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Phases of gully erosion in the Lublin Upland and Roztocze region

Fazy erozji wąwozowej na Wyżynie Lubelskiej i Roztoczu

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Słowa kluczowe: antropopresja, historyczna erozja wąwozowa, zmiany krajobrazu, obszary lessowe, Polska wschodnia

INTRODUCTION

Gullies represent one of the most characteristic features of loess relief and an important feature of the cultural landscape of areas used for agriculture. In extensive parts of the Lublin region, the average gully density exceeds 2 km·km^{-2}, and in the vicinity of Kazimierz Dolny (Nałęczów Plateau) and Szczebrzeszyn (Szczebrzeszyn Roztocze), it reaches 10 km·km^{-2}, which is unique on the European scale (Maruszczak 1973).

The natural conditions in some loess areas (the western part of the Nałęczów Plateau, the Szczebrzeszyn Roztocze) are exceptionally conducive to the development of gullies. These conditions include primarily the occurrence of thick loess covers, considerable elevation differences and quite frequent torrential rainfall events in morphological escarpment areas. The prevailing view, however, is that these natural determinants were not sufficient to trigger the intensive processes of gully erosion (Maruszczak 1988; Bork 1989; Vanwalleghem et al. 2003). It was the deforesting (broad-leaved and mixed) linked with the development of agriculture that led to the dynamic development of gullies (Vanwalleghem et al. 2006; Dotterweich 2008).

Until recently, studies on historical gully erosion in the Lublin region had been conducted on a small scale. Estimations of the age of the gullies were based on the analysis of changes in population density (level of anthropogenic pressure on the environment) and climate changes (frequency of torrential rains). On that basis, Maruszczak (1973; 1988) and Buraczyński (1991) conclude that most gullies in the loess areas are not older than 1,000 years.

Cartographic materials do not provide any information on the age of gullies. Relatively accurate maps are not older than 100 years while older topographical measurements conducted in forested areas with varied relief are not reliable. Only a few sites located within the loess covers have been examined in detail, i.e. by analysing sediments (including ^{14}C dating) within fossil and recent gully forms. One of these forms, the Jedliczny Dół gully, is located in the Szczebrzeszyn Roztocze (Schmitt et al. 2006). The other ones are located in the western part of the Nałęczów Plateau, namely the gully in Parchatka (Śnieszko 1995), gully in Kolonia Celejów (Zgłobicki, Rodzik 2007; Rodzik 2010), the Doły Podmularskie gully near Kazimierz (Dotterweich et al. 2012) and the Zimny Dół gully near Celejów (Superson et al. 2013) (Fig. 1). The objectives of the abovementioned studies were to distinguish the phases of historical gully erosion in the Lublin region and their relation to human induced landscape changes.

THE STATE OF RESEARCH ON HISTORICAL GULLY EROSION UNTIL THE END OF THE 20TH CENTURY

Some archaeological studies (e.g. Nogaj-Chachaj 2004) assert that the first gullies may have formed as early as the Neolithic in connection with a large local pressure of colonisation and agriculture on the environment. The analysis of sediments filling the dry valley near Parchatka, dissected by a gully, indicates the local occurrence of gully erosion (Śnieszko, 1995). The slash-and-burn agriculture commonly used in that period led to the deforestation of the loess plateau tops and development of erosion processes, including gully erosion.

According to Maruszczak (1988) who, however, did not conduct detailed studies of sediments linked with gully erosion, the first gullies began to develop in prehistoric times, i.e. the Neolithic and Bronze Age. However, due to the relatively limited human pressure on the environment (limited deforestation), the intensity of these processes was rather small. In the early Middle Ages (6th to 13th c.), on the other hand, only a few gullies developed owing to the lack of stability of the field-forest boundary. A considerable change occurred in the late Middle Ages when stable field-forest boundaries developed and permanent deforestations

