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Types of gullies and conditions of their development in silvicultural loess catchment (Szczebrzeszyn Roztocze region, SE Poland)

Katarzyna Dobek, Piotr Demczuk, Jan Rodzik, Beata Hołub

Faculty of Earth Science and Spatial Management, Maria Curie-Skłodowska University, Lublin, Poland
e-mail: katarzyna.dobek.geo@gmail.com

Abstract: The aim of this paper is to present a characteristic of loess permanent gullies, which form the branched erosion system, with the total length of almost 7.8 km, dissecting an erosion-denudation dry valley. Only 20% of the gully system catchment is cultivated as the result of steep slopes and considerable height differences up to 100 m. 80% of the catchment is covered by fir coniferous forest and Carpathian beech forest, and gully development is the result of intensive forest exploitation. Five types of gullies have been selected on the basis of the runoff directions, which are determined by the following: original relief, runoff concentration from fields, runoff concentration from fallplaces, skidding and course of forest roads used to carry a timber.

Keywords: gully in forest area, gully types, Roztocze region, SE Poland

Introduction

In the Lublin uplands region the permanent gullies usually dissect loess covers which are bound to be the perfect base for the development of fertile *Luvisols*. The beginning of gully development, deforestation and agricultural activity are considered to be the parallel processes (Maruszczak 1973). The agricultural use of catchment results in the contemporary development of gully systems as well as the location and dynamic of erosion is determined by agrarian structure (Rodzik 2010). Favourable natural conditions make the area vulnerable to gully erosion also in a silvicultural catchments as a result of intensive exploitation of forest (Rodzik et al. 2004, 2010). Contemporary, the gullies are developing also within catchments almost entire covered by forest (Buraczyński & Wojtanowicz 1972, Bąska & Lewartowicz 2004), but the intensity of erosion processes is much lower than within cultivated catchments (Pałys & Mazur 1994). Those gullies are not considered as a threat for arable lands so that's why they didn't usually draw attention. The aim of this paper is to determine types of permanent gullies and their natural and anthropogenic conditions of development in a silvicultural loess catchment.

Study area

The catchment of the Jedliczny Dół gully is located in the Szczebrzeszyn Roztocze. It is one of mesoregion of Roztocze, which is framed by longitudinal valleys of Wieprz and Gorajec rivers. Within its northern part covered by loess, an area of approx. 100 km^2 has more than 400 km of gullies. They occupy 7.5% of the mesoregions' area. Near Szczebrzeszyn, the gully density exceeds 6 km km^{-2}, and in some places, where gullies occupy 20% of the area, density reaches even 10 km km^{-2}. Natural conditions and human activity are particularly favourable to gully erosion. The loess up to 10–20 m thick covers slopes and hilltops of catchments located approx. 100 m above valley beds. Mean annual sum of precipitation is about 650–700 mm and the specific discharge exceeds 5 dm^3 s^{-1} km^{-2}. The considerable part of the area is used as an arable land for few hundreds of years despite the diverse relief (Buraczyński 1977, 1989/90, 2002).

The gully of Jedliczny Dół (Fir Hole) is located near southern border of extent loess cover of Szczebrzeszyn Roztocze, 4 km NW of Zwierzyniec. It is the largest branched gully of this area, which dissects the system of the erosion-denudation dry valley (Fig. 1).

