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Influence of field and road pattern change on gully development in the Bug River valley side (E Poland)

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Abstract: Causes of dynamic development of a permanent gully dissected in sandy river valley side were presented in this paper. Road and field pattern change conditioned the gully forming during one downpour. A new pattern and crop structure caused fast surface flow on the side. Flow concentration along the road and balks causes dissections of gully escarpments and development of the gully branches.

Keywords: sandy gully development, field and road pattern, Bug River valley, E Poland

Introduction

Permanent gullies in Poland, especially in the Lublin region, are forms typical for loess uplands with height difference exceeding 50 m and annual precipitation 600 mm (Maruszczak 1973). Within the Polish Lowlands, gullies are located on edges of till plateaus and large river valleys sides (Drozdowski 1977, Smolska 2007). One of the most intensively/densely dissected sites is the left, sandy side of the Bug River valley below the Krzna River mouth, in the beginning of the Podlasie Bug River Gorge (Fig. 1).

At this place, height of side cut by the Bug River exceeds about 20 m and total height difference is 30 m. Annual precipitation amounts 550 mm. Under such natural conditions, permanent gullies usually cannot form. However, their forming is possible in susceptible sandy deposits and strong anthropopression conditions, for example intensive arable and road using of a slope (Rodzik & Terpiłowski 2005). On 1 km long and relatively short – about 200 m – side section, density of gullies amounts as much as about 10 km per 1 km^2. These gullies became established by dry-ground forest and since 1995 they have been protected in the "Podlasie Switzerland" Nature Reserve. Some existing gullies are active today and even new gullies develop at the Nature Reserve boundary (Rodzik et al. 2004).

Observations and measurements

Two largest gullies has been taken under systematic observation since their rapid development in 2002. The gullies catchments were allocated and surficial flow lines, modifying by ground roads, balks and furrows were mapped (Fig. 2). Archive documents were obtained and interviews about changes of land use were carried with local farmers. Investigations were made on the request of local administratives in order to determine: reasons of rapid erosion, possibilities of its restriction and prognosis of gullies development.

New dissections of the gullies are documented after erosion episodes. An annual photographic documentation were made. Detailed tachymeter measurements of the largest gully were made in May 2004 and July 2009. On this basis, a gully volume, its changes and an erosion rate were calculated.

Development of a new large gully

A small dissection, perpendicular to the Bug river valley edge, has formed since 1996. In 2000, the length of dissection was about 20 m, and its width and depth didn't exceed 10 and 5 m, respectively. On the 28th of May 2002, under the influence of rapid downpour (in Terespol – the nearest mete-

