RAINFALL THRESHOLDS FOR SURFACE RUNOFF AND SHEET EROSION IN AGRICULTURAL CATCHMENTS

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Soil erosion resulting from rainfall is usually most noticeable and spectacular during extreme events like local heavy downpours. Agricultural slopes, devoid of natural vegetation cover, react very quickly to short-duration, high-intensity rainfall events (Starkel 1976, Froehlich and Starkel, 1995). It is widely known that soil erosion takes place only after exceeding rainfall thresholds. Soil erosion rarely happens on all slopes in a catchment simultaneously, and its intensity is differentiated along the longitudinal profile of the slope. Soil loss from farmland causes the reduction of the thickness of topsoil layer, leading at times to its complete removal. Erosion not only causes long-term impoverishment of soil and the reduction of crop yield, but also makes farming difficult, and sometimes permanently damages large land areas (Auzet *et al.*, 1990; Boardman, 1995; Boardman *et al.*, 2006; Stankoviansky, 2002).

The slope and the channel in a catchment are transformed after exceeding rainfall thresholds, when a local linkage between the slope and channel systems may take place consisting in sediment supply from slopes to the channels. The coupling or decoupling of slopes and channels (sediment supply or its lack) is not a stable state in a catchment.

Each catchment has its individual conditions that initiate erosion on slopes and export of suspended material out of the catchment. The most important are climatic conditions and agricultural use.

Setting rainfall thresholds in relation to land use has practical implications, because they can be used to predict future erosional events (Schumm, 1979; Coates and Vitek, 1980; Hart, 1986; Maggi, Maraga, Ottone, 2003)

The research was carried out in the lowest part of the Carpathian Foothills, where the Field Research Station of the Institute of Geography and Spatial Management of the Jagiellonian University is located (Figure 1). Dominant lithologies are flysch series belonging to the sub-Silesian and Silesian overthrust, and Miocene clays and sandstones, which are covered with Quaternary loess-like formations. The soil cover is weakly differentiated with Haplic and Stagnic Luvisols. The dominant type of relief are low and medium hills. Convex-concave slopes smoothly transform into broad alluvial valley floors. The area is used for agriculture (Świechowicz, 2002). Mean annual precipitation measured from 1987 to 2006 was 657 mm. Annual precipitation totals ranged from 433 mm in 2003 to nearly 800 mm in 1998 and 2001. There were on average 167.1 days with precipitation in hydrological years 1987- 2006. Maximum daily precipitation in a year varied from 21.0 mm in 1993 to 83.4 mm in 2006.

The paper presents the results of research in Dworski Stream catchment, which is small (0.3 km^2), intensively farmed, with arable land covering 80% of the catchment area. The Dworski Stream catchment is controlled by hydrometric profiles with a flume and a limnigraph. During hydrological years 1987-2007 water levels were measured and 1 litre water samples were taken every four days to determine suspended and dissolved matter concentration. Precipitation data were collected in 1987-2007 at the Meteorological Station which is located in Dworski stream catchment. The research into soil erosion was carried out on the pasture land slope (1989-1990), two experimental plots (1989-1991) and in 1998-2007 by mapping erosion features caused by extreme rainfall events that took place on agricultural land.