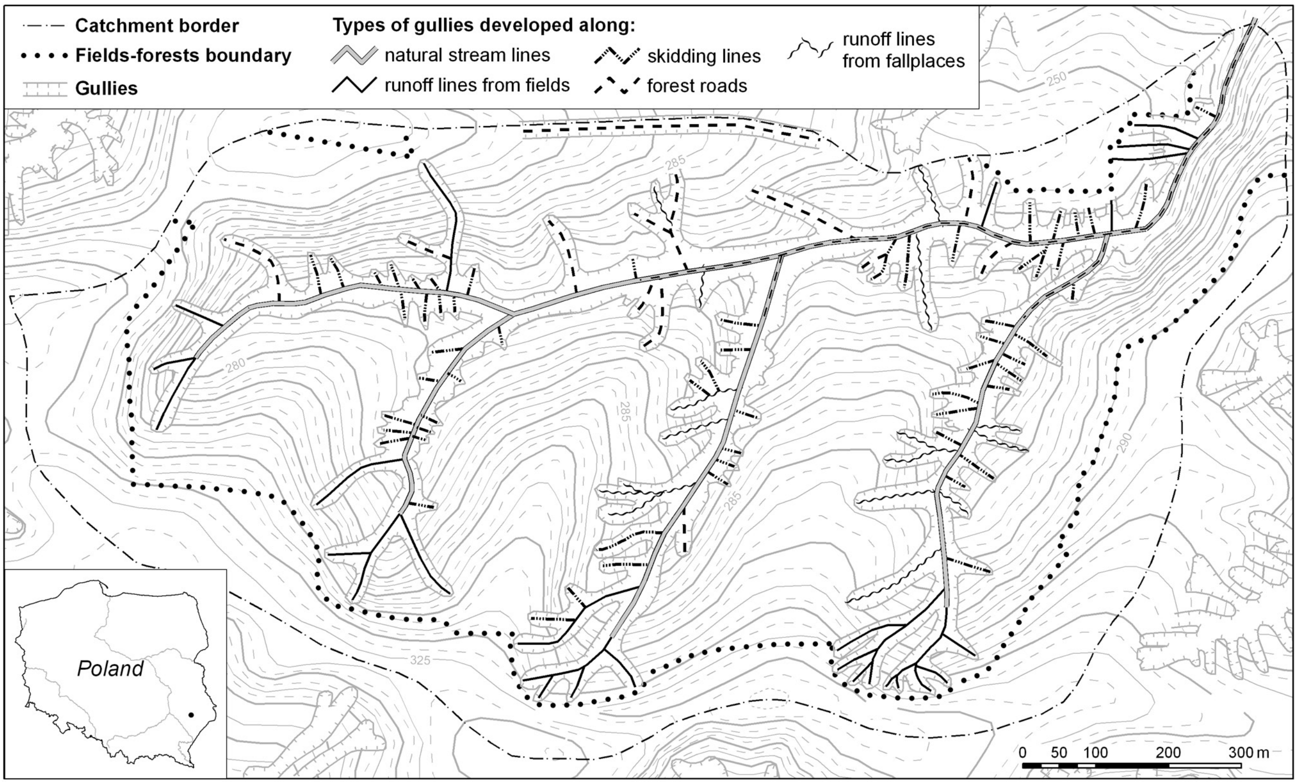

Fig. 1. Catchment of the Jedliczny Dół gully system with location of different types of gullies (made on basis of topographic map 1:10,000 and gully measurements)

Natural conditions in the catchment of Jedliczny Dół gully enable the gully erosion: almost its entire area is covered by loess, height differences reach up to 100 m, slope gradients reach value of 10–15°, and in many cases they exceed 20°. Such conditions, typical rather for the foothill regions, hinder agricultural development of the catchment. As a result 80% of its area is covered by beech-fir forest. The lower parts of valley slopes are dominated by fir, while the upper parts by beech. Arable fields occupy only upper fragments of the catchment (20%). Based on an analysis of archival maps it has been determined that the remainder of the catchment was not cultivated; only in the middle of the 20th century part of the forest was overexposed and used to graze the cattle. Exploitation of the forest, which was intensively conducted periodically in prehistoric, historical and contemporary times, contributed to development of gully system (Rodzik et al. 2004, Schmitt et al. 2006).

Gully system measurements

Erosion processes in Jedliczny Dół gully system became active during heavy rainfalls in the summer of 2002. As a result of surface runoff, mainly from this gully, many households in Turzyniec and Topólcza villages were flooded and silted. The profiles of sediments and fossil soils that were exposed become a subject of geomorphologic and paleogeographical research (Bąska & Lewartowicz 2004, Rodzik et al. 2004, Schmitt et al. 2006).

