Landform Analysis, Vol. 17: 209–214 (2011)

The development of ephemeral gullies in cultivated areas of Wiśnicz Foothills, Poland

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Abstract: Ephemeral gullies most frequently form and develop on cultivated slopes in natural drainage lines or they are associated with man-made agricultural activities like field borders, furrows, tractor traces and cart roads. The paper presents the results of ephemeral gullies studies carried out in hydrological years 1998–2009 on cultivated slopes in the Wiśnicz Foothills. Ephemeral gullies usually form and develop during single rain or several subsequent rains of high erosivity (of several hundred MJ mm ha^{-1} h^{-1}) on long cultivated slopes, particularly at the beginning of vegetation period, when most slopes are devoid of vegetation cover or plants are in the inicial stage of growth.

Keywords: ephemeral gullies, rill erosion, soil erosion, Wiśnicz Foothills, Poland

Introduction

Carpathian Foothills cover 47% of the area of the Polish Carpathians. In the foothill zone the dominant relief type is low hills, convex-concave slopes (5–20°), flat and broad valley bottoms which separate slopes and stream channels. The thickness of slope cover amounts to 20 m. There are also loess patches several to a dozen meters thick which may potentially contribute to severe erosion. Carpathian Foothills have been profoundly transformed by man's economic activity. Type of relief, thick loess slope covers, large area of cultivated slopes, high single rain erosivity should potentially contribute to severe soil erosion by water (Święchowicz 2002, 2008a). On cultivated foothill slopes soil erosion by water leads to their distinct transformation and causes damage to agriculture (Święchowicz 2008b, 2009).When water is channelled across unprotected land and washes away the soil, ephemeral gullies are formed along the drainage lines. The aim of the paper is to describe the mechanism and intensity of development of ephemeral gullies on cultivated slopes in the Wiśnicz Foothills.

Study area

Research was carried out on the Jagiellonian University's farm, which is located in the village of Łazy. The farm covers an area of 103 ha. The dominant relief type is low hills. Ploughed land constitutes 86% of the area of the farmland, meadow and pastureland – 13% and only 1% of the area is covered with forest (Święchowicz 2009). Pseudogley soils (Stagnic Luvisols) developed from lessive soils (Haplic Luvisols) are dominant. On cultivated slopes brown soils (Cambic Luvisols) occur only in small patches surrounded by Stagnic Luvisols (Klimek 1995). The Jagiellonian University's farm is the only one in the village of Łazy that covers such a large area. Farms with area smaller than 1 ha constitute 61% of all the farms in the village, and 37% of the farms cover the area between 1–5 ha each. Most small farms consist of several separate field plots.

Methods

The results presented in this paper come as a result of the mapping of the ephemeral gullies created after the rainfalls in years 1998–2009 (Fig. 1). The field survey included the measuring of the length,

