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Current and historical gully erosion and accompanying muddy floods in Slovakia

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Abstract: Comparison of commonly acting gullying and muddy floods at present (in the post-collectivization period) and in the past (mostly in the period of the 16th to 19th centuries) has showed considerable disparities; they are conditioned by the character of land use and climate changes, mostly in the case of their synchronous occurrence what has profoundly multiplied their geomorphic response. In the case when extreme events occur in the area with permanent, historical gullies, the current common operation of gully erosion and muddy floods can show similar features with their acting in the past. In such cases the material of muddy floods is coming not only from fresh ephemeral gullies but also from old permanent gullies that were deepened during these events. It was confirmed during extreme events that happened in cadastral areas of two villages in western Slovakia in 2009 that were not comparable with geomorphic effects of other events within the last period.

Keywords: gully erosion, muddy floods, natural hazards, environmental issues, Slovakia

Introduction

Gully erosion and its direct consequences – muddy floods represent a significant natural hazards and serious environmental issues in hill land and upland landscapes in Slovakia. They occur in areas where the original woodland was affected by lumbering, changed to pastures and in particular to arable land. The main objective of this paper is to refer both to disparities and similarities of these commonly acting phenomena in actual and past environmental conditions of Slovakia.

Material and methods

The systematic investigations of muddy floods in Slovakia in the context of the complex operation of runoff geomorphic processes, including gully erosion, started in 1993. In the 1990s they were exclusively performed in the territory of the Myjava Hill Land, in the 2000s gradually extended to other parts of Slovakia (Fig. 1). The effect of particular muddy floods was always documented shortly after the event by means of detailed mapping of accumulation bodies and estimation of their thickness. The total geomorphic effect of series of muddy floods at the same sites was evaluated by means of sampling and the analysis of correlative sediments. The impacts of known recent events were reconstructed on the basis of interviews with officials of Local authorities and farm employees, affected citizens, information acquired from municipal chronicles and articles in local and regional newspapers, as well as precipitation dates from the Slovak Hydrometeorological Institute, Bratislava. The assessment of possible impacts of unknown, assumed muddy floods within the last seven centuries was based on historical sources and comparative material acquired by personal terrain reconnaissance as well as from the investigations of other authors.

Disparities in common operation of gully erosion and muddy floods in contemporary and past conditions

The contemporary agricultural landscape in Slovakia is characteristic by large blocks of fields inherited from the collectivization times what affects its high susceptibility to runoff erosion processes. Concentrated flow erosion in current conditions, un-