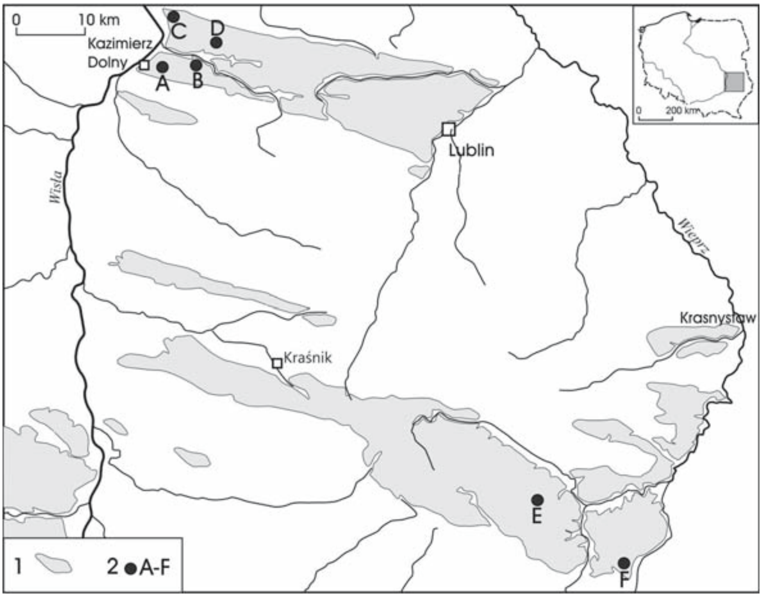

Fig. 1. Location of the investigated gullies in relation to the loess covers. 1 – loess covers, 2 – sites described in the text: A – Doły Podmularskie, B – Zimny Dół, C – Parchatka, D – Kolonia Celejów, E – Jędrzejówka, F – Jedliczny Dół

started to reach considerable proportions. It was probably only then that the system of loess gullies began to develop on a larger scale (Maruszczak 1988).

In his subsequent studies, Maruszczak (1973, 1988) expresses a view that the most intensive development of gullies in loess areas of varied relief has occurred during the last 1,000 years while earlier human interference with the environment had been limited and forest vegetation had probably covered 85% of the area. After measuring the volume of two gully systems in the Grodarz catchment (the environs of Kazimierz Dolny), adopting the modern denudation rate and taking into account extreme events, Maruszczak et al. (1984) determined that the development of the two investigated forms had required 440 and 1,000 years respectively.

Analysing the landscape changes in Roztocze, Buraczyński (1991) asserts that a clear intensification of agriculture occurred here between the 14th and 16th century. He concluded that human economic activity contributed to increased soil erosion and gully development. The erosion processes resulted in an increased accumulation of loess colluvial deposits forming a 4 to 7 metre-thick layer in the bottoms of dry valleys. That period was also typified by a high intensity of catastrophic rainfall events. For this reason Buraczyński believes that the main phase in the development of gullies in the Roztocze occurred in the 14th century. Torrential rainfall events resulted in another period of intensive gully development in the late 18th and early 19th century, and large gullies existing today originated mostly in that period (Buraczyński 1991). The same author also takes note of the significant role of field patterns in the development of gullies.

Based on sediment dating in the gully system at Parchatka, Śnieszko (1995) indicates two periods of intensive gully erosion: a) 6.5 to 1.7 ka BP, b) 11th century to the modern times. The considerable intensity of these processes from the 11th c. onwards, is confirmed by the study results of the sediment profile at Jędrzejówka in the Roztocze region. The profile contains a horizon with fragments of fallen trees, which can be regarded as a result of an exceptionally heavy torrential rainfall in this area at the end of the 11th/beginning of the 12th century. The overlying loams were deposited by gully erosion that intensified after the formation of the initial channel after the downpour.

RESULTS OF STUDIES IN THE EARLY 21ST CENTURY

The Jedliczny Dół system

The Jedliczny Dół gully system is located near Turzyniec in the Szczebrzeszyn Roztocze region. The concentration of gullies here reaches 5 km·km^{-2}. The natural conditions of the analysed catchment are highly conducive to gully erosion: the elevation differences reach 100 m along a 1.5 km stretch, the gradient of most slopes of dry valleys ranges from 10° to 15° or, in some cases, even 25°. A loess cover with silty-sandy interbedding, a few to about 15 metres thick, occurs in almost the entire area of the catchment. The upper reaches of the system, with a V-shaped cross section, dissect the loess cover, thinner on the valley sides, and cut into Upper Cretaceous gaizes. The middle part of the main gully, up to about 15 m deep, have a flat depositional bottom, successively dissected due to head-cut erosion. Terrace ledges have remained on the gully walls; they are composed of laminated loamy-sandy sediments with small pieces of carbonate rock.