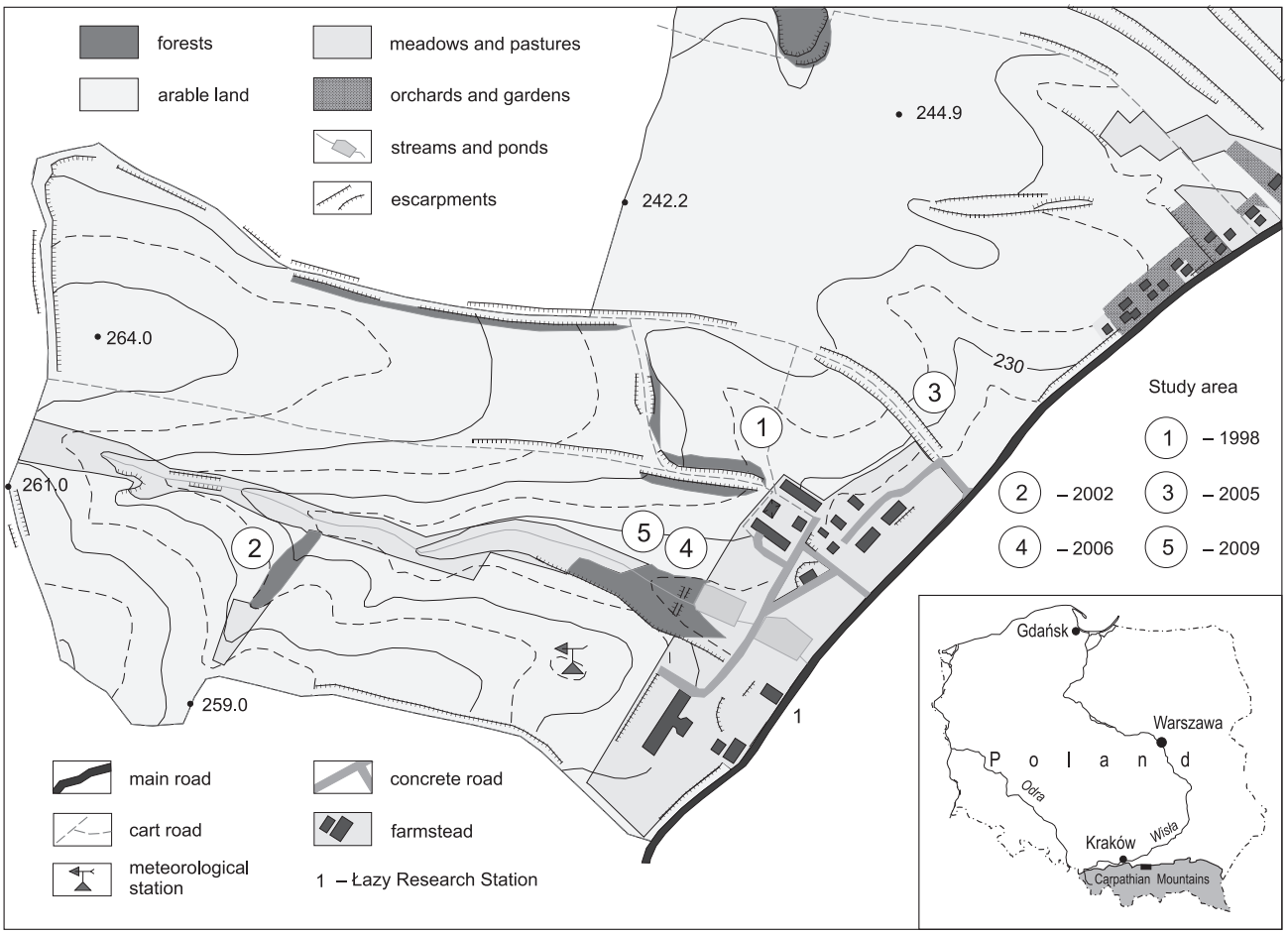

Fig. 1. Location of the study area

width and depth of erosive incisions using a metre rule with the accuracy of +/–1 mm and tape. Then the soil loss was evaluated by calculating the volume [m^3] and the amount of eroded soil [Mg].

All erosive rainfall events were evaluated according to the same procedure consisting in the calculating (on the basis on hyetograph records) of kinetic energy of rainfall according to Brown & Foster (1987) formula, and single rainfall erosivity [EI_{30}] according to Wischmeier & Smith (1978).

Results

On agricultural foothill slopes, soil erosion by water happens rarely (up to a dozen times a year). Soil erosion hardly ever occurs on the whole area of slopes in the catchment, and transport of eroded material is irregular and not simultaneous. The formations of ephemeral gullies happens once a year or once in a few years. The events are occasional and happen locally. Ephemeral gullies most frequently form and develop on cultivated slopes in natural drainage lines or they are associated with man-made agricultural activities like field borders, furrows, tractor traces and cart roads (Fig. 2). The frequency of occurrence of these forms depends on the vegetation cover and the condition of the soil surface in the period just before the process begins as well as on the erosivity of rainfall. Ephemeral gullies form both during the spring thaw and during rainfall of high erosivity. The research shows that more effective are rainfalls of high erosivity especially when they come at an early stage of vegetation process. Ephemeral gullies form most often as a result of overlapping of several factors: the sowing of one crop on a large area (mainly root crops) and the occurrence of several high intensity rainfalls at an early vegetation stage.