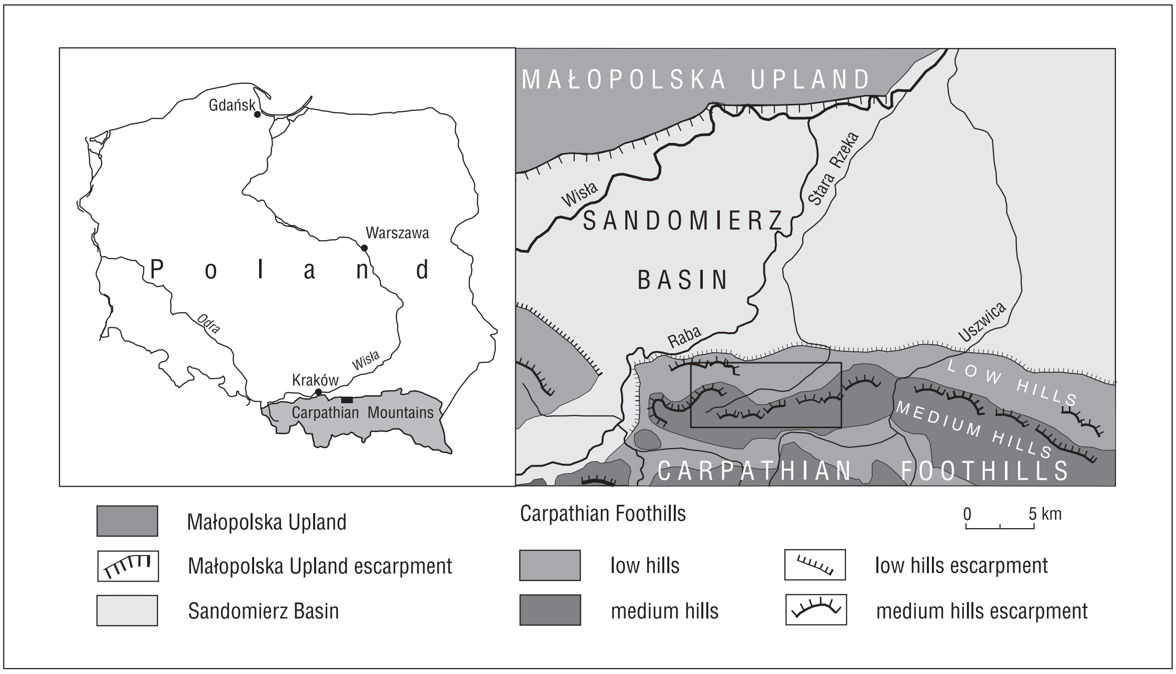

Figure 1. Location of the study area

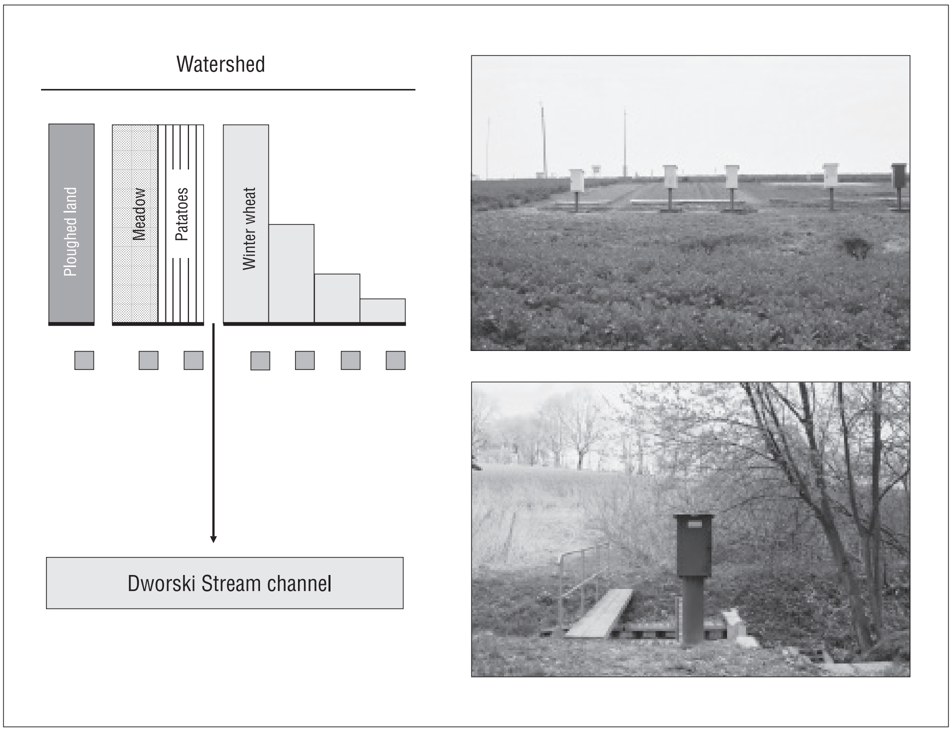

Figure 2. Pattern of experimental plots

Since November 2006 soil erosion has been measured on seven plots. All the plots are 2 m wide but they differ in length (22.1 to 2.8 m). All the plots are closed with 2 m plastic Gerlach troughs. Water and material eroded from each plot are caught by the troughs and go into a separate water tank with a limnigraph. Out of the seven plots one is devoid of vegetation cover and is like arable land, one is grassland, one is a potato field whereas the remaining four, which differ in length, have wheat crops. The ploughed land and grassland will remain as such for the whole period of research while the crops on the remaining plots will alternate every year as it usually happens on agricultural farms in the foothill area (Figure 2). After each rainfall, measurements of surface flow and soil erosion are taken to allow comparing the intensity of the processes on plots which are differently used for agriculture.

The main aim of the research is to establish rainfall threshold values which cause soil erosion on agricultural slopes and the supply of the suspended material to the stream channel and also to determine the intensity of erosion in relation to land use.

The research shows that the soil erosion is an occasional process. The rainfall of the same parameters, even within short and uniform slope plots, does not always bring about surface runoff and slope wash on every plot. The intensity of surface runoff and soil erosion depends mainly on the type of crops. Only sporadic short-duration and high-intensity rainfall events may trigger severe overland flow and soil erosion causing serious loss of topsoil (Figure 3). The process leads to significant changes of the forms already present on the slope and to the formation of rills and gullies, and the material transported down the slope is accumulated on the footslope plains or in the valley bottom in the form of deluvial fans. Deposition of the material at the bottom of the slope and in the valley floor leads to the elevation and extension of the valley bottom and hindering transport of solid material from the slope to the channel. Consequently, slope-channel coupling and material supply becomes only local and episodic.