On the gully walls, at the base of a 5-metre thick colluvial series, a well-developed fossil soil was preserved; it has features of a Luvisol, locally a Cambisol (Fig. 2). The highest and thus the youngest colluvial sediment series contains (at its base, along the gully axis) well-preserved remains of bark and branches (cal AD 1262–1301), which indicates forest-felling activity in the catchment in the past (Schmitt et al. 2006). The several-metre thick colluvial series overlying the soils is thus a result of intensive and long-lasting erosion in the upper reaches of the gully caused by the exploitation of the forest, probably associated with the colonisation commenced in the 14th century. In the preceding period, correlated with the early Middle Ages, the intensity of erosion processes was moderate as evidenced in the colluvial sediments by the thin loam series with organic horizons. The fossil soil with quite well-developed profile on a steep slope (25–50°) indicates a period of stabilisation lasting for at least several hundred years. This period may correspond to a decline in human settlement and lack of a distinct anthropogenic pressure in ancient times, from the La Tène Culture period to the Migration Period (Gurba 1985; Skowronek 1998). On the other hand, the most likely assumption is that the oldest (and largest) erosional form could have developed during the expansion of the Lusatian Culture in the first millennium BC. Erosion, in modern times, in the late Middle Ages and in the oldest periods, is probably linked with forest exploitation rather than agriculture. At present, fir and beech forests cover 80% of the catchment. The conditions for agriculture here are too difficult, but the configuration of the catchment was conducive to the logging of timber. Increased demand for timber (as building material and fuel) undoubtedly existed during the colonisation of this area, from the 14^{th} to the 16^{th} century, as well as the 19^{th} and first half of the 20^{th} century. An even earlier demand for timber can probably be linked with iron smelting in the late period of the Lusatian Culture.

Detailed dating as well as geomorphological and sedimentological analysis let us distinguish the following phases in the evolution of the catchment's environment and detailed phases of gully erosion from the 14^{th} century (beginning of the intensive human impact) to the modern times (Schmitt et al. 2006): before 14^{th} c.: stabilisation of gully, development of soils; 14^{th} to 15^{th} c.: deforestation; 15^{th} c. to 16^{th} c.: gully erosion; 16^{th} c.: infilling of the gully by sediments; end of the 16^{th} c. to the turn of the 19^{th} c.: stabilisation of the gully; first half of the 19^{th} c. to the turn of the 20^{th} c.: gully erosion; second half of the 20^{th} c.: stabilisation of the gully.

The gully in Kolonia Celejów

The Kolonia Celejów catchment, covering 1.24 km^2 and having small elevation differences of not more than 50, is dissected by a gully system whose total length is 7.5 km. Two main phases of gully erosion were distinguished, relatively long-lasting (several centuries long) and associated with the agricultural use of the land: the Neolithic phase and the late mediaeval/modern phase lasting from the 15^{th} century to the present. Both phases are coincident with periods of intensified colonisation and agriculture in the Nałęczów Plateau, confirmed by archaeological research (Nogaj-Chachaj 2004). In the nearby Karmanowice, a large Funnel-beaker Culture settlement functioned for 800 years, exerting its influence on the catchment under study. This clear relationship is indicated by the deposition of colluvial sediments over the soil in the plateau depressions within the catchment in that period, as confirmed by ^{14}C dating (cal BC 5050–4350). Neoholocene soil developed on the Neolithic colluvial sediments, which indicates a long-lasting interruption in agricultural activity. This soil is overlain by another layer of colluvial sediments, with a massive structure, which indicates another period of agricultural use lasting several centuries up to the present (Rodzik 2010).

Fig. 2. Soil and sediments on the left side of the Jedliczny Dół gully

Well-developed, Neoholocene Luvisol has survived in some places on the walls of the gully dissecting the catchment, which indicates a long-lasting stabilisation of the gully walls. In the lower reaches, the Luvisol is covered by colluvial sediments accumulated at the gully bottom as a result of the erosion of the gully head and its tributaries. The beginning of their accumulation was dated, using the ^{14}C method, to the period soon after the establishment of the nearby villages and the coincident beginning of the Little Ice Age (Zgłobicki, Rodzik 2007). These colluvial sediments thus originate from the second phase of gully erosion and are coincident with the upper massive agriculture-related colluvial sediments in the catchment. If the Neoholocene soil was developing concurrently on the Neolithic colluvial sediments in the catchment and the gully walls, the main gully must have developed in the Neolithic.

