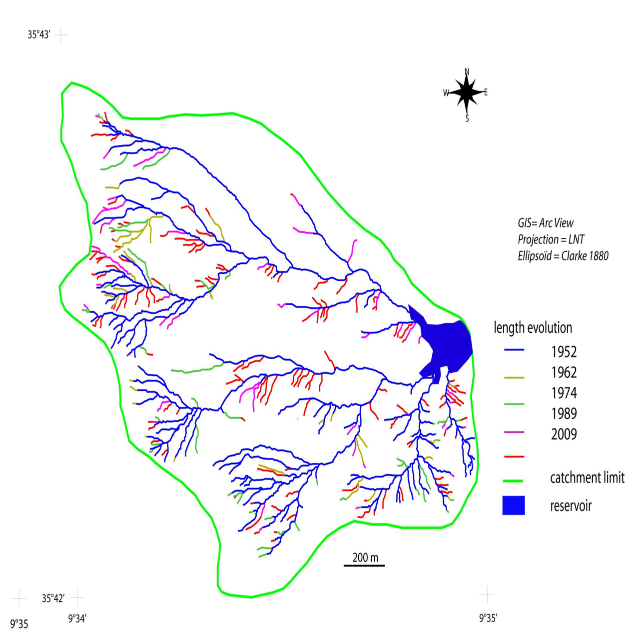

Figure 3: Evolution of the gully network between 1952 and 2009 within the Fidh Ali catchment

The spatial correlation between the distribution of gully length/evolution and factors showed that:

i) slope and land use are the main drivers of gully spatial distribution;

ii) rainfall patterns is a significant driver of gully length evolution (Tab 1 and Fig 4).

Table 1: Density of gullies (m/ha) in 2009 by slope or land cover

Studied Factors		Density (m/ha)
Slope (°)	0-3	138,6
	3-6	117,5
	6-15	182,7
	15-20	258,3
	>20	121.2
Land use	Crops (cereals/legumes/ fruit trees)	115,4
	Rangelands	42,4
	Badlands and degraded area	376,2

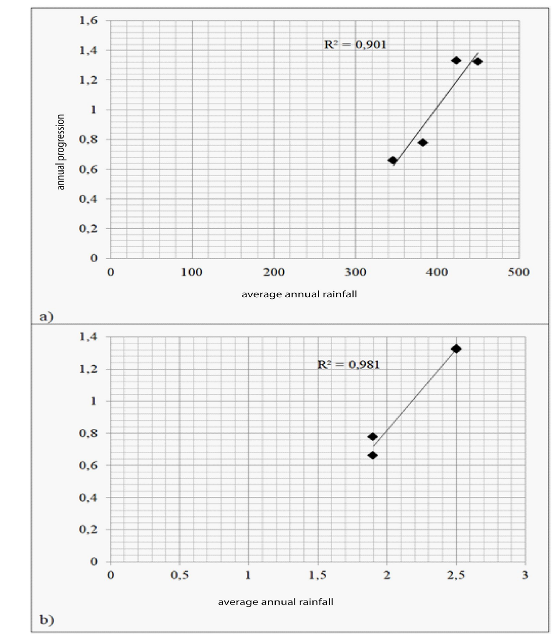

Figure 4: Linear correlation between the annual increase in gully drainage density over each period of interest (1952-1962; 1962-1974; 1974-1989 and 1989-2009) and: (a) the average annual rainfall over each period; (b) the annual rainfall frequency greater than 30 mm/d over each period.

Given that the frequency of intense rainfall is expected to increase as a result of climate change, the results obtained in this study show that gullying is therefore likely to increase significantly. Our results also provide tangible elements to guide the sectors to be protected as a priority in contexts similar to that of the catchment studied. Finally, there is an urgent need to implement erosion control measures in this type of environment in order to preserve soil resources and the water mobilisation capacity of hill reservoirs.

Conclusions and perspectives

The results showed that slope gradients and land cover were important factors in explaining the variability of gullies presence within the catchment. The results also showed that the evolution of the gully over the entire catchment was logically driven by the rainfall regime, and in particular by the occurrence of intense rainfall events. Slope gradients also appeared to play also a major role in the progression of gullies over time.

These results can be used to guide the orientation of anti-erosion strategies to protect water infrastructure (reservoirs) and agricultural land. Similar studies need to be conducted in different biophysical and anthropogenic contexts to identify whether the hierarchy of factors may change in different contexts.

For further information: Rebai H. et al., 2021. Facteurs et dynamique du ravinement dans le bassin versant de Fidh Ali (Tunisie) de 1952 à 2009. Annales de l'INRGREF (2021), 22, 53-76 p ISSN 1737-0515.

INRGREF International Scientific Days 2023. 10 and 11 October, 2023 - Sciences City of Tunis, Tunisia.