

Gully erosion rate by means of anatomical changes in exposed roots tree rings in the Proboszczowicka Plateau (southern Poland)

Ireneusz Malik

University of Silesia, Earth Science Faculty, Sosnowiec, Poland
irekgeo@wp.pl

Network of gullies can increase above 300 % during about 80 years (Swanson et al., 1989). More often the rate of gully erosion is 0,2-0,8 m/year (Martinez-Casasnovas, 2003). The analyze of precipitation, valley morphology and sites where erosion occurs can be use to building the local erosion models. The models allow estimate future gully erosion and very often we can estimate local thresholds to erosion occurs. One of the main factors conditioning gully erosion is the quantity and intensity of precipitation. In wet periods gully erosion may occur several times faster. However, studies conducted in Canada prove that natural processes associated with climatic fluctuations are insufficient to cause gully initiation, but may contribute to ongoing gully expansion. According to (Stankowianski, 2003) gullies are formed during periods of extensive forest clearance and expansion of farmland, but the triggering mechanism of gullying are extreme rainfall events. Local hill slopes gradient and drainage-basin area are the most important topographic parameters affecting gully erosion. Also lithological conditions as well as the thickness of dusty sediments and the underlying rock structure can be significant factors affecting the development of gully erosion.

Studies of gully erosion velocity are often based on the comparison of gully lengths on maps produced in different centuries or on aerial photos (Burkard and Kostaschuk, 1995). Another method of measuring the velocity of gully erosion includes continuous monitoring of headcuts. Also a dendrochronological method has been used for estimating the speed of gully erosion (Vandekerckhove et al., 2001).

Research has been conducted for some time on the possibility of determining an erosion episode based on anatomical changes occurring in root wood after exposure (Gärtner et al., 2001). The research has shown that cells within annual increments become more numerous and smaller after exposure. One can clearly see the division into early wood and late wood within annual increments originating after exposure. In the process of exposure roots are often wounded. Scars frequently occur on the boundary between exposed and unexposed annual increments. They document one erosion episode that has led to their exposure. These anatomical changes in root tree rings allow one to date erosion episodes.

Studies were carried out on the Proboszczowicka Plateau, the northern part of which belongs to the Silesian Upland and the southern part of which falls in the Silesian Lowland (Figure.1). A dense network of permanent gullies 10-20 meters deep dissects large areas of the summit surface at 270-300 above m. s. l. This gully network has been formed in loess sediments. These sediments are on average about 10 m. thick and are underlain with Triassic dolomites and limestones or, in places, with Quaternary fluvio-glacial sand.

The gullies in the area where research was conducted are covered with forest as opposed to the extensive areas of summit plateau used for agriculture. Arable land in the area under consideration constitutes 88% of the surface area, whereas forests only comprise 11%. In the gullies the predominant tree is mainly beech (*Fagus sylvatica*).

The biggest monthly precipitation reported in Leśnica is considerable and amounts to 200-260 mm (the precipitation measurement station in Leśnica is situated about 1.5 km away from the gully studied). Daily precipitation exceeded 60 mm occur last 50 years tree times: in 1984, 1991 and 1997. During heavy downpours the run-off intensifies, which leads to the occurrence of new incisions in gullies. Erosion not only initiates dusty sediments, but also causes transportation and deposition of the limestones and dolomites underneath them.

The Commune of Leśnica, which covers the area of research, already had the character of an agricultural settlement similar to nowadays at the beginning of 13th century. Based on results from the analysis of the course of gullies on maps dating from the mid 19th century and on contemporary maps, the valley under consideration and adjacent valleys are of the same size, and also the tree cover indicated on maps coming from different centuries is the same. Thus, one may say that the gullies have been stable during the past 150 years.

The research was conducted in an 800 m long gully whose upper part is narrow and V-shaped. The valley is wide, flat-bottomed and possesses terraces in the lower part (Figure 1). Samples were collected at 4 sites in the upper part of the valley.