Based on the condition and degree of development of the soils on the gully walls as well as the proluvial sediment sequences infilling the open and fossil erosional forms, we found that the two main branches of the gully systems developed in different periods: one in the Neolithic and the other in the cooling phase of the Little Ice Age, coincident with the development of manorial economy that involved the cultivation of cereals for export. Towards the end of the second phase, two sub-phases occurred: the 19th/20th-century sub-phase, associated with the parcellation of the Celejów estate and land fragmentation (Kowalik-Bodzak 1964) and the 20th/21st-century sub-phase, associated with the establishment of bilberry and cabbage vegetable plantations (Rodzik 2010).

The Doły Podmularskie system

The Doły Podmularskie system, with a total length of 3 km, dissects the bottom and sides of a tributary valley whose catchment covers 0.35 km^2. Except for the forested gully, the catchment of this system is used for agriculture. We carried out a detailed investigation of a tributary gully, 300 m long and consisting of two distinct parts. In the upper reaches of the gully, several metres deep, with stable walls and accumulative bottom, there is a road providing access to the fields. The lower part is a typical young gully with steep walls susceptible to landslides and with a colluvial bottom modelled by piping. The two parts of the gully are separated by a 4- to 5-metre step. The main exposure located on the wall of the step is 15 m long, with a sequence of colluvial sediments up to 3.8 m thick (Fig. 3).

Fig. 3. The main exposure in the Doły Podmularskie gully

A detailed analysis of sediments and numerous archaeological and radiocarbon dates enabled a reconstruction of the phases in the development of the form under study (Dotterweich et al. 2012). In the Early and Middle Holocene, Luvisols developed in the area dissected by the gully. The study area has been colonised for 4,000 years, as evidenced by the Bronze Age pottery found in the bottom part of the profile. Charcoal dating back to that period was also found in the sediments infilling the deepest, steep and narrow fossil gully (cal BC 2011–1830). The lack evidence of soil-forming processes and absence of younger artefacts indicate that the gully was filled in shortly after its formation. Only the deepest parts of the infilling have been preserved up to the present. Thus, the first phases of gully erosion of the gully wall under study occurred in the Bronze Age

(Phase I). Small gullies could have developed here also in the Early Middle Ages (Phase II). Human activity in this area in that period is suggested by fragments of pottery (800–1000 AD) found in the sediments filling the gully bottom and charcoals in the sediments filling a small dissection in the gully wall.

The youngest dates in the stratigraphic sequence indicate that intensive gully erosion occurred here also in modern times. Another gully was broader and less steep in comparison with the oldest gully (Phase III). The catchment (excluding the gully itself) was used for agriculture; hence the gully was successively filled with material eroded from the upper reaches of the catchment and gully walls. Fragments of pottery dated to the Bronze Age (archaeological age: 2300–1300 BC) and the early Middle Ages (archaeological age: circa 800–1000 AD), found in one layer, were probably redeposited along with the eroded material. The age of the largest gully is determined by the youngest date (cal AD 1642–1951). It developed not later than 300 years ago, probably in the mid-17th century, in the final period of intensive grain exports from the river port in Kazimierz. It coincided with the climate pessimum of the Little Ice Age with its frequent extreme weather events. Historical records mention torrential rainfalls, gully erosion and local flooding occurring in Kazimierz in that period (Teodorowicz-Czerepińska 1981).

Some layers in the upper part of the analysed profile are enriched with organic matter redeposited from the humic horizons. An *in situ* humic horizon also occurring here indicates the halting of erosion processes in the catchment about 250 years ago, as indicated by the dates of sediments established for the humic horizons and cultivated horizon at the edge of the gully. It can be concluded that the catchment was at least partially reforested at that time. However, this phase did not last longer than several decades.

The subsequent agricultural use of the catchment enabled the further development of the gully. A particularly intensive erosion phase occurred in the lower reaches of the gully in the last 20 to 30 years. It is connected with a greater frequency of torrential rainfall events in this area (Rodzik, Janicki 2003), which led to the dissection and exposure of older sediments in the gully bottom (Phase IV).

