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200 years of land-use change and gully erosion – a case study from Małopolska, SE Poland

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Abstract: Loess areas are highly affected by human impact since the Neolithic revolution. Within the study in Małopolska we assess the impact of land-use changes on geomorphological processes for the last 200 years. Phases of deforestation and a subsequent intensive agricultural use can be correlated with the appearance of gully erosion.

Keywords: gully erosion, human impact, land-use change, Małopolska, Poland

Introduction

Land-use changes in historical times had a significant impact on geomorphological processes in different landscapes all over the world. In particular, sensitive loess areas are highly affected by human impact since the Neolithic revolution (Starkel 2005). During the last decades different research projects focused on the effects of land-use changes in combination with climate fluctuations, as well as on the complex interactions between human and environment. Many case studies show that phases of deforestation and a subsequent intensive agricultural use can be correlated with the appearance of gully erosion.

In the centre of our investigations land-use changes and different erosion processes on the local scale were detected and examined. A chronology of erosion processes for the last 200 years was developed. Additionally, we assess the impact of land-use changes in this fragile loess landscape. Thereby climatic changes and the occurrence of heavy rainfall events were taken into consideration. The elaboration was developed mainly on investigation and results of Heinrich & Krüger (2005) and Schmidt (2007).

Methods

To identify and quantify surface forming processes various methods which are to a large extent in accordance with those of the four-dimensional landscape analysis were used (Schmidtchen & Bork 2003, Dotterweich 2004). Pedological and geomorphological investigations were carried out in the research area. Soil classification follows the guidelines of AG Boden (1994) and Munsell (1975). Different erosion forms were measured in detail to calculate the translocated sediment volume. Documents about the historical development of settlements and land-use change as well as historical maps, aerial images and photographs complemented the investigations. For our research area Sznajderski (2004) gives a good overview of the development and changes in modern times. The loss of vegetation cover during the last 200 years was quantified by a GIS-based survey of the historical maps.

Research area

The study area is situated at the border between the Voivodeships Małopolskie and Świętokrzyskie in the macroregion Niecka Nidziańska (Nida Basin) (Kondracki 2002). Investigations focus on two gully systems in the area around Rzemiedzice and Słaboszów, about 50 kilometres northeast of Kraków (Fig. 1). It belongs to the eastern part of Garb Wodzisławski, a loess area characterised by a diverse morphology and an average thickness of loess about 10 to 15 m, partly up to 20 metres (Geological Map of Działoszyce, scale 1:50,000). The altitudal differences between valley floors and plateaus ex-

Fig. 1. Location of the study area in Poland

tend up to 80 metres. In the study area Lessivé (*Luvisol*), brown soil (*Cambisol*) and Chernozem are the dominating soil-types generated by the Holocene soil forming processes (Maruszczak 1986).

Results

A period of deforestation and subsequent intensive agricultural use is proved for the Late Middle Ages and afterwards. Most of the recent villages in the research area were founded in the 14th century (Table 1). The name of the village Działoszyce (Działoszyc → Zalesice → 'les' → 'las' = forest), located in the study area, and historical papers with landscape descriptions document the huge forest areas in historical times (Sznajderski 2004). For

Table 1. List of villages in the study area with their first mention (after Sznajderski 2004)

Actual name	First mention of the village	
	Historical name	Year
Biedrzykowice	Biedrzychowice	1389
Bronocice	–	(2700 v. Chr.)
Działoszyce	Dzialoszyc	around 950
Dzierążnia	Dzierezna	1174
Iżykowice	Juricouicz	1376
Marianów	–	1885
Niewiatrowice	Newetrouicze	1356
Opatkowice	Opathkowycze	1363
Sancygniów	Sadzignew	1376
Słaboszów	Slawosza	1210
Szyszczyce	Syscycze	1365
Wolica	Wolycza	1398

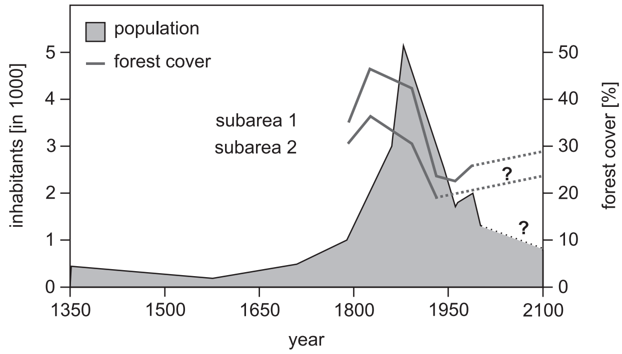

Fig. 2. Population and forest cover changes at the area of Działoszyce

Działoszyce the highest population increase is confirmed approximately for the period between the 1830s and 1920s (Fig. 2).