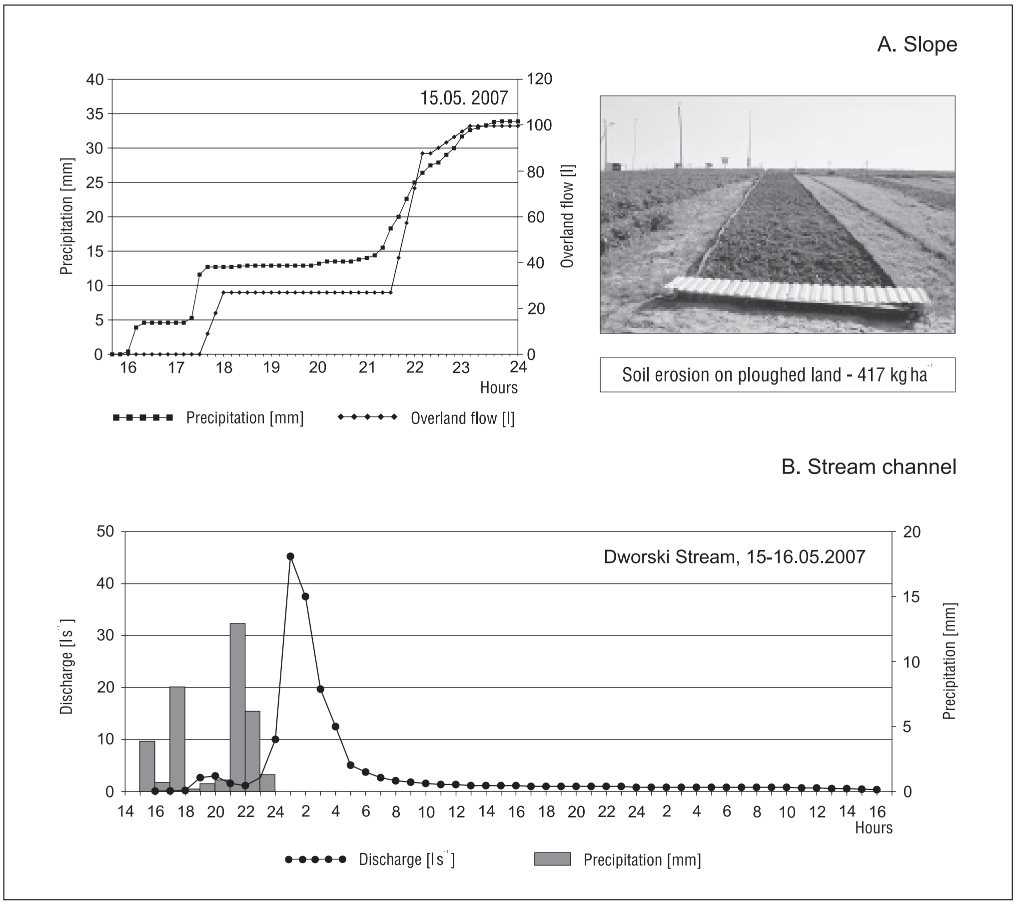

Figure 3. Overland flow, sheet erosion and stream discharge in the Dworski Stream catchment during rainfall event on 15 May 2007

References

Auzet A.V., Boiffin, J., Papy F., Maucorps J., Ouvry J.F., 1990: *An approach to the assessment of erosion forms and erosion risk on agricultural land in the northern Paris Basin, France*. In: J.B. Boardman, I.D.L. Foster, J.A. Dearing, (eds.) *Soil Erosion on Agricultural Land*, John Wiley & Sons: 384-400.

Boardman J.B., 1995: *Damage to property by runoff from agricultural land, South Downs, southern England. 1976-93*. Geographical Journal, 161: 177-191.

Boardman J.B., Verstraeten G. and Bielders, Ch., 2006: *Muddy floods*, In: J. Boardman, and J. Poesen, (eds.) *Soil erosion in Europe*. John Wiley & Sons: 743-755.

Coates D.R., Vitek J.D., 1980: *Perspectives on geomorphic thresholds*, In: D.R. Coates, J.D. Vitek (ed.) *Thresholds in Geomorphology*, London: Allen and Unwin: 3-23.

Hart M.G., 1986: *Geomorphology pure and applied*. George Allen & Unwin, London: 1-228.

Froehlich W., Starkel L., 1995: *The response of slope and channel systems to various types of extreme rainfalls (temperate zone – humid tropics comparison).* Geomorphology, 11(4): 337-346.

Maggi I., Maraga F., Ottone C., 2003, *Erosive rains related to in channel sediment delivery in a small Alpine basin (North-Western Italy.* In: L.Holko, P. Miklánek (eds.), *Interdisciplinary approaches in small catchment hydrology: Monitoring and research,* Proceedings of the 9th ERB Conference (Demänovská Dolina, Slovakia, 25-28 September 2002, Technical Documents in Hydrology 67, Unesco: 91-98.

Schumm S.A., 1979: *Geomorphic thresholds: the concept and its applications.* Transactions of the Institute of British Geographers 4: 485-515.

Stankoviansky M., 2002, *Bahenné povodne – hrosba úvalín a suchych dolín*. Geomorphologia Slovaca, 2: 5-15.

Starkel L., 1976: *The role of extreme (catastrofic) meteorological events in the contemporary evolution of slopes.* In: J. Wiley (ed.), *Geomorphology and Climate*: 203-246.

Święchowicz J., 2002: *Linkage of slope wash and sediment and solute export from a foothill catchment in the Carpathian Foothills of south Poland*. Earth Surface Processes and Landforms, 27(12): 1389-1413.