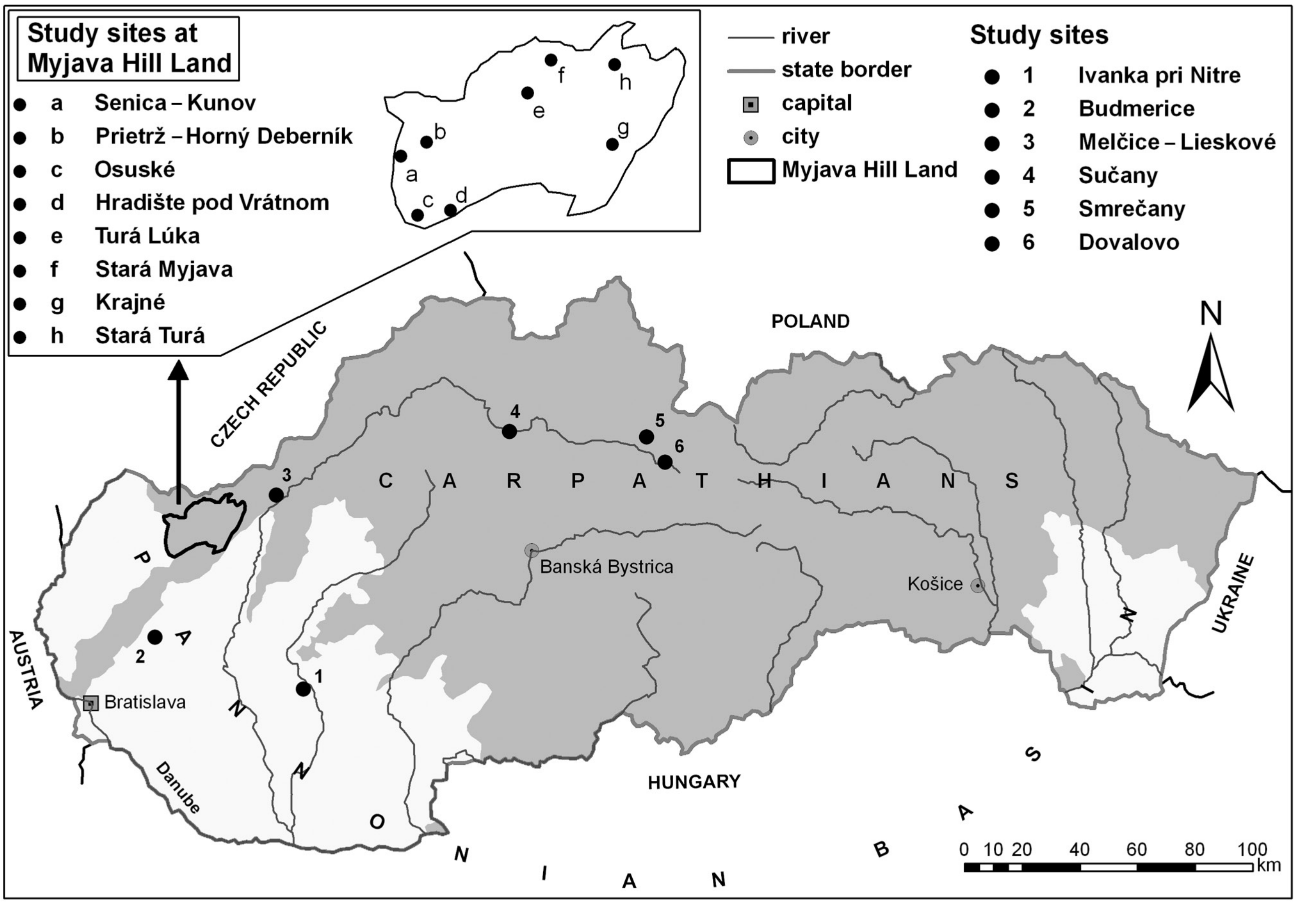

Fig. 1. Sites of muddy flood investigation in Slovakia

like in the past, is predominantly topographically controlled, giving rise to ephemeral gullies of two different types. Usually they are wide (up to 5–6 m) and shallow (from some cm up to 25–30 cm), cut only into the cultivation layer. Much more rarely they are cut into the firm sub-cultivation layer (plough pan); in such cases their depth usually does not exceed 1 m. Ephemeral gullies are always erased by the subsequent tillage operation but are formed again on the same places during the next extreme events (Stankoviansky 2003a).

Concentrated flow erosion, occurring mostly along thalwegs of dry linear depressions, is the main factor responsible for the muddy flood formation. According to Boardman et al. (1994), the ideal conditions for generation of muddy floods provide landscape with a dense network of dry valleys that concentrate runoff what multiplies its erosion force. The similar role as dry valleys plays also the system of dells (Stankoviansky 2002). Muddy floods accompany concentrated flow erosion during extreme rainfalls and sudden snowmelts in time when the soil is not protected, or only poorly protected by vegetation, mostly in spring months. Results from the Myjava Hill Land in western Slovakia showed that thickness of muddy beds, deposited during individual muddy flood events in the 1990s, ranged from a few to 50 cm. The volume of deposited material depends on the extent of contributing area and on the rate of erosion, especially of concentrated flow erosion leading to incision of ephemeral gullies and thus generating the majority of transported sediment. The thickness of accumulation body depends also on size and shape of accumulation space, presence of barriers etc. Naturally, the muddy deposits in built-up areas, as well as on linear constructions such as roads, railways or canals are removed (Stankoviansky 2003a). Results acquired by the documentation of the effects of muddy floods in some sites in other parts of Slovakia in the 2000s (Melčice-Lieskové: June 6, 2003, Smrečany: June 2, 2004, Dovalovo: July 21, 2004, Budmerice: September 11, 2005) did not differ from those in the Myjava Hill Land (Stankoviansky 2009).