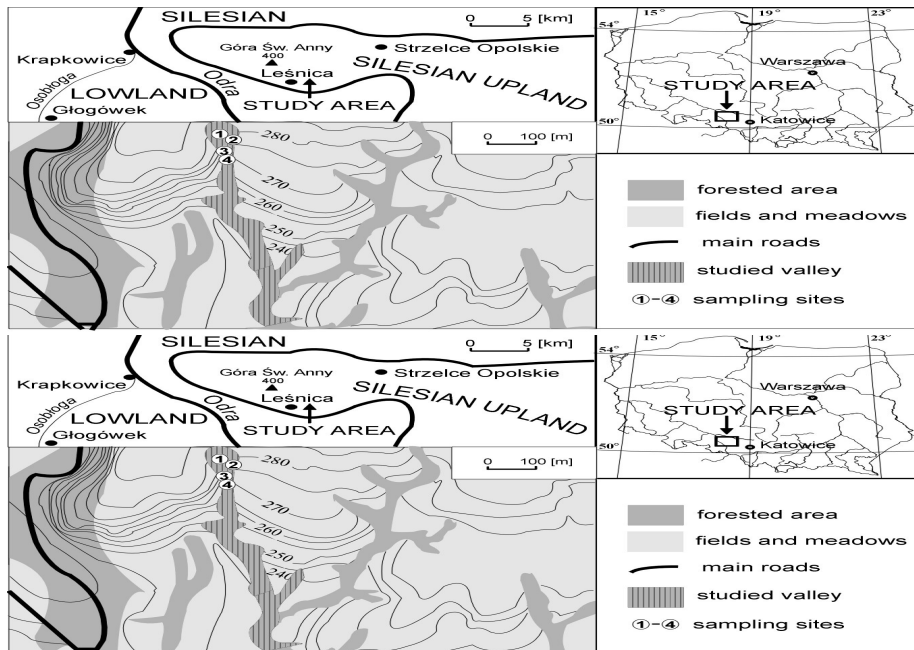


Fig.1. Location of study area and sampling sites

The height, width and length of incisions were measured by means of a rod and a measuring tape, while in the upper course and at the mouth cross-sections were made of the whole valley. Next, 10 cm fragments of exposed beech tree roots were collected by means of a handsaw. In 4 sites, 23 samples were collected from 17 roots. Between 1 and 3 samples were collected from each root, depending on the individual circumstances. In favourable conditions two samples were collected in places where the root connects with the soil and a third one from the middle of the exposed part of the root. In order to date the initiation of incision, and not its deepening or extension, samples were collected from halfway through the length of exposed roots located in the surface parts of incised gully. The height of the root outcrop above the gully bottom and the distance from the beginning of the incision was also measured. All samples were cut with knives in order to show the structure of the wood in root cross-section. The moment of exposure was identified afterwards by means of a binocular microscope on the assumption that it is indicated by a obvious decrease in tracheid size and increase in their number, as well as a division of cells into early wood and late wood within each annual increment occurring after exposure (Figure 2). The exposure time was calculated by counting the number of annual increments younger than the first one in which anatomical changes were reported. In addition scars occurring on the boundary between anatomical differences in root wood of were noted.