The research shows that the formation of these forms is possible particularly at the beginning of the vegetation period, when the soil has been cultivated and most of the area of arable land is devoid of vegetation cover.

This was the case in the research area for example in wet 2002 hydrological year with annual precipitation total of 725.4 mm, and with monthly totals of precipitation in May and June much higher than the

Fig. 2. Natural and man-made conditions for the development of ephemeral gullies in Carpathian Foothills (phot. by J. Święchowicz): A – natural drainage lines, B – field borders, C – cart roads

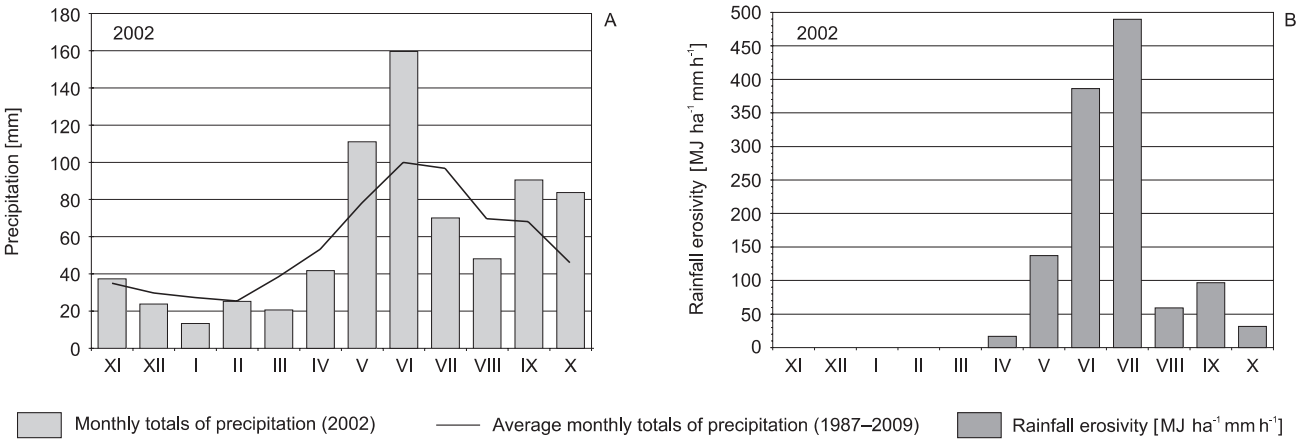

Fig. 3. The characteristics of precipitation in hydrological year 2002 (Łazy Research Station): A - monthly totals of precipitation [mm], B - rainfall erosivity [MJ mm ha^{-1} h^{-1}]

average totals from 1987–2009 (Fig. 3). Rainfalls of high intensity and erosivity which took place at the beginning of vegetation season led to the formation of an ephemeral gully on the beet root field (Fig. 4; Święchowicz 2002). After the rainfall of 28th June, the maximum depth of ephemeral gully was 68 cm (Fig. 5). On the 16th July there was another rainfall with the amount of 40.4 mm, high erosivity of 473.1 MJ mm ha^{-1} h^{-1} and 30-minute maximum intensity of 52.5 mm h^{-1}.

