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Permanent gullies in the Nitra Hill Land, Slovakia: about the cause of gully formation

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Abstract: The paper deals with the spatial evolution of permanent gullies (under forest at present) in time in the northern part of the Nitra Hill Land (Slovakia) with the discussion on possible cause of their formation. For the purpose analyses of historical and current maps from the years 1783, 1838, 1882 and 2001 as well as aerial photographs from the second half of the 20th century and various historical written sources related to the years 1770, 1783, 1817, 1843 and 1956 were used. Based on the gained results an erosion activity of gullying can be found in the study area between the seventies of the 18th century to the sixties of the 20th century. Beyond the two main possible causes of the erosion activity as climatic change or (and) alteration in land use also conditions, such as agricultural system, different land use pattern, demographic characteristics or level of human society development may be considered.

Keywords: permanent gullies, historical and current maps, historical written sources, cause of gully formation, Nitra Hill Land (Slovakia)

Introduction

During the last period, interest in permanent, historical gullies has increased significantly (e.g. Bork 1989, Buraczyński 1989/1990, Bork et al. 1998, Gábris et al. 2003, Stankoviansky 2003a, Dotterweich 2005, Schmitt et al. 2006 and others; the more comprehensive overview of contributions dedicated to this phenomenon is available in articles by Vanwalleghem et al. 2006 and Dotterweich 2008). An increased interest to study permanent gullies connects with the fact that these geomorphic features provide important insights into the impacts of natural and socio-economic conditions for erosion processes acting at timescales that are not measurable in laboratory or field studies (cf. Vanwalleghem et al. 2005).

A deeper research of genesis of permanent gullies in Slovakia has been made mostly by Stankoviansky (for example 2000, 2003a, 2003b and others) who investigated the topic over wide areas of the Myjava Hill Land in western Slovakia. Study area relating to this paper has a total area of 32.5 km^2 and is situated in the distance to the Myjava Hill Land of about 70 km in the east direction.

The contribution deals with the spatial evolution of permanent gullies (under forest) in time in the northern part of the Nitra Hill Land with the discussion on possible cause of their formation. The paper is thematically divided into two parts. The first one deals with the quantitative spatial development of permanent gully network in time and the second part is dedicated to discussion on the cause of formation of these landforms based on the results.

Materials and methods

The study was based on analysis of historical and current maps and written historical sources. Aerial photographs from 1955, 1970, 1976 and 2002 were also used to supplement the research. Evaluation of historical sources has been used in several papers concerning historical gully erosion (Láznička 1957, Hard 1976, Buraczyński 1989/1990, Pietrzak 2000, Stankoviansky 2000, 2003a, Gábris et al. 2003). The maps of military surveys of the Habsburg Monarchy (later Hungary) from the years 1783, 1838, 1882 as well as current topographic maps (2001) were processed in Geographic Information System (ArcGIS 9.2).

Maps of the 1st Military Survey from 1783 were processed just partial because of the missing relevant cartographic projection. Each of the evaluated mappings has been originally created using various cartographic techniques (in case of the mentioned mapping from 1783 not sufficient ones). That means there always will be a question of comparability of exact values as length or density of gullies. Density of gully network was calculated for entire study area (32.5 km^2). There are also some flat parts of the study area with no permanent gullies meaning that there is a higher density of gullies in some selected areas than the calculated average for the whole region. Information from historical written sources supplement the report on the occurrence of gully erosion over time. They are represented by various facts collected by historians in which gullying is also mentioned beside others.

Area description

Study area is situated in the northern part of the Nitra Hill Land, one of geomorphic subunits of the Danube Hill Land, representing the higher step of the Danube Lowland. It administratively covers cadastral areas of villages Nemečky, Prašice and Tvrdomestice in the Topoľčany District (see one part of the Fig. 1). The presence of dense network of permanent gullies and history of the area well investigated by historians were the main factors for choosing the territory.

Investigated part of the Nitra Hill Land has a character of gently inclined plain dissected by a system of parallel shallow valleys with a relative relief of 30–50 m. One group of permanent gullies was formed on the slopes of the valleys; the other one is situated on the slopes of short dells. The geologic complex is built by the Dacian fluvial to fluvio-limnic sediments of the Volkovce Formation (gravels, sands and variegated clays), covered by sediments of the Lower, Middle and Upper Pleistocene and the Holocene.

Sediments of the Lower and Middle Pleistocene were covered by the beds of loess. For most of the study area loess is substituted by the Pleistocene-Holocene aeolian-deluvial sediments (loess loams with beds of loess; Pristaš et al. 2000). Soil types are Haplic Luvisols, Albic Luvisols and Planosols and Stagnosols. The mean annual precipitation is 600 mm. Most of the study area is an agricultural land (mostly arable), marginal parts are under forest and permanent gullies are wooded enclaves of the landscape. The territory has been probably settled and used by man since Neolithic (4,500–4,000 BC) with some hiatuses in time (Early and Middle Bronze Age, eventually others depending on found evidence). According to historians, the continuous existence of settlement is documented from the 12th century to present, although during that time period there were some demographic fluctuations, including short-term depopulation (for example the village Prašice around the year 1245; Lukačka 1995).

Permanent gullies in the study area: spatial development in time

Permanent gullies in the study area are represented by numerous landscape elements at present. Their depth ranges most often from 4 to 6 m, in some cases more (up to 15 m). The vast majority of described landforms is under forest at present, pointing to their origin in the past.

Analysis of historical and current maps

Despite the above mentioned absence of the appropriate cartographic techniques, maps of the 1st. Military Survey of the Habsburg Monarchy from 1783 have a high value and represent the first maps displaying gullies in the study area. The measured density of gully network is 0.64 km km^{-2}. This value was calculated using displayed graphic scale on the maps, as the mapping has not been georeferenced (in contrast to maps from 1838, 1882, 2001). Visual comparison with the next cartographic sources proves that many permanent gullies existing at present (at least their base) are already drawn on these maps.

Maps of the 2nd Military Survey from 1838 show an increase of gully density in comparison to the maps from 1783. According to this source, number of new gullies 100–200 m long was created in this time period. Total gully density is 0.88 km km^{-2} (see another part of the Fig. 1) and it is an increase of about 38% compared to the previous mapping. The vast majority of present-day permanent gullies is delineated on the maps of this survey.

There is again an increase in the measured variable which shows the maps of the 3rd Military Survey from 1882. The gully density is 1.16 km km^{-2}, and the increase 32%. An extension of the existing gullies and gullies' branches (also a creation of new branches) as well as a formation of new gullies in few cases was recorded during this period.

Present topographic maps show the current status of permanent gullies. Their total length is 28.650 km (0.88 km km^{-2}). Compared to the 1882 map it is a fall by about 24%. This reduction is a result of recultivation works in the process of collectivization of agriculture in the former Czechoslovakia (in the study area with beginning of the 1960s) when a lot of gullies (or