HISTORICAL GULLY EROSION WITHIN LOESS AREAS OF SE POLAND – NATURAL CONDITIONS AND HUMAN IMPACT

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1. Introduction

Gullies constitute one of the most characteristic elements of loess relief in SE Poland. Particularly dense net of permanent gullies – in some places more than 10 km?km^{-2} – appears in areas of specific conditions of abiotic environment which favour gully erosion. However, it is generally believed that these conditions were not a natural landscape (Bork 1989, Schmitt et al. 2006, Vanwalleghem et al. 2003). Only after the devastation of the natural plant cover of mixed and deciduous forests, resulting from agricultural expansion, the erosion began to develop dynamically.

The purpose of this article was to determine the influence of natural factors and human activity on the processes of gully erosion (density of permanent gullies). The existing gully systems were examined and the achieved results give an idea about the processes taking place in the past.

2. Area of study and methods used

Three similar in size test areas in south-eastern Poland were chosen for the research ("Markowa", "Wàwolnica", "Wilczyce"). The areas occupy about 100 km in total. The analysed terrain is characterised by the following environmental features: - the domination of the eolian deposits (loess): 59% to 78% of the area; - substantial percentage of the areas where slope angles exceed 6°: 22%-27%; the domination of arable grounds: 55%-66%.

Spatial analyses of gully erosion conditions were carried out within the test areas by means of GIS software. The measurements were taken for 35 gully catchments and for buffer zones of 50 and 100 m in width, adjacent to gully edges. Moreover, within the test area "Wawolnica" the profiles of colluvial and alluvial deposits were studied and the geochemical analysis and radiocarbon dating were carried out.

3. Results

3.1. Catchments features

The statistical calculations presented in this article were carried out for 21 catchments with an area of 10 to 100 ha (smaller and larger catchments were excluded). The analysed catchments are characterised by diverse environmental features, as proved by a wide range of examined parameters. In comparison with all the studied areas, the analysed catchments have a bigger share of loess covered areas and terrains with slope angles exceeding 12° (Table 1). The average density of permanent gullies is 4.2 km·km^{-2}, reaching 10 km·km^{-2} in one of the catchments.

Table 1. Features of gully catchments.

	range	average	test areas
area [ha]	11-84	34	3300
inclinations [°]	2.4-7.2	4.0	3.5
area of loess cover [%]	61-100	79	67
relative heights [m]	24-133	40	80-193
area of steep slopes (>12°) [%]	0-31	6	4
density of gullies [km·km^{-2}]	2-10	4.2	0.9-2.3

3.2. Spatial analysis

The research into the parameters of environmental features of gully catchments did not show any correlation between the density of gullies and the abiotic components. Only a positive relation between the density of the examined forms and the relative heights, as well as the area occupied by loess, was determined. The lack of clear relations can result from the fact that the analysed catchments varied in area, which might have caused averaging of all the relations. The gullies cut into the bottoms of almost all dry valleys – places of flow concentration – in the examined areas.

Frequency of appearance of areas occupied by certain components of abiotic environment in close vicinity of the gullies (buffers of 50 and 100 m) was compared with the frequency of their appearance within the whole test area. It allowed for determining the features favouring the gully formation. The indices were calculated according to the formula:

$$W_x = (P_x \cdot P_x^{-1}) \cdot C_x^{-1} \quad (1)$$

P_x – the area occupied by the component "x" within the buffer zone; P_b – the area of buffer zone; C_x – the frequency of appearance of component "x" within the whole research area; $W_x \leq 1$ – the component does not favour gully erosion; $W_x > 1$ – the component favours gully erosion.

In all cases the relation between the gully formation and abiotic conditions was stronger for the 50 m buffer. For the areas of "Markowa" and "Wawolnica", the relation of the occurrence of young ravines with colluvia is clearly visible – the gullies cut into the bottoms of dry valleys. For the

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remaining test areas the conditions connected with the type of surface deposits were not that clear cut (Table 2).

Table 2. Abiotic conditions of gully formation.

	50 m buffer			100 m buffer		
	1	2	3	1	2	3
surface deposits						
clays	-	3.3	0.1	-	3.1	0.1
fluvioglacial	0.3	2.0	-	0.8	1.9	-
colluvial	1.8	0.8	3.3	1.4	0.8	2.6
loess	1.1	0.9	0.5	1.1	1.0	0.7
inclinations						
plateaus (0-3°)	0.5	0.4	0.4	0.6	0.6	0.4
gentle slopes (3-6°)	1.7	1.4	0.7	1.5	1.3	0.8
medium slopes (6-12°)	1.9	1.9	2.5	1.7	1.7	2.3
steep slopes (>12°)	1.6	4.1	4.8	1.5	3.1	3.8

test areas:
1 – "Wąwolnica", 2 – "Wilczyce", 3 – "Markowa"

The relations between gully development and the relief were similar in all three tested areas. A component favouring the occurrence of the gullies within the catchment is a big share of steep slopes (Table 2).

3.3. Gully erosion phases

Study of the deposits filling the gullies allows for determining the development phases of these forms. Such studies were carried out in the western part of Lublin Upland (in Kazimierz Dolny area). The determined sequence of colluvial deposits points to four phases of gully erosion connected with periods of strong anthropopressure: Bronze Age, early Middle Ages, 16th–17th c. and the second half of the 19th c. – modern times (Schmitt et al 2004).

River valley bottoms of loess areas are places where intensive redeposition of the material removed as a result of gully erosion processes takes place. For example, the thickness of deposits connected with erosion of loess areas in the bottom of the Bystra river valley (test area "Wawolnica") reaches 3.5 – 5.0 m. The research showed that while single erosion forms could appear in Neolith and Bronze Age, these were only short hilltop gullies. The bottom of the river valley at that time was undergoing organogenetic sedimentation: peat beds were formed. The beginning of filling processes of the valley bottom by deposits connected with gully erosion took place in 10th-11th c. At the beginning, the material accumulated in the valley bottoms was of organic alluvia character. In 14th c., in the bottom of the Bystra river valley, sedimentation of anthropogenic "alluvial soil", as well as the colluvia originated from the denudation of valley slopes took place (Zglobicki, Rodzik, in print). The process of filling of the valley bottom continues up to the present moment. However, the increase of its dynamics occurred in 19th and 20th c. The above-mentioned phases of intensive gully erosion show strong relations with the periods of stronger human influence on the environment of the examined area (increase of population, development of farming). More detailed analyses of the relation between gully formations and deforestation are difficult to carry out because of significantly limited amount of cartographic materials.

4. Conclusions

Natural features of loess areas create favourable conditions for development of gullies on a regional scale. On the catchment scale (the area <100 ha) correlations between the density of gully network and the natural environment factors are not distinct. More clear cut relations appear in the case of direct gully vicinity (buffer zones of 50 and 100 m) – local conditions. Also, it seems that spatial distribution of the examined forms can be to a large extent influenced by human activity. It can be observed in diverse range and intensity of deforestation processes, as well as in agricultural activities and features like field arrangement (Fig. 1).

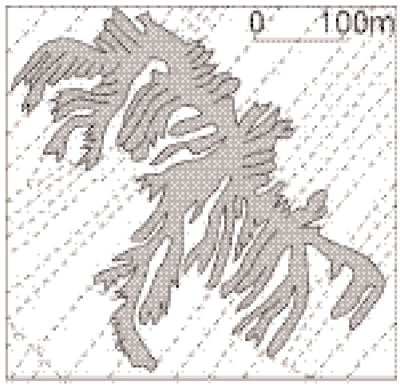

Fig. 1. Gully system against the field arrangement.

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