The most harmful impact of muddy flood identified until recently in Slovakia is connected with the village of Ivanka pri Nitre. It was affected by two floods, namely in April 30, 1995 and May 1, 1996. Especially the latter, caused by the 85 mm cloudburst, reached extraordinary parameters. The village is situated below the eastern marginal, gently inclined slope of the Nitra Hill Land built of loess. A broad dry valley is deepened shallowly in the slope. In May 1996, one large cooperative field sown with corn cov-

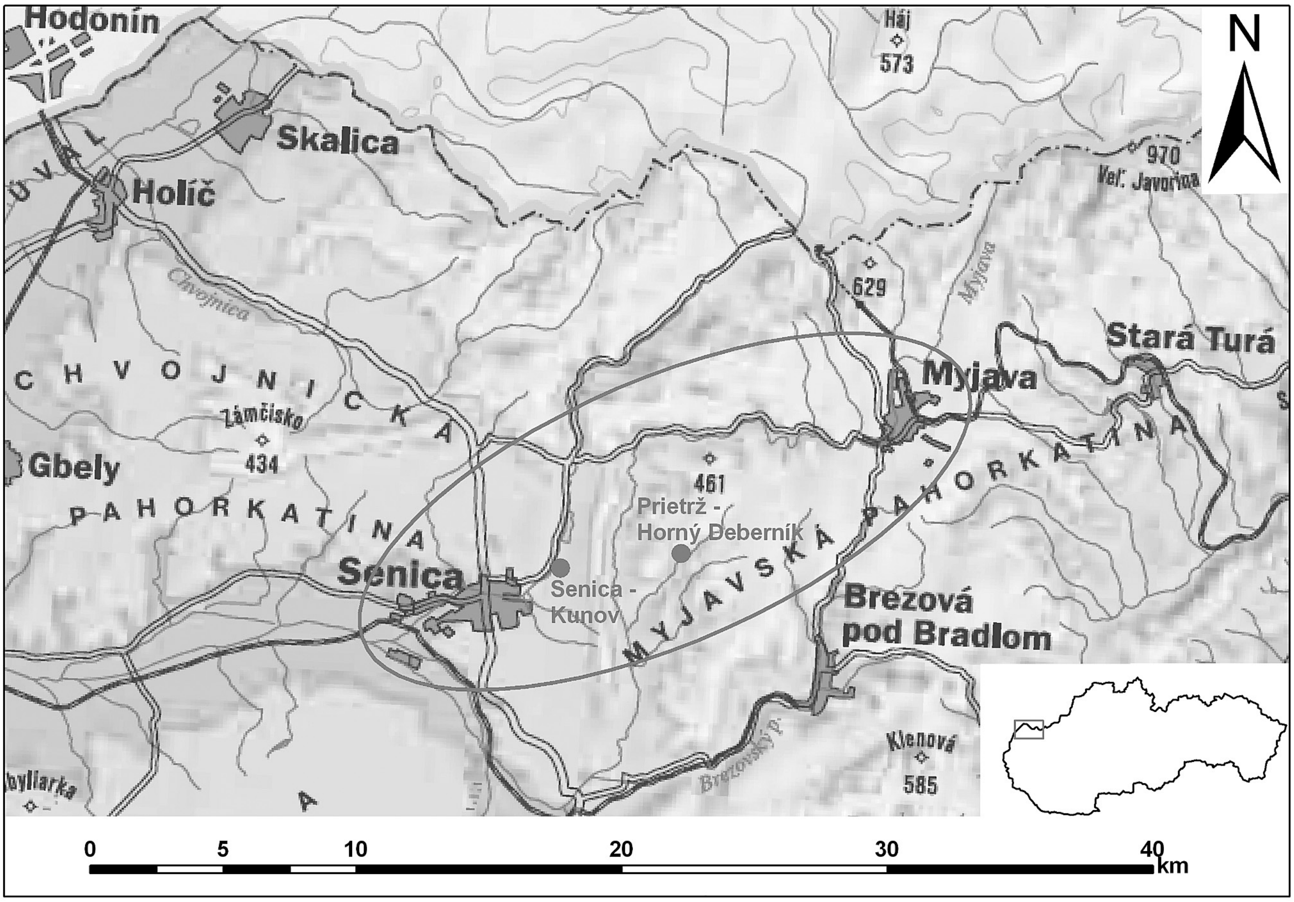

Fig. 2. The area in the western Slovakia affected by heavy rainfall event accompanied by disastrous muddy floods in June 6, 2009

ered the entire slope. Some tens of meters wide wild water flow, generated in the valley, washed all what was standing in its way, including cars. In total 175 houses were flooded, and 4 of them were even destroyed. The effect of this muddy flood event was reconstructed on the basis of personal communications with representatives of the local institutions (cf. Stankoviansky 2009). Similar reconstruction of muddy flood effects was realized in the case of the village of Sučany, where the biggest event happened in June 19, 1994 (Stankoviansky et al. 2010).

Though the current gully erosion is relatively intensive it is not comparable with much more intense gullying in some periods in the past resulting in the formation of a dense network of permanent gullies. Detailed studies of these gullies in the Myjava Hill Land revealed their clear linkage to the old, pre-collectivization land use pattern. Gullies were formed in stages mostly along artificial linear landscape features such as access roads, paths, baulks, field borders, headlands and drainage ditches, fewer on pastures. They are often 10–15 m deep, more rarely up to 20 m and occasionally exceed 20 m. Most of permanent gullies have represented the geomorphic effect of gully erosion in the period since the 16th to 19th centuries. Gully formation just in this period is an illustrative example of cumulative geomorphic response to two synchronous environmental changes in the same area. The first is the land use change, namely the transformation of woodland into a cultural land, performed mostly by settlers of the youngest colonization waves (Walachian and the so-called “kopanitse“ colonizations). The second is the climate change, namely the Little Ice Age, characteristic by the increased frequency of extreme events (Stankoviansky 2003b).