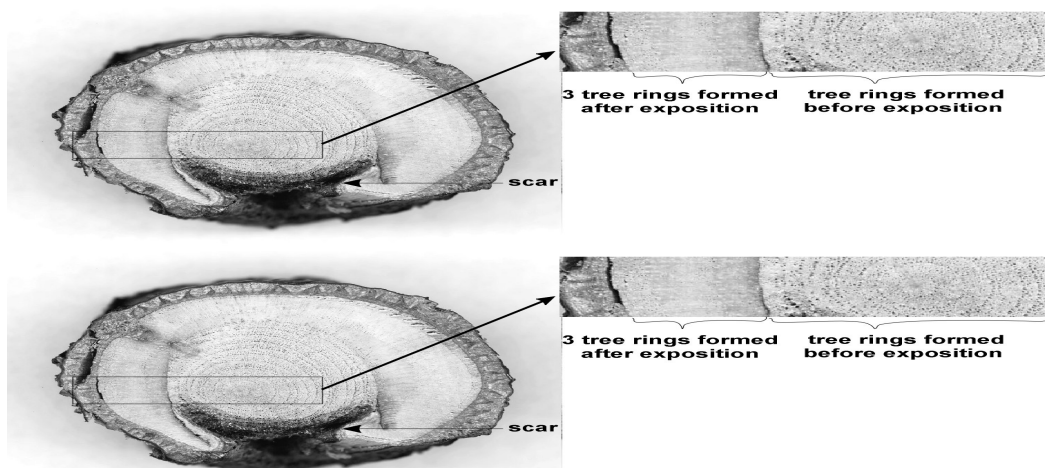


Fig. 2. Changes in wood anatomy of root cross-section

Erosion in the bottom of the upper part of the valley (sites 1,4), was most intense in the years 1981-1984 and 1992-1994 (Figure 3). The precipitation episodes of, 1984 and 1991 mainly account for the origin of incisions. Parts of roots nos. 3 and 4 which were collected from below sediments had wounds covered with earth dating from 1984 and 1997 respectively. This proves that those parts of the roots were initially exposed and later

covered with earth again. Site 1 is located at a point where there is a significant increase in slope gradient below the boundary between a basin-like valley and the beginning of a V-shaped gully. There is therefore a higher likelihood of erosion on this boundary between two forms of valley. It seems from the dating evidence that this occurs alternately with the deposition of material coming from the erosion of the relatively steep slopes of the basin, frequently incised during downpours. This alternate occurrence of erosion and deposition in the incision does not permit one to estimate the speed of reverse erosion. However, we may state that this takes place slowly taking into account the small gradient of the bottom of the gully examined, so that the material can be transported for small distances. Roots at site number 4 included markers regarding exposure in the years 1982-1989 and 1993-1995. This site was composed of incised rocks in the bottom of the gully lying under dust-like material. This means that the incision was formed during precipitation episodes in 1984 and 1991, similar to the incision at site 1.

The incisions are relatively young at sites nos. 2 and 3, located on the valley slope (Figure 3). The vast majority of roots have given markers dating from 1998-2000. The incision at site number 2 was initiated in the lower part of the site and afterwards retreated. The lower part of the incision originated in 1984, whereas the upper part developed after rainfall in 1997. It is likely that the incision could also have been initiated during a precipitation episode in 1971 since the exposure of one of the roots in the lower part of the incision was dated to 1981. At a distance of about 5 m the maximum age difference identified between roots is 19 years. This means that the incision retreats at least 0,25 m/year. At site no. 3, the exposure of roots in the niche took place as a result of a precipitation episode in 1991. Roots in the incision above it were exposed after extensive rainfall in 1997. This implies that the niche occurred as a result of a tree falling, which, at a later date, caused the erosion above the site. Reverse erosion at site no. 4 amounted to 3 m/year. The results obtained enable one to conclude that the rate of erosion is much faster in the area of very steep hill slopes than in the bottom of the upper part of the valley.