Analyses of topographical and soil maps as well as remote sensing data show that the appearance of gullies is highly connected with the relief and the distribution of sediments: they are located at the steep slopes of the loess plateaus next to the valley floors. Actually almost all gullies are stabilised by a dense vegetation cover. At few places next to the gully heads and in almost all sunken lanes relocations of sediment can be observed. It is caused by present agriculture, even during low rainfall events.

The gully system north of Rzemiedzice, most likely emerged at the beginning of the 19th century, after 1790. First signature of a gully with its characteristic forested surrounding is shown on the map of 1830 (Fig. 3), whereas on the map of 1790 deforested land, probably agricultural used land exists. It appears that the initial structure was a farm track along a relatively steep slope up to the farmhouse shown on the map of 1830.

During the next two centuries the gully was covered by vegetation. Excavations and drillings in both catchments show similar results concerning soil dis-

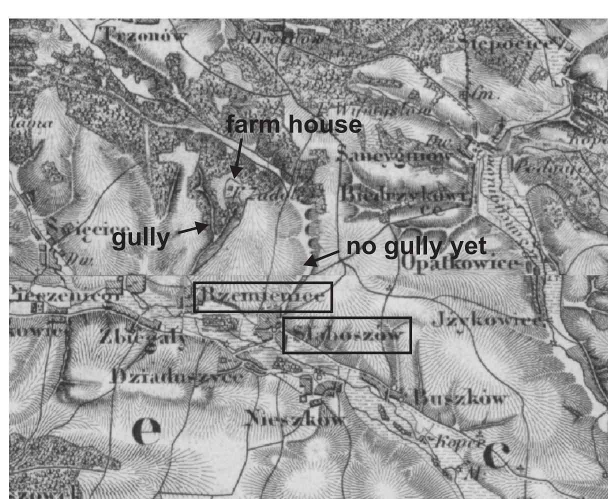

Fig. 3. Detail of the historical map from 1830 ("Mapa Kwatermistrzowstwa")

tribution. Eroded soil profiles are widespread on the slopes. North of Słaboszów Rendzinas (Rendzic Leptosols) on Mesozoic marlstone are intersected at the steep slopes, exposed to the west.

There exists no gully north of Słaboszów until 1890 (Fig. 3). The initial structure is probably also a farm track. Later it follows an artificial drainage canal (Schmidt 2007) along the thalweg of the dry valley. This linear gully is actually 700 metres long and gully erosion processes are currently active (Fig. 4).

The older part of the gully, around 600 metres, is quite similar to the other gullies regarding structure, vegetation cover, slope inclination and soil distribution. At present it is partly used as a farm track. The newest part, around 100 metres up to the gully head, was formed between 1995 and 2004. A couple of years with heavy rainfall events caused the extension of the gully. The reconstruction of several erosion events for the 20th century affecting this gully and a detailed field survey was the basis for the calculation of the volume of the translocated sediment. Table 2 shows the results.

The last heavy rainfall event in 2001, for instance, eroded approximately 4,800 cubic metres of sediment. It must be pointed out that the sediment per event is calculated on the basis of the field survey of 2006. It means that erosion and accumulation processes within the gully during formation modified the cross-sections. The results for 1995 and 2005 are estimated and mainly based on interviews with local farmers and field survey.

Historical maps illustrate that for the whole study area the intensive agricultural exploitation in the