Older gullies were preserved obviously only sporadically. In accordance to Bork (1989) we suppose that the oldest gullies had not longer lifetime, but they were either partially or totally filled during the following centuries. However, later they were formed again in the same places, of course only in the case of those gullies that were not overgrown by forest vegetation.

An accompanying phenomenon of often disastrous gully erosion in the past, provoked by extreme events of those times, had to be muddy floods with equally disastrous manifestations. Understandably, it concerns above all the period of the Little Ice Age, but also prospective older periods of gullying. Right disastrous gully erosion together with equally intense muddy floods could be responsible for an abandonment of numerous villages in the western margin of the Myjava Hill Land in the 14th and partially also in the 15th centuries (Stankoviansky 2002). A similar cause of the abandonment of the village of Bystřec in the Drahanská vrchovina Upland in the Moravian part of Czechia in the period of the 13th to 14th centuries was stated by Hrádek (2006).

Similarities in common operation of gully erosion and muddy floods in contemporary and past conditions

As it was stated above, the assessment of commonly acting gully erosion and muddy floods at present and in the past referred rather to their disparities in contemporary and past conditions. However, the documented manifestations of extreme events that affected neighbouring villages Kunov and Prietrž in the western Slovakia in spring and summer 2009 indicated that under specific circumstances their current common operation can show also similar features with their acting in the past. The village of Kunov (the administrative part of the district town Senica) was affected three times within three months, namely in May 4, June 6 and July 2, the neighbouring village of Prietrž only in June 6. The most harmful consequences had the extreme rainfall event of June 6 that affected the area of elliptical shape between towns Senica and Myjava, including both mentioned villages (Fig. 2). The highest rainfall total in individual communities within the affected area was recorded in Turá Lúka (the administrative part of Myjava) – 66 mm.