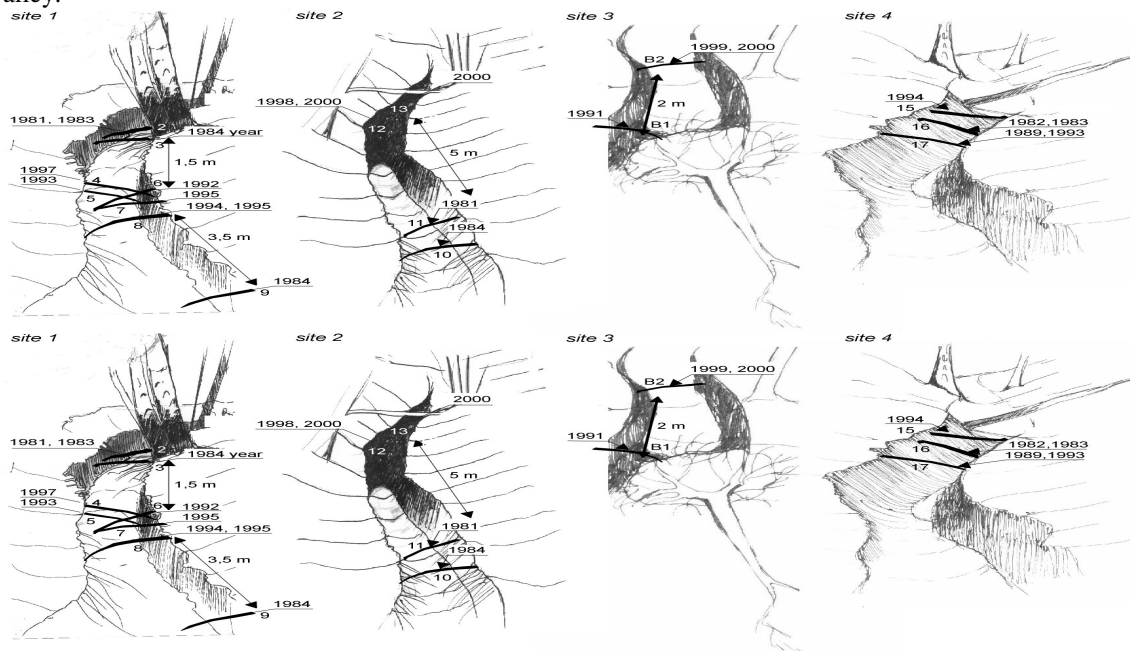


Fig. 3. Erosion cutting in the bottom of the valley on sites 1-4

Erosion started in the valley studied within the last 20 years. That erosion has resulted from the occurrence of extensive precipitation episodes taking place since the 1980s. Erosion also happened several years after large precipitation episodes, which was the consequence of the exposure of erodable dust sediments during extensive downpours. The observed erosion contributes to the deepening and headcut retreat of the valley, as well as to the origin of new incisions on hill slopes. The bottom of the upper part of the valley was mainly formed during extensive precipitation episodes in 1984 and 1991. Sediments are being eroded there and the incisions thus formed may be filled with sediments again. The rate of bottom erosion in the upper parts of the valley is relatively slow. The hill slopes of the valley examined were intensely incised during rainfall in 1997, however, erosion was initiated during earlier precipitation episodes. The incisions on the hill slopes retreat with a speed of at least 0,2-0,3 m/year.

This article presents the results of research conducted under a grant from the Committee of Scientific Research, KBN, 3 PO4E 023 25.

References:

- Burkard M.B., Kostaschuk R.A. (1995): Initiation and evolution of gullies along the shoreline of Lake Huron. *Geomorphology*, 14: 211-219.
- Gärtner H., Schweingruber R.H., Dikau R. (2001): Determination of erosion rates by analysing structural changes in the growth pattern of exposed roots. *Dendrochronology*, 19, 1: 81-91.
- Martinez-Casasnovas J.A. (2003): A spatial information technology approach for the mapping and quantification of gully erosion. *Catena*, 50: 293-308.
- Stankowiański M. (2003): historical evolution of permanent gullies in the Myjava Hill Land, Slovakia. *Catena*, 51: 223-240.
- Swanson M.L., Mathias Kondolf G., Boison P.J. (1989): An example of rapid gully initiation and extension by subsurface erosion Coastal San Mateo County, California. *Geomorphology*, 2: 393-403.
- Thomas J.T., Iverson N.R., Burkart M.R., Kramer L.A. (2004): Long-term growth of a valley-bottom gully, western Iowa. *Earth Surface Processes and Landforms*, 29: 995-1009.
- Vandekerckhove L., Muys B., Poesen J., De Weerd B., Coppé N. (2001): A method for dendrochronological assessment of medium-term gully erosion rates. *Catena*, 45: 123-161.