The Zimny Dół gully system

The Zimny Dół gully system is located on the left-hand side of the Bystra valley in the vicinity of Celejów. It dissects the bottoms and sides of the system of dry valleys covering 0.75 km^2. The total length of all gullies in the catchment is 6.7 km, i.e. the overall gully density is 8.9 km·km^{-2}. An alluvial fan with a radius of about 200 m developed at the mouth of the gully system, on the floor of the Bystra valley (Superson et al. 2013).

The first phase of gully development in the catchment occurred in the second half of the 11th or in the 12th century, which is evidenced by the covering of early mediaeval peats (cal AD 1010–1160) by sandy-loamy sediments originating from gully erosion. This phase may be linked with the establishment of a knight's castle in Celejów and use of a road running along the Zimny Dół gully towards the Vistula river crossing in Kazimierz. The road was probably intensively eroded and material was deposited on an alluvial fan. The intensification of erosion is manifested in the dissection of the fluvioglacial gravels underneath the loess that were subsequently strewn across the bottom of the gully mouth and the then surface of the alluvial fan. Those processes could only occur during catastrophic rains because gravels up to 24 cm in diameter were transported over a distance of several hundred metres. It probably happened during the 14th-century humid period preceding the onset of the Little Ice Age (Maruszczak 1988). After that period (episode) of erosion, relative stabilisation occurred in the catchment while soil began to develop on the walls of the gully (Superson et al. 2013).

Another period of intensive traffic in Zimny Dół must have occurred from the mid-16th to the mid-17th century when the largest volumes of grain were handled in Kazimierz (Teodorowicz-Czerepińska 1981). It coincided with the period of considerably cooler and more humid climate during the Little Ice Age when the intensity of snowmelt and frequency of torrential rainfall increased significantly. A series of laminated sandy silts (1.0 m–1.5 m thick) filling the bottom of the gully mouth originate from that period. As the road was dissected by head-cut erosion, the old route to the plateau top was abandoned and a new one was established, which led to the strong dissection of the loess valley side by tributary gullies (Superson et al. 2013).

The next phase of gully development is linked with the forest clearances carried out in the watershed areas in the second half of the 19th century, which led to the development of badlands along the edges of the former road gullies formed in the Little Ice Age. Material eroded from the badlands accumulated mostly on the bottoms of those gullies.

In the 1930s, a large part of the catchment became deforested following a partial parcellation of the Celejów estate (Kowalik-Bodzak 1964). Fields and pastures were established in the cleared areas. The short-lasting agricultural use of the steep slopes (for about 50 years) led to the erosion of soils and further development of badlands, but these changes were local.

DISCUSSION OF RESULTS

The changes to the natural environment, linked with Neolithic agriculture based on crop rotation and fallowing, were not sufficiently large to initiate gullying on a larger scale. Individual gullies certainly developed locally, particularly in areas with natural conditions conducive to erosion and particularly intensive colonisation. A similar situation occurred in the Bronze Age as indicated by the studies conducted in the Doły Podmularskie gully system. The earliest gullies usually had small dimensions and dissected primarily the bottoms of dry valleys and trough-shaped valleys whose catchments were used for agriculture. Relatively large gullies could develop in the bottoms of valleys with large catchments and long-lasting use which was the case with Kolonia Celejów.

The low intensity of gully erosion in the Neolithic and Bronze Age is indicated by the formation of peats in the bottom of the Bystra valley in the Nałęczów Pleateau in that period. The intensity of the erosion processes was so low that the eroded material did not reach the bottoms of the river valleys or formed local alluvial fans (Zgłobicki, Rodzik, 2007; Superson (ed.), 2012). The covering of peats by flood sediments in the Celejów area began in the early Iron Age (Superson [ed.] 2012), and the development of the first large gully in the Jedliczny Dół system in the Szczebrzeszyn Roztocze is also dated to that period. The exploitation of timber (particularly beech) for the smelting of bog iron ores in the river valleys probably contributed to gully erosion in that period.

However, intensive aggradation of flood sediments and colluvial sediments eroded from gullies on the floodplain of the Bystra river began as late at the 10th century (Superson et al. 2003; Zgłobicki, Rodzik 2007). The phase of revived erosion in the early Middle Ages is also documented by the fossil gully in the Doły Podmularskie system, dated to the 11th century (Dotterweich et al. 2012) and a branch of the Zimny Dół gully in the Celejów area (Superson et al. 2013). The development of gullies in that period is linked with the development of human settlements at the time when Polish statehood was being established and strengthened (Fig. 4).

