

INFLUENCE OF SNOWMELT AND HEAVY RAINFALLS ON WATER AND SEDIMENT YIELD FROM LOESS GULLY CATCHMENT (LUBLIN UPLAND – POLAND)

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1. Introduction

Gully erosion is a troublesome process in the loess areas of the SE Poland. In places, where relative heights are 50-100 m, density of gullies reaches $2.5 \text{ km} \cdot \text{km}^{-2}$, and locally it is over $10 \text{ km} \cdot \text{km}^{-2}$. In the humid temperate climate, gullies have been fixed by forest vegetation, but the water runoff from fields during heavy rainfalls and snowmelt induces erosion processes even on the slopes of wooded gullies (Rodzik, Zglobicki 2000). This causes splitting of arable land as well as silting and sliming of meadows, roads, and settlements in the valleys. The intensity of present-day erosion is difficult to determine because of its episodic occurrence. The effects of disastrous heavy rainfalls and snowmelts can be assessed by means of geomorphological mapping (Buraczyński, Wojtanowicz 1974; Rodzik 1984; Gardziel, Rodzik 2005). However, to seize the brief, particularly night-time rainfall runoff, requires the installation of recording devices.

2. Investigation area

Detailed research was conducted in the gully catchment in Kolonia Celejów, in the NW part of the Lublin Upland, at the edge of the region with the gully net of the highest density in Poland. The gully catchment with the area of 1.23 km^2 and relative heights reaching 50 m (213-165 m a.s.l.) is cut by gullies 5-15 m deep whose total length is 7.5 km. The surface of the catchment is covered by loess 10-20 m thick, on which Luvisols have developed, presently in various degree of erosion. The system of gullies takes up 18% of the gully catchment, the rest being under cultivation. Cereal growing prevails, but recently orchards and berry-shrubs have covered 1/3 of the farmland. The field pattern usually follows the slopes, and that stimulates the development of gullies (Rodzik, Zglobicki 2000) in which secondary succession of dry-ground forest Tilio-Carpinetum has occurred.

3. Research method

The water discharge from the gully catchment was recorded at the mouth of the main gully. A concrete baffle was built, with a water-level indicator, Thomson's V-notch weir, and a digital limnigraph THALIMEDES by OTT, with HYDRAS data recording software. During surface runoffs, every 1-2 hours, water was sampled for turbidity. To

determine the sediment load, raising functions were used, derived from the relation between the flow and the turbidity. The results were presented in the hydrological year system (November-October).

Measured were also snow-cover thickness and precipitation level – with Hellmann's ombrometer and by means of a TPG-023 digital pluviograph by A-STER, accurate to 0.1 mm. After each major runoff, the active erosion forms in the gully and within the catchment were mapped and the accumulation volume (area and thickness of depositional forms) on the gully bottom was measured.

4. Results

4.1. Climate and weather conditions

Average multi-annual temperature in this region is 7.7°C , July: 18.1°C , January: -3.4°C . Average multi-annual total precipitation is 600 mm; the highest monthly mean (83 mm) is that of July. Snow cover is present for 75-80 days and usually disappears in March. Average annual discharge is 110 mm, including the surface runoff of 30 mm.

Compared to the above, the period 2003-2006 was dry, with average annual precipitation of 517 mm (Table 1). It was solely in the years 2005-2006 that heavy rainfalls occurred (five times) with the totals of 15-65 mm and the intensity reaching $0.5\text{-}2.5 \text{ mm} \cdot \text{min}^{-1}$. The winters were quite snowy, with the maximum snow-cover thickness of 30-40 cm. During the winter of 2002/2003 the ground was ice-covered and frozen to 30 cm, during the next one (2003/2004) it did not freeze. In the winter of 2004/2005 the frost penetration was 5-10 cm deep and in the winter of 2005/2006 15-20 cm.

Table 1. Water and sediment yield from the Kolonia Celejów gully catchment in the hydrological years 2003-2006.

Hydrological year	2003	2004	2005	2006	Mean
Precipitation (mm)	419	538	530	580	517
Discharge (10^3 m^3)	37.9	6.6	10.3	17.9	18.2
Discharge index (mm)	30.8	5.4	8.4	14.6	14.8
Sediment load (t)	94.8	0.3	29.2	30.2	38.6
Denudation ($\text{t} \cdot \text{km}^{-2}$)	77.1	0.2	23.7	24.6	31.4

4.2. Surface runoff and sediment load

During the time of research, ten runoffs occurred, with the intensity of $>50 \text{ dm}^3 \cdot \text{s}^{-1}$ (five snow-melt runoffs and five

rainfall runoffs) and with considerably diversified geomorphological effects (Fig. 1). The highest flow, $382 \text{ dm}^3 \cdot \text{s}^{-1}$ ($308 \text{ dm}^3 \cdot \text{s}^{-1} \cdot \text{km}^{-2}$), was recorded during the thaws on March, 28th, 2006. In four years, from the gully catchment $72.8 \cdot 10^3 \text{ m}^3$ of water and 155 t of sediment was discharged. 31% of the water discharge and 58% of the sediment transport took place during the several days of the runoff in March, 2003. It was the second big snowmelt runoff in this region in the last twenty-five years (Gardziel, Rodzik 2005). Its volume (18.2 mm) was affected by deep freezing and ice-covering of the ground during January snowmelt. In the first (2003) year of the research, when as many as three snow-melt runoffs occurred, the water discharge was 52% and the sediment load was 61% of four-year totals.