The erosivity of all the 6 single rains at the beginning of the vegetation period was 422.3 MJ mm ha^{-1} h^{-1} and almost the same as the erosivity of the rain which took place on 16 July in the middle of the vegetation season (473.1 MJ mm ha^{-1} h^{-1}). The total volume of the gully before the rainfall of 16 July 2002 was 33.7 m^3, and after the event increased only by 5.1 m^3, representing 13.1% of the total volume of the gully. A relatively small effectiveness of this rain in relation to its erosivity was influenced by dense vegetation cover, which protected the soil well against erosion. At the same time the surface soil layer was washed away at the beginning of the vegetation period, and the deepening of the gully consisted in eroding Bt horizon. Thus, the development

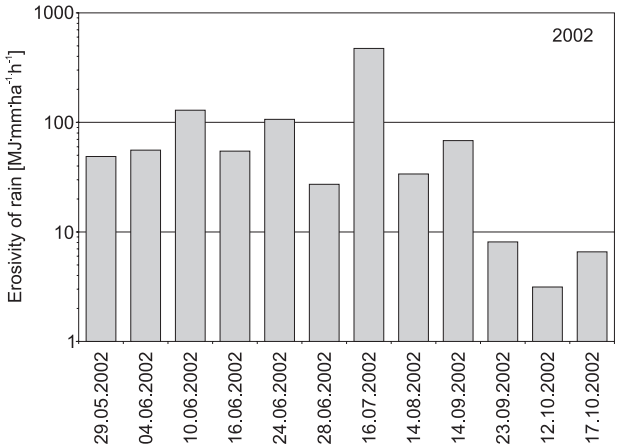

Fig. 4. The erosivity [MJ mm ha^{-1} h^{-1}] of single rainfall events in 2002 hydrological year (Łazy Research Station)

of the gully in July mainly consisted in its widening and lengthening through headword erosion as well as its deepening which, due to the resistance of Bt horizon, was not as effective as it was at the beginning of the vegetation season (Fig. 5). The ephemeral gully was then filled up by farmers after the sugar-beet harvest.