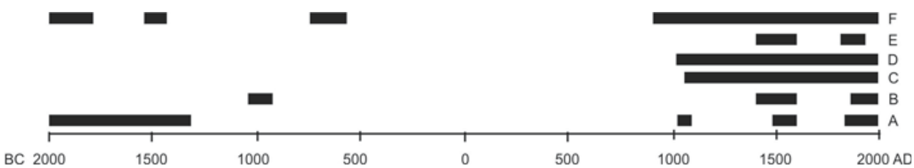

Fig. 4. Phases of gully erosion in the Lublin region according to various data. A – Dotterweich et al. 2012, B – Schmitt et al. 2006, C – Buraczyński 1991, D – Maruszczak 1988, E – Śnieszko 1995, F – Superson et al. 2013

A revival of gully development, clearly visible in all the investigated sites, occurred in the late Middle Ages (Schmitt et al. 2006; Rodzik 2010; Dotterweich et al. 2012; Superson et al. 2013). It was related to a change in the geopolitical situation of the Lublin region in the second half of the 14th century. Thanks to the annexation of Podolia and the subsequent Polish-Lithuanian Union, this region, previously peripheral and exposed to numerous invasions, found itself in the centre of the Commonwealth. This led to an economic boom: intensified colonisation, increased acreage of arable land and development of transport routes. The land ownership structure and field-forest boundaries were stabilised. The growing anthropogenic pressure was accompanied by a greater frequency of heavy rainfall in the cooling phase preceding the Little Ice Age.

The most intensive gully erosion occurred in the catchments in the 16th and 17th centuries (Fig. 4) which saw a distinct increase in arable land in the Lublin Region in connection with the development of manorial economy producing grain for export. It was also a period of exceptionally intensive snowmelt and probably the most frequent torrential rainfall events in the Little Ice Age. Similarly to the previous phase, a distinct erosion of unpaved roads, particularly susceptible to precipitation runoff, occurred. As the roads crossing the slopes were eroded, they became connected to the gully systems (Dotterweich et al. 2012) or entire systems developed on their basis (Superson et al. 2013).

The 19th and 20th centuries saw another revival of erosion processes due to the intensification of agriculture: introduction of crop rotation and root plant cultivation. Cattle was put to pasture in the gullies and in the first half of the 20th century some gully bottoms and walls were used for agriculture owing to the "hunger for land" caused by wars and economic crisis. Intensive gully erosion occurred in that period in the Doły Podmularskie, Zimny Dół and Jedliczny Dół gullies, mainly in their upper reaches and walls of the main branches.

The above data indicate that a majority of contemporary gully (erosion) systems have formed or developed during the last millennium. On this basis, the mean annual rate of historical gully erosion was calculated at 120 $m^3 \cdot km^{-2}$ in areas with moderate gully density (about 2 $km \cdot km^{-2}$) and 600 $m^3 \cdot km^{-2}$ in areas with the largest gully density (up to 10 $km \cdot km^{-2}$) (Maruszczak 1973; Buraczyński 1991). The results are only tentative because the effects of erosion varied and occurred over an extended period; hence they cannot be dated precisely. In modern times, based on research conducted in the years 2003–2006 in the Nałęczów Plateau (Rodzik et al. 2009), the mean annual volume of debris transported from the catchment of one of the active gullies was calculated at about 25 $m^3 \cdot km^{-2}$. It was found that the amount of material eroded (mainly during snowmelt) and accumulated at the valley bottom was several times higher. Snowmelt runoff prevailed in that period and the conditions were not conducive to the dissection of the gullies and removal of material from the gully bottoms. During torrential rainfall, most (up to 90%) of the eroded material is transported outside the catchment. In extreme cases, the volume of debris transport from a gully catchment is from 3 to $7 \cdot 10^3$ $m^3 \cdot km^{-2}$ per single event (Buraczyński, Wojtanowicz 1974; Rodzik 1984; Rodzik, Janicki 2003).