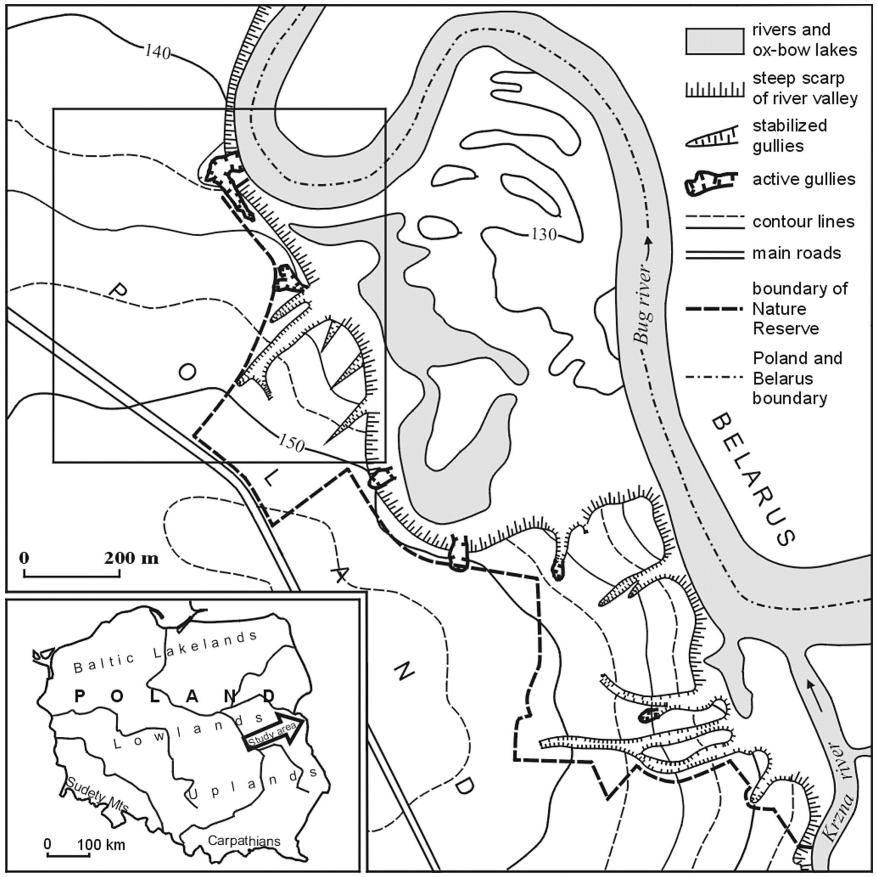

Fig. 1. Location of gullies in the "Podlasie Switzerland" Nature Reserve (study area in a frame)