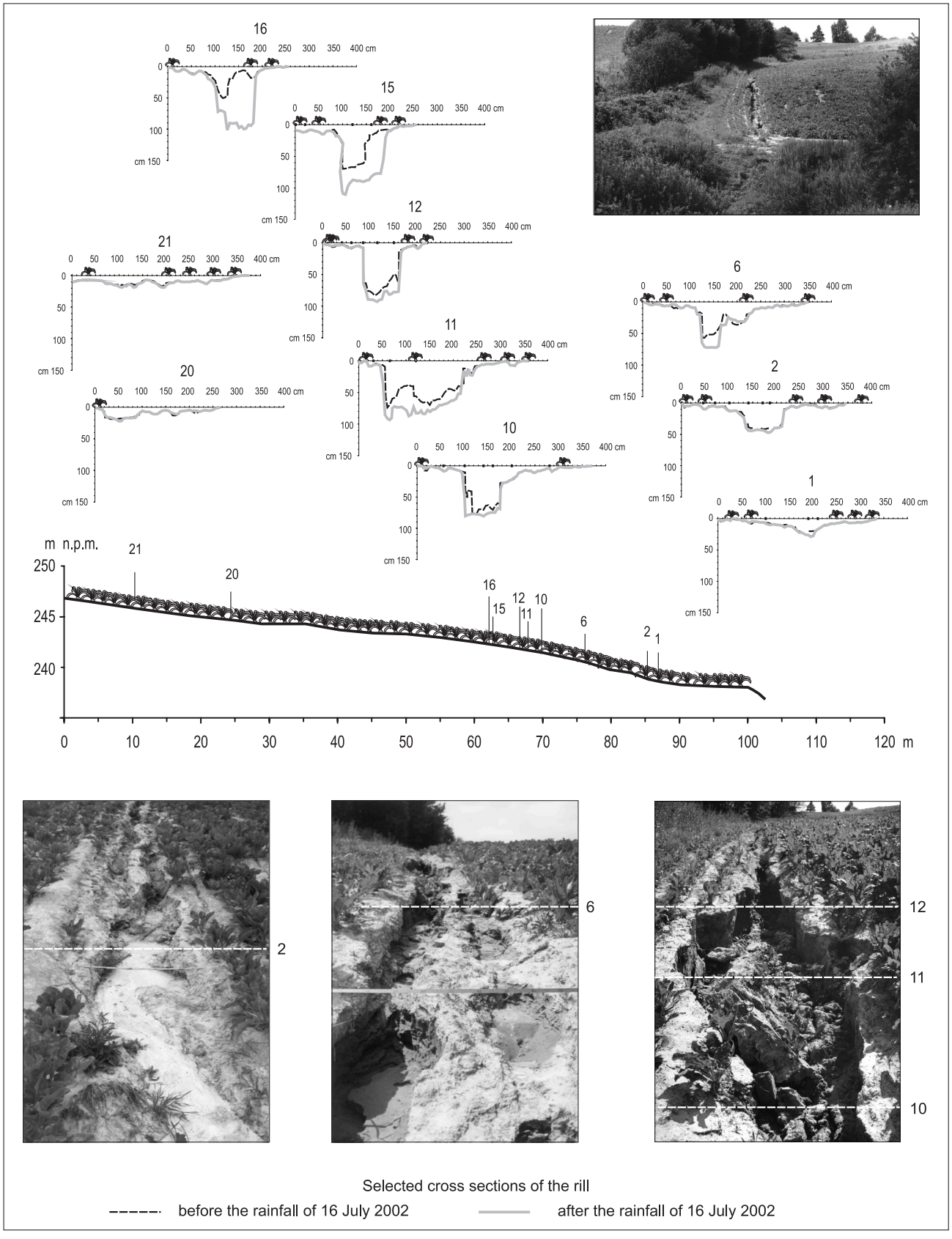

Fig. 5. Morphological results of intensive rainfall which took place on 16 July, 2002 (photo J. Święchowicz)

Discussion and conclusion

Although agricultural areas in the Carpathian Foothills are prone to severe erosion, there are not many studies on the formation and development of ephemeral gullies. Some information can only be found in few studies on extreme rainfalls (Olecki 1970, Święchowicz 2004, 2008b, 2009, Długosz & Gębica 2008) or general studies concerning erosion processes in the Foothills (Reniger 1955, Woźniak-Strojna 1963, Drużkowski 1998, Święchowicz 2002).

The research carried out in Wiśnicz Foothills shows that the development of ephemeral gullies was limited both by extrinsic (erosivity of rain) and intrinsic thresholds (the lenght of slope, the presence (or lack of) Bt horizon, soil moisture, type and calendar of crops and farming activities). Ephemeral gullies usually form and develop during single rain or several subsequent rains of high erosivity (of several hundred MJ mm ha^{-1} h^{-1}) on long cultivated slopes, particularly at the beginning of vegetation period, when most slopes are devoid of vegetation cover or plants are in the inicial stage of growth. The process of enlarging and deepening of ephemeral gullies slows down when the incision of a gully reaches Bt horizon. Then the effectiveness of even high erosivity rainfall is much smaller. Similarly, very high erosivity of rainfall in the middle of the vegetation season is not able to cause such serious effect and the intensity of deepening of ephemeral gullies is much smaller. The process of intensified linear water erosion is more significant on commercial farms with a large acreage of crops. On cultivated foothill slopes soil erosion by water leads to their distinct transformation and causes damage to agriculture. As a result all the mapped erosion forms were disposed of by farmers (e.g. by ploughing or filling up). If these forms were left untouched, they would develop and get deepened during consecutive rainfalls of high erosivity, leading as a consequence to the exclusion of strips of land.

Acknowledgements

Thanks are due to Alicja Waligóra-Zblewska for preparing the English translation of the paper. This project is partially supported by Ministry of Science and Higher Education of Poland in the years 2008–2010 (grant no NN 306 048334) and Jagiellonian University Grants (DBN-414/CRBW/XVII-45/2005 and WRBW/BiNoZ/39/2007).

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