The village of Kunov is situated in the bottom of the lowermost portion of the forked dry valley system deepened in the western marginal slope of the Myjava Hill Land (Fig. 3). The slope is long ca 1,300–1,500 m and gently inclined, built of the Miocene Prietrž beds consisting of alternating sandstones, siltstones and mudstones. Its middle and lower parts are covered by loess and loessy loams. The area of the drainage basin of the forked dry valley is 108 ha. Permanent gullies are cut along thalwegs of both branches of the fork while the length of longer of them is more than 900 m. Both gullies were afforested in the past. Besides forest in gullies, all drainage basins represent a set of large blocks of fields sown with maize, sunflower, sugar beet and partially also winter barley in time of the June 6 rainfall event. Its precipitation total was 37 mm (within 36 minutes). The height of the muddy flood body in the village reached up to 1 m. Muddy water flowing

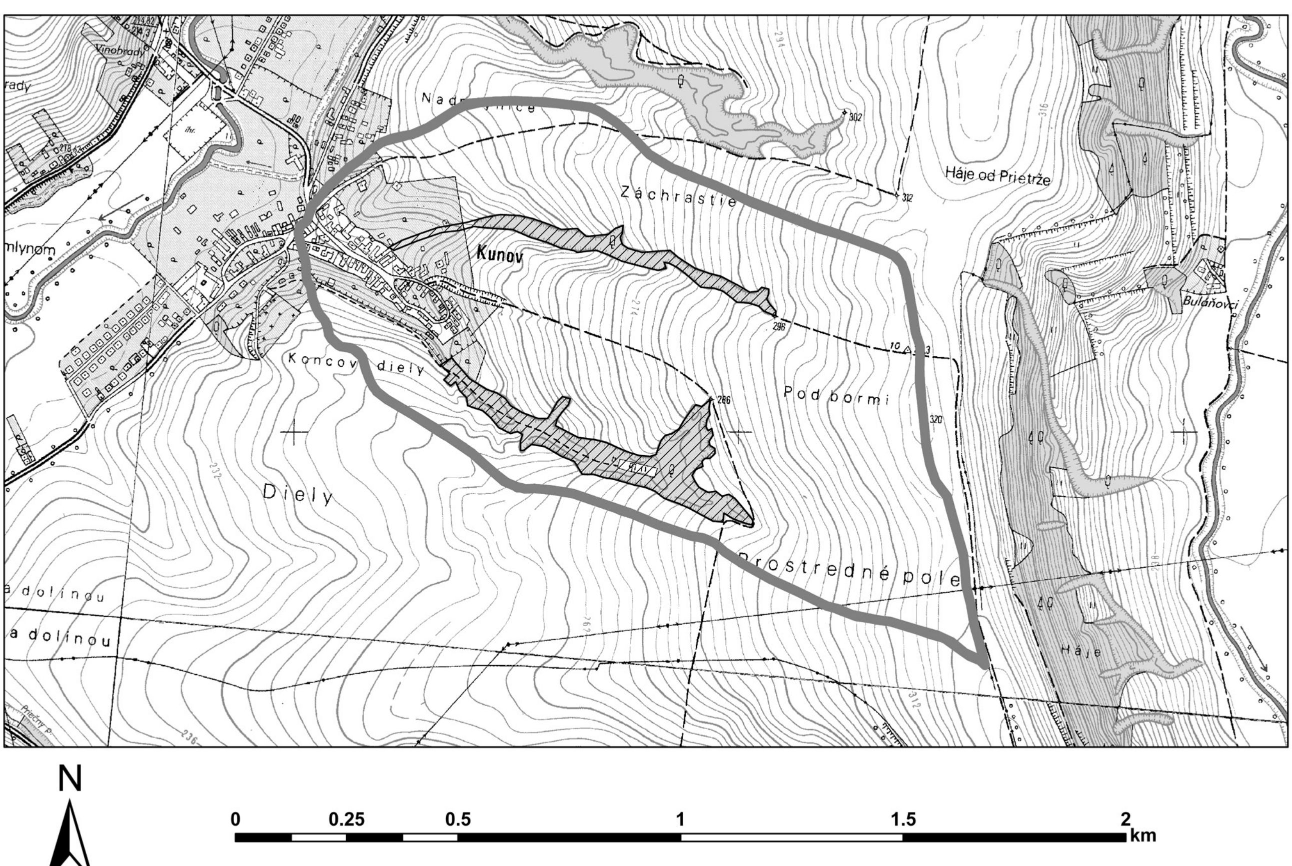

Fig. 3. Drainage basin of the the forked dry valley system with permanent gullies (indicated by an oblique hatching) in thalweg positions at the village of Kunov, affected by intense gullying and accompanying muddy floods during heavy rainfall events in May 4, June 6 and July 2, 2009