Gully erosion is the main source of material delivered to fluvial systems (Poesen et al. 2003). In the loess areas in the western part of the Lublin Upland, one can observe a distinct increase in the sediment accumulation rate on floodplains. The rate is 0.1–0.7 mm·yr^{-1} for the last 10,000 years; it is even higher for the last millennium: 0.7–4.0 mm·yr^{-1}. The sediment accumulation rate reached its maximum values in the last 100 years: 3.0–16.0 mm·yr^{-1} (Zgłobicki, Rodzik 2007; Zgłobicki 2013). This process should be slowed down by the present-day introduction of perennial crops and leaving the fields fallow in some places, which helps stabilise the catchment and limit the development of gullies (Dotterweich et al. 2012; Superson et al. 2013).

CONCLUSIONS

Gullies in the loess areas of the Lublin region developed in stages, almost "by leaps", and the erosion phases were interspersed with phases of stabilization. Gullies began to develop concurrently with the beginning of human settlement and agriculture in a given area, and the subsequent phases of gully erosion coincided with periods of intensified colonization and farming. The overexploitation of forests also contributed to the development of gullies. The phases of the stabilization of the gullies were linked with a decrease or abandonment of farming in the catchments and abandonment of unpaved roads.

Six phases of gully development can be distinguished; they correspond to the main human settlement phases in the loess areas of the Lublin region, namely the Neolithic, Bronze Age, Early Iron Age, Middle Ages (11th to 14th c.), period of manorial economy coincident with the Little Ice Age, second half of the 19th century to mid-20th century. Not all of the above phases occurred in all the study areas due to the asynchronicity of human activity in the particular catchments.

Most gully systems have developed during the last millennium and the main gully development phase occurred in the Little Ice Age, particularly its cooling phase. The accelerated clearance of forests as well as the intensified production of grain for export and use of unpaved roads coincided with climate changes associated with a greater frequency and intensity of snowmelt and rainwater runoff.

From a long term perspective (millennia and centuries), the gully development phases are coincident with deforestation and development of agriculture. From a short-term perspective (years and decades), the influence of weather phenomena and climate conditions is more pronounced.

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STRESZCZENIE

W pracy dokonano przeglądu dotychczasowych studiów nad historyczną erozją wąwozową na Lubelszczyźnie i podsumowano wyniki najnowszych badań w kilku wąwozach na Wyżynie Lubelskiej i Roztoczu. Stwierdzono, że w obszarach lessowych regionu lubelskiego rozwój wąwozów przebiegał etapami, niemal „skokowo", zaś fazy erozji przeplatały się z fazami stabilizacji. Początek rozwoju wąwozów był synchroniczny z początkiem osadnictwa i rolnictwa w danym terenie, zaś późniejsze fazy erozji wąwozowej były zbieżne w czasie z okresami intensyfikacji osadnictwa i gospodarki rolnej. Do rozwoju wąwozów przyczyniała się także intensywna gospodarka leśna, prowadzona w sposób rabunkowy. Fazy stabilizacji form wąwozowych związane są z ograniczeniem lub zaniechaniem uprawy roli w zlewniach oraz porzuceniem dróg gruntowych. Wyróżniono sześć faz erozji wąwozowej, odpowiadających głównym fazom osadniczym w obszarach lessowych regionu lubelskiego. Są to: neolit, epoka brązu, wczesna epoka żelaza, średniowiecze (XI–XIV w.), synchroniczny z małą epoką lodową okres gospodarki folwarcznej, druga połowa XIX w. do połowy XX w. Nie wszystkie fazy zaznaczyły się we wszystkich badanych obszarach z powodu asynchronicznej działalności człowieka w poszczególnych badanych zlewniach. Potwierdzono pogląd, że większość systemów wąwozowych rozwinęła się w ostatnim tysiącleciu, ponadto we wszystkich badanych obiektach główna faza erozji wąwozowej miała miejsce w małej epoce lodowej, zwłaszcza w jej fazie wstępującej. Na przyspieszoną trzebież lasów oraz intensyfikację uprawy zbóż na eksport i użytkowanie dróg gruntowych nałożyły się w tym czasie zmiany klimatyczne, związane z większą częstością i intensywnością spływów roztopowych i deszczowych. Stwierdzono, że w skali długookresowej (tysiącleci i stuleci) fazy rozwoju wąwozów są synchroniczne z wylesieniem i rozwojem rolnictwa. W skali krótkookresowej (lat i dziesięcioleci) zaznacza się wyraźniej wpływ zjawisk pogodowych i warunków klimatycznych.