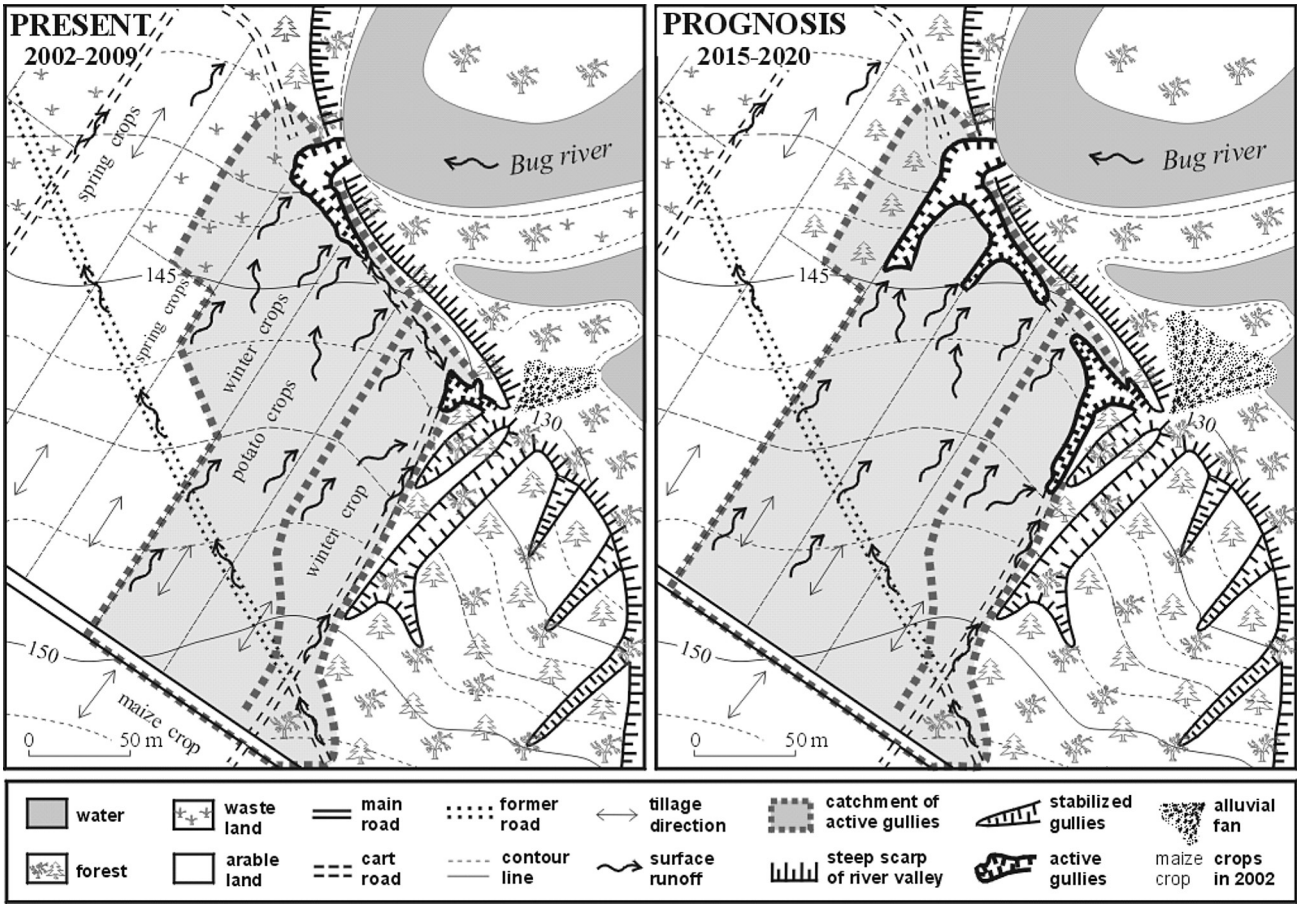

Fig. 2. Anthropogenic conditions of surface flow in the catchment: present condition and prognosis

Fig. 3. Upper segment of the new gully in: May 2004 and April 2008

orological station, 15 km from the gully – size of downpour amounted 43 mm), this gully developed rapidly. It cut a track running along the Bug River valley edge to a depth of 10 m, on the length over 50 metres and width about 10–15 metres. On March 2004, the gully has elongated due to head-cut erosion by relatively small dissection of 20-m length and 3–4 m width (Fig. 3). A volume of the gully, calculated on the basis of tachymeter measurements, amounted $3.1 \cdot 10^3$ m^3.

In summer 2004, a few shallow (about 1 m depth) side dissections of a few metres length were formed as a result of an overland flow from fields. They have lengthened, deepened and widened insignificantly in the next years. In the main gully, a slow stabilization of sandy sides succeeded whilst the floor was alternatively cut and infilled.

Next significant gully development took place in June 2009. During torrential, short-lasted rainfalls, side branches developed by head-cut erosion in lower and medium parts of the gully (Fig. 4). It was the result of the field flow along furrows and baulks. After this episode, the main form is 100 metres long and total length of all dissections amounts to 150 metres. A gully volume increased to $4.0 \cdot 10^3$ m^3, i.e. by 29% during 5 years.