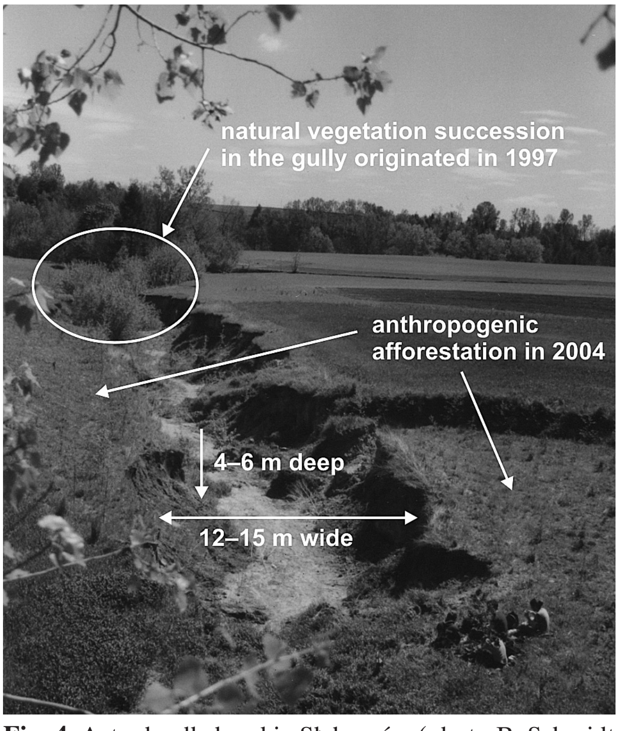

Fig. 4. Actual gully head in Słaboszów (photo R. Schmidt 2005)

second half of the 19th and the first decades of the 20th century caused a massive deforestation. Qualitative analysis of forest cover shows that up to the end of the 19th century the catchment in Słaboszów is covered with trees in 50%. At the beginning of the 20th century a rapid decrease during a period less than 50 years is proved. New small forest areas at steep slopes led to an increase during the last decade.

Table 2. Calculated sediment volume, estimated values (bracketed)

Year	< 1937	1937	1947	1995	1997	2001	2004
Length of the gully [m]	270	420	520	(570)	610	700	(700)
Volume [m^3]	10,855	22,668	3,510	(1,000)	5,396	4,800	(500)

Table 3. Results of GIS-based survey concerning forest cover

Year	Total of all forest areas [km^2]	Forest area ratio [%]	Total number of forest areas	Average forest areas size [km^2]
Subarea 1 (total: 264,58 km^2)				
1790	80.65	30.48	20	4.0324
1830	97.81	37.01	53	1.8474
1890	81.27	30.72	60	1.3545
1936	50.19	18.97	81	0.6196
Subarea 2 (total: 48,36 km^2)				
1790	16.91	34.96	5	3.3818
1830	22.94	47.43	11	2.0855
1890	20.57	42.54	15	1.3716
1936	11.42	23.61	22	0.5189
1959	10.97	22.68	51	0.2150
1982	12.67	26.20	202	0.0627

A GIS-based survey of forest cover in two subareas was made to assess the rate of changes (Table 3). The highest value of forest cover (37.01% and 47.43%) is detected for 1830. During one hundred years this ratio decreased to nearly half of it (1936: 18.97% and 23.61%). At the same time the size of the average forest area diminish consequently which leads to a fragmented forest in the study area. Just a few fragments have been under forest during the last 220 years.

Summary

The increase of settlements during the Late Middle Ages (Sznajderski 2004) led to significant land-use changes. A rise of soil erosion processes is caused by farmland at the slopes and uplands and especially by the large amount of farm tracks. Gardziel et al. (1996) suggest that farm tracks are one of the main reasons for gully erosion, assuming that the settlements are located next to the valley floors. Thus, high differences in relief caused gullying. Similar results are discussed by Schmitt (2006) for Lublin area.

The development of the gullies of today within the research area started most likely in the Late Middle Ages and continued during the 19th century. The maps of 1890 already show the current spreading. Recent gully erosion processes and similar effects of heavy rainfall events during the 1990s are presented as well by Rodzik & Zgłobicki (2000), Janicki et al. (2002), Rodzik & Janicki (2002) and Zgłobicki (2002) for Lublin area. In the Miechów Uplands less vegetation cover during harvest time, farm tracks as well as contour ploughing were the main reasons for erosion during the heavy rainfall event on September 15th 1995 (Dwucet & Śnieszko 1996, Czyżowska 1996, Starkel 1997).

Regarding soil distribution, only eroded profiles were intersected. Similar results show the former investigations, i.e. of Śnieszko (1985), Heinrich & Krüger (2005) and Heinrich et al. (2007).

The effects of current agriculture, characterised by small acreage farming are described in detail by Heinrich & Krüger (2005), Rejman & Rodzik (2006), Heinrich et al. (2007), Schmidt (2007), Schüttoff (2008) and Schneider (2009). In many cases in the study area concentrated surface runoff along the field borders (Polish 'Miedza', Maass 2001) was investigated. Thereby, unfavourable situations in relief induce linear erosion processes. This process can be observed in Lublin area as well (Janicki et al. 2002). Dam-like structures between the individual fields indicate the high level of soil loss. In this context it has to be pointed out that this kind of subdivided fields is not really preventing erosion processes (e.g. Heinrich et al. 2007, Schüttoff 2008).

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