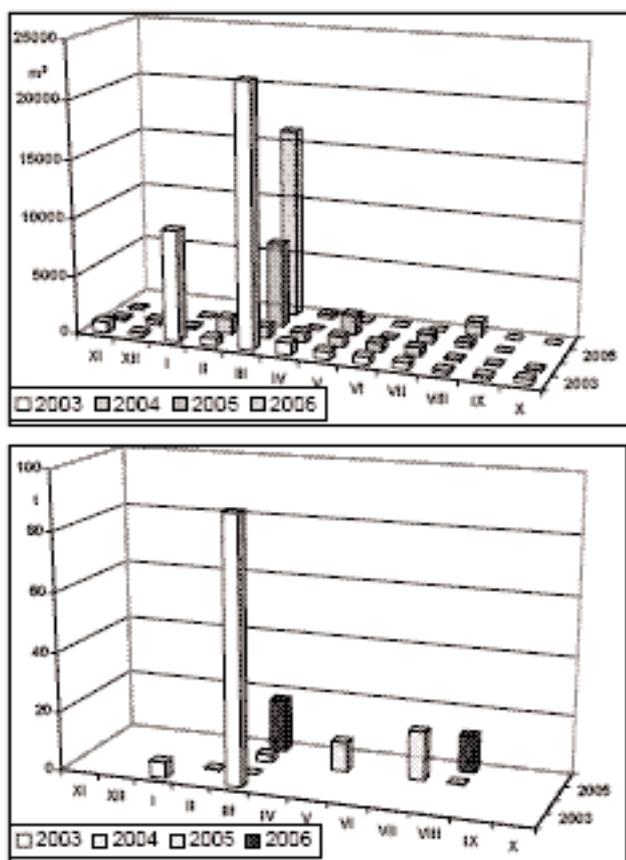


Fig. 1. Monthly totals of discharge (top) and sediment load (bottom) from the Kolonia Celejów gully catchment in the years 2003-2006

In the years 2003-2006 average annual discharge was $18.2 \cdot 10^3 \text{ m}^3$, and the discharge index was 14.8 mm, which is by half less than average annual discharge index of several decades. Snowmelt discharge was 81% of the figure, whereas heavy rainfall discharge was 6%. The share of snowmelt in sediment load was 75%, and that of heavy rainfalls 25%. However, only 1/4 of the material, set in motion mainly by piping, was discharged from the catchment, the effects of surface wash in the gully and within the catchment was very limited. Most of material (>400 t) was accumulated as colluvial fans and covers in the

bottom of the gully. In the accumulation process the prevalence of snowmelt is clearly marked (90%), whereas the role of heavy rainfalls (25%) is mostly visible in sediment load.

Table 2. Snowmelt and heavy rains share in water and sediment yield from the Kolonia Celejów gully catchment in hydrological years 2003-2006.

Index	Snowmelt	Heavy rainfall	Other
Discharge	81%	6%	13%
Sediment transport	75%	25%	0%
Accumulation	90%	10%	0%
Total erosion	84%	16%	0%

Caused by rainfall runoff, the highest flow was $284 \text{ dm}^3 \cdot \text{s}^{-1}$, and the highest discharge index was 1.3 mm. During the research, however, the precipitation was not as big as in the years 1997-1999 (Zglobicki 2002). Gully bottoms are eroded particularly by disastrous heavy rains occurring every 50-100 years, with the total rainfall of about 100 mm and the intensity of $1-2 \text{ mm} \cdot \text{min}^{-1}$; at such time mechanical denudation can reach $4-10 \cdot 10^3 \text{ t} \cdot \text{km}^{-2}$ (Buraczyński, Wojtanowicz 1974, Rodzik 1984).

5. Conclusions

The surface discharge from the gully catchments of the Lublin Upland (Poland) usually is not very high and amounts to about $15 \text{ mm} \cdot \text{yr}^{-1}$. It is mainly an episodic discharge of snow/rainfall regime. Surface runoff and rill erosion are caused by rains of the total >10 mm and intensity $>1 \text{ mm} \cdot \text{min}^{-1}$, the main factor of gully erosion is however snowmelt runoff. Most of the material set in motion at that time remains at the bottom of the gully, and can be carried away during heavy rainfalls.

Acknowledgements: The work reported in this paper was financially supported by the programmes of Scientific Research Committee (Poland): "KBN 3P04E 01322" and "PZB-KBN-086/P04/2003".

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