The Jedliczny Dół gully system consists of the main gully in length of over 1.5 km and three branches with a length of 500–700 m each (Fig. 1). These forms, 10–20 m deep, cut the bottoms of dry valleys. The edges of gullies and lower parts of valleys' slopes are dissected by side forms in the length up to 150 m. The total length of the gullies, according to maps of 1:10,000, is 7.8 km. In the catchment of 1.16 km^2, it gives a density of 6.7 km km^{-2}. During the field works it was concluded that some relatively large, inactive side forms, were not even marked on the topographic map 1: 10,000, and many of those that were marked are inconsistent with reality.

Catchments covered by forest, especially fir type, in many cases unable a correct measurements, by using photogrametry or GPS system. Therefore, they were carried out mainly by using hand carried equipment. Measurement of longitudinal profile of the main gully and its branches was carried by a leveller, the remaining measurements (cross section and longitudinal profiles of side forms) were performed using a compass, klinometer and measuring tape.

The shape of a gully and its relation to the location of the original relief and forms of land use, in most cases allows determining reasons for its development. Five types of gullies were determined within the investigated catchment. They were developed along runoff direction conditioned by original relief,

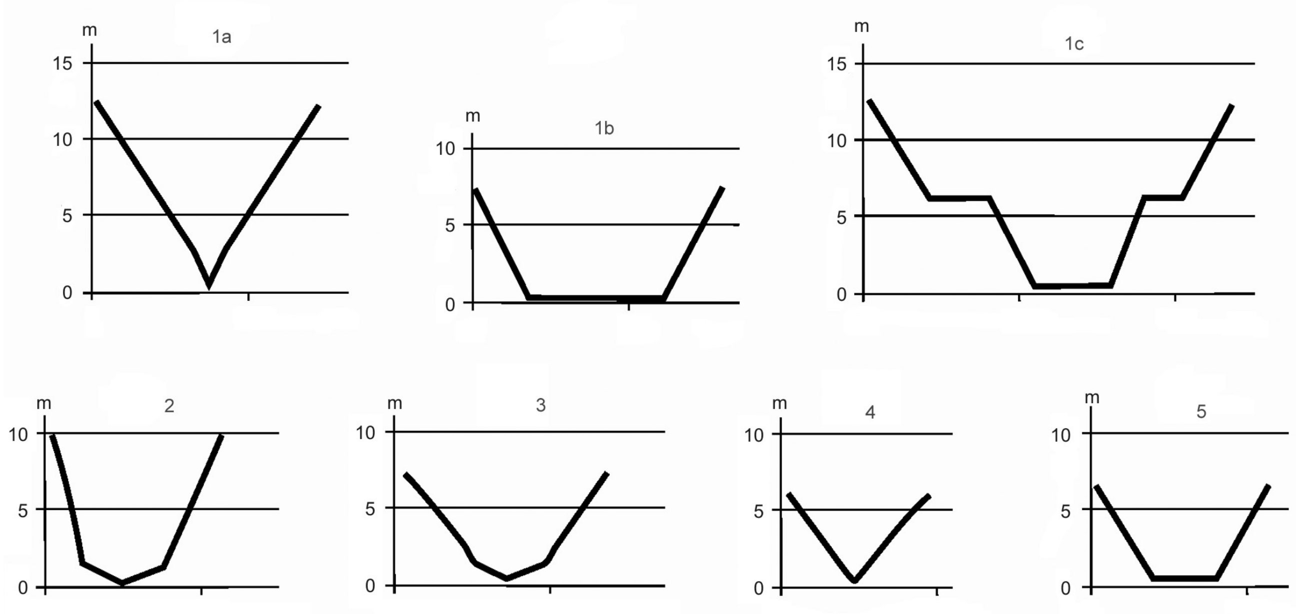

Fig. 2. Schematic cross-sections of different types of gullies in the Jedliczny Dół gully system, developed along: 1 – natural stream lines (a – upper reach, b – middle reach, c – lower reach), 2 – runoff lines from fields, 3 – runoff lines from fallplaces, 4 – skidding lines, 5 – forest roads

skidding, runoff concentration from fields, runoff concentration from fallplaces and course of forest roads (Fig. 2).