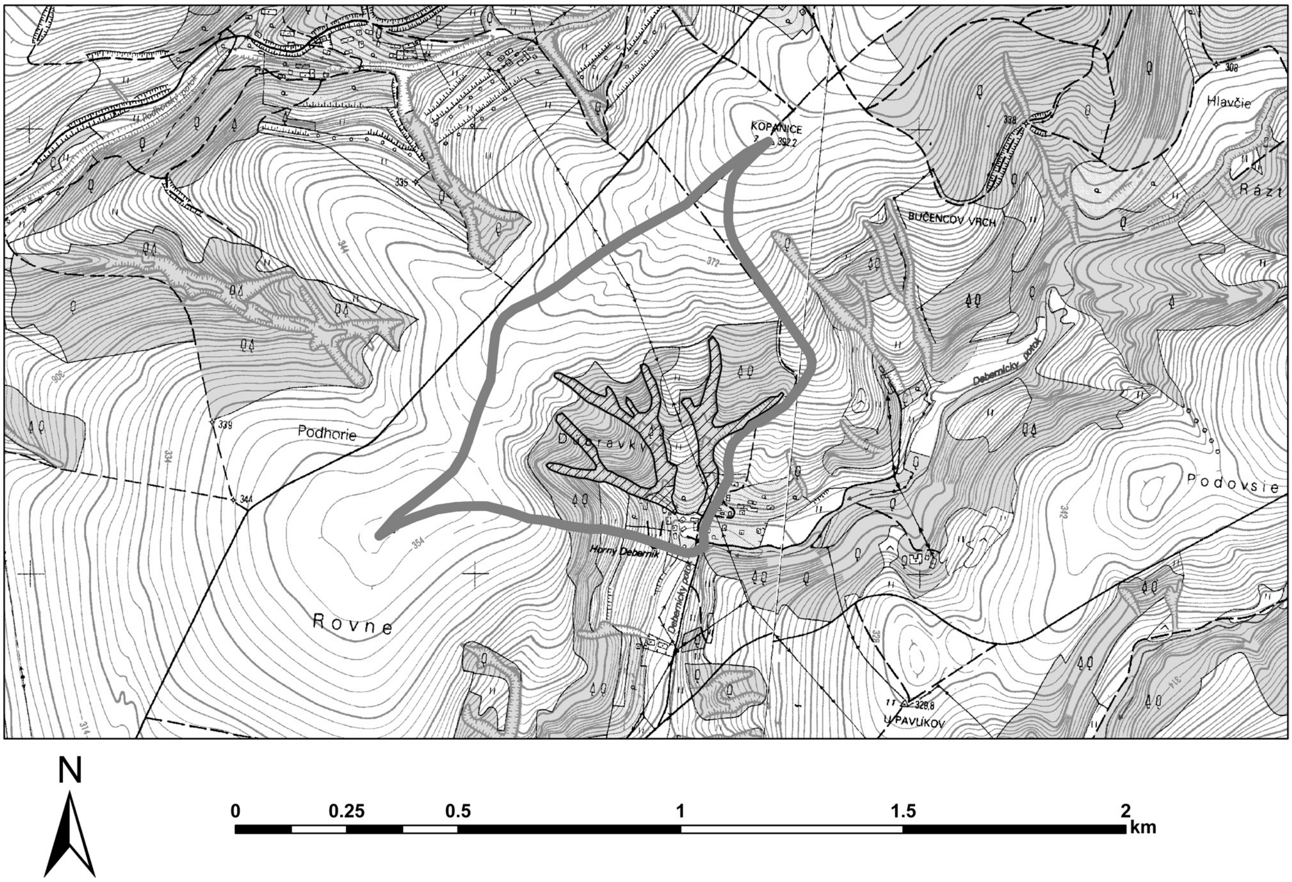

Fig. 4. Drainage basin of permanent gullies (indicated by an oblique hatching) at the hamlet of Horný Deberník in the cadastral area of the village of Prietrž, affected by intense gullying and accompanying muddy flood during heavy rainfall event in June 6, 2009

wildly along the main road washed away anything in its way, including cars. The thickness of muddy sediments after the flood was up to 20–30 cm.

The worst situation during the June 6 event in the neighbouring village of Prietrž was in the hamlet of Horný Deberník, situated in the northern part of its cadastral area (Fig. 4). The measured precipitation total in the village was 64 mm (within approximately 30 min.), but the exact highest value is not known, as rainfall gauge in the most affected hamlet of Horný Deberník was not able to catch the whole amount of rain water. The hamlet is lying in the valley bottom of the Debernícky river brook below the slope long ca 500–850 m. The slope is built of the Miocene marls and sandstones and covered by the thick deluvium. Three systems of permanent, forked gullies, incised in the slope, meet in the hamlet. The drainage basin of all these gullies, which are under the forest at present, is ca 40 ha. The length of the longest gully is ca 440 m. The forest-free part of the basin represents one large block of field; it was sown with maize in time of the event. Concentration of the flowing water in gullies resulted in such a rise of its level that the wave has killed one local inhabitant.

The above mentioned specific circumstances of the current common operation of gullying and muddy floods are represented by the occurrence of permanent, historical gullies. Thus, the material transported by muddy floods is coming not only from fresh ephemeral gullies (as well as from rills and inter-rill areas) but also from historical, permanent gullies that were deepened during these