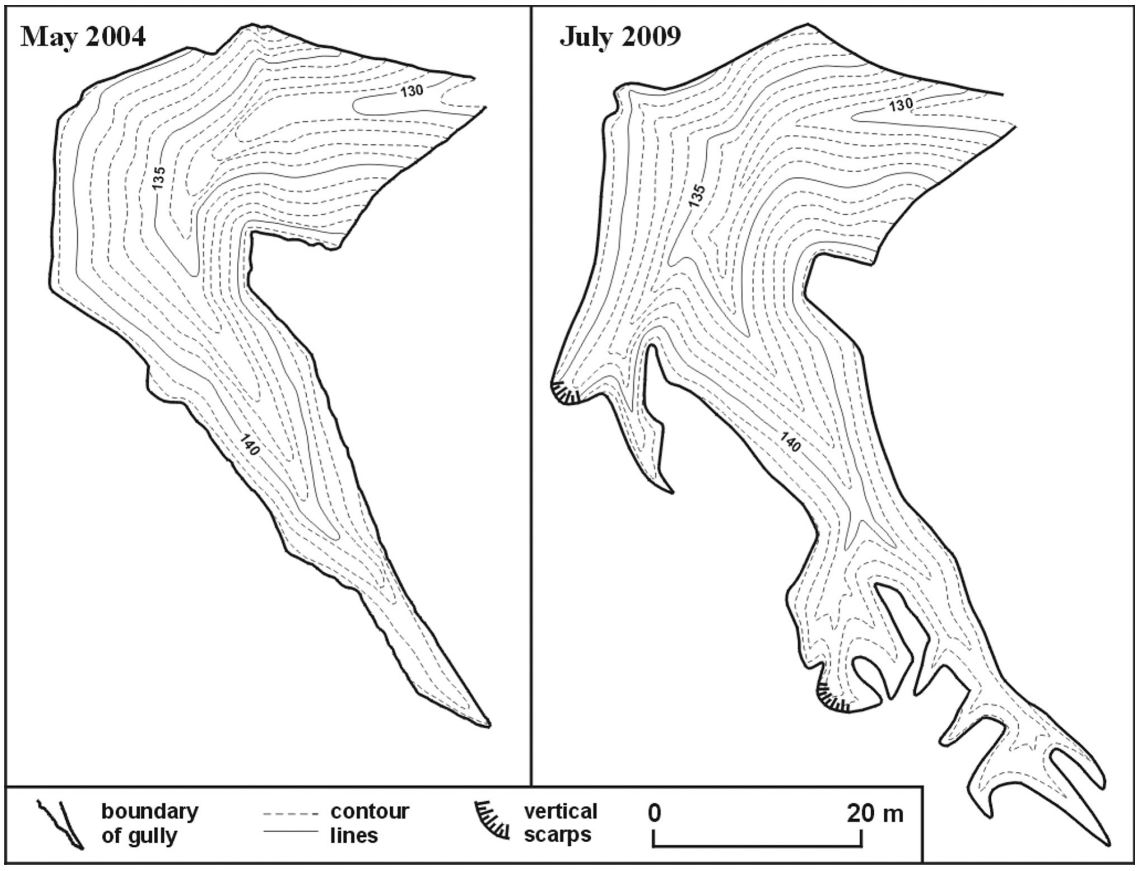

Fig. 4. Development of new gully in the 2004–2009 period on the basis of tachymeter measurements

Fig. 5. Field and road pattern change as a result of a field arrangement carried in 1972, aerial photo from 1971 and 1981

Human impact on gully erosion

A current field and road pattern developed as effect of field arrangement, carried out in order to have easier access to parcels (Fig. 5). On adjacent to the Reserve, agriculturally used side, direction of cultivation was changed that time from across to down-slope one. An old road, collecting a surface flow previously, was ploughed but a shallow depression crossing new fields, remained. It collected and dispersed flow from upper sections of fields till 2002 year. However, during 30 years, it became filled with colluvia layer with 50 cm thick. In turn, the new road, running along the Nature Reserve boundary, has deepened a little (< 30 cm) during this time, It was the result of washing during intensive using by visiting the Reserve school children, tourists, also anglers and farmers.

On 28th May 2002, during the mentioned downpour, the old road depression stopped to function as a channel carrying out the surface flow. It was directed along furrows and baulks to the new track located alongside the edge. The track also collected flow from adjacent fields, perpendicular to road, especially from a big (1 hectare) with sprouting potatoes one (Fig. 2). This field, practically without canopy cover, had downslope furrows. A flow concentration on the track resulted in intensive erosion and the gully development.

Final remarks

Lithological and geomorphological conditions on the Bug river valley edge are favourable to gully erosion. However, the main reason of new gullies development is the field and road pattern change, because an ancient pattern dispersed overland flow on the slope. Its unintentional alteration hasn't caused an instant erosion for an ancient system of overland flow has functioned for 30 years yet. Its part conformity to the new field pattern happened during the downpour on 28th May 2002, what resulted in strong gully erosion. An entire adaptation of the flow is able to occur after filling of the former road depression on successive field. It will cause further increase of the catchment and gully erosion along roads and furrows (Fig. 2), begun in 2004–2009 period (Fig. 3, 4).

The simplest way of gully development limitation would be a restoration of previous field pattern before 1971. However, it requests a change of boundary lines of arable land belonging to various owners. Limitation of intensive touristic movement here, which is a main factor of devastation of vegetation around the new gully, is also advisable. On the other hand, dynamic development of the gully comprises the biggest attraction of the didactic path in the "Podlasie Switzerland" Nature Reserve.

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