Types of gullies in Jedliczny Dół gully system

The gullies, developed on the natural stream lines of concentration of surface runoff from the hillsides and secondary forms, represents main forms, over 10 m deep. They cut the bottoms of dry valleys. Their length makes up 26% of the whole gully system. These forms are also the oldest and their bottom undergoes erosion and accumulation processes alternately. The accumulative bottom in the lower and middle reaches of the system is flat with a gradient of 1–3°, additionally dissected by the gully in its lower reach. It is shaped like the reversed trapezium in the middle reach and double trapezium in the lower reach. A V-shaped cross-section with convex slopes indicates that the erosion processes predominate in the upper reaches of this type of gullies, where the gradient is higher (even up to 5°).

Concentration of runoff from fields is taking place mainly at the field-forest boundary. Intensity and frequency of runoff from fields together with piping cause an intensive erosion, and the active gullies of this type are characterized by steep slopes and unlevelled bottom as a consequence. If place of runoff concentration is constant from hundreds of years, depth of gullies might exceed even 10 m. But if runoff changes its course the development of erosion forms is stabilized. It can also lead to the formation of new forms and badlands (*vide* Rodzik 2010). This type of gullies makes up 20% of the whole its length in the catchment.

Runoff from fallplaces is not so frequent and intense as runoff from fields. Thus gullies developing along these lines are more shallow and their stabilization is faster. The erosion begins usually at the edge of the upper gully. It was observed that initial erosion process depends on the time between tree clearance and "effective" rainfall. During the first two years linear slopewash, which is inhibited by a forest litter and roots, is taking place. The intensive infiltration is determined by the development of grass-herbaceous ground cover during the next few years. Then overloading of slopes and mass movements might appear as a result of heavy rainfall. A developed landslide headwall is becoming a place of piping and head-cut erosion processes and their effects.

Gullies developed along skidding lines are represented by relatively shallow slope forms with a high gradient of 10–15° and V-shaped cross-section. They are usually short (20–50 m), but their number results in quite large total length; they makes up 21% of the whole length of gullies in the catchment. The development of some gullies along skidding lines and runoff lines from fallplaces is probably related to their former course. This type of erosion forms is typical for mountainous regions (Parzóch 2001).

Forest roads used to carry timber are usually without vegetation cover as a result of shade. The poor vegetation cover along the skidding lines together with high gradient makes them vulnerable to wash and linear erosion processes. Deepening of forest roads is not so fast as in the case of dirt roads established between the fields, but still their depth may ranged from 5 m to even 10 m in some cases. They are shaped like the reversed trapezium as a result of processes on the sides forest roads deepening. Only forms, located on the watershed, which are developing along the roads leading to the fields, are characterised by like-box cross-section. Flat bottoms and slopes of the main gully are dissected by forms, determined by the course of roads. Their course is diagonal on the slopes in order to decrease the gradient. As a result, they form fork-like pattern (*vide* Rodzik 2010). The sum of road gullies length is considerable; they makes up 22% of the whole gully length in the catchment.

Final remarks

Development of gullies in catchments with favourable natural conditions might be also determined by intensive exploitation of forest. Steep slopes without well-stocked shield of trees are threatened by runoff and erosion processes, especially during rainstorms. Runoff concentration at the bottom of dry valleys results in dissection and development of main gullies. Edges of gullies, without trees, are vulnerable to mass movements and dissection.

Development of gullies in a sylvan catchment might be also related to the direct human activity like skidding and carrying of timber. Runoff concentration along the skidding lines from the slopes may lead to the erosion processes. Main lines of runoff concentration within the silvicultural catchment relate to forest roads, used to carry timber. They are located along the bottom of the main valley or diagonally on slopes. Flow lines are diverted quite fast into the gullies despite the fact that human activity is not so intensive here, like in agricultural catchment.

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