events. The fresh incision in the bottoms of permanent gullies in both sites, often in underlying Miocene substratum, ranges from 0.5 to 3 m. A combined delivery of sediment of muddy floods from both ephemeral and permanent gullies shows similarities with the acting of these processes in the past.

Conclusions

Gully erosion and its direct consequences – muddy floods represent a significant natural hazards and serious environmental issues in hill lands and uplands in Slovakia. Comparison of the spatial distribution, extent, rate, geomorphic effect and environmental impact of both phenomena at present (in the post-collectivization period) and in the past (mostly in the period of the 16th to 19th centuries) has showed considerable disparities; they are conditioned by the character of environmental changes (land use and climate changes), mostly in the case of their synchronous occurrence what has profoundly multiplied their geomorphic response.

Under specific circumstances, especially when extreme events occur in the area with permanent, historical gullies, the current common operation of gully erosion and muddy floods can show similar features with their acting in the past. In such cases the material of muddy floods is coming not only from fresh ephemeral gullies but also from permanent gullies that were deepened during the events. It was confirmed during extreme events that happened in cadastral areas of villages of Kunov and Prietrž in western Slovakia in spring and summer months 2009 that were not comparable with geomorphic effects of other events within the last period.

Increased frequency of extreme rainfall events within the last period resulting in intense gullying and accompanying muddy floods indicates that it could be the manifestation (beside land use changes due to collectivization in agriculture) of the global climate change.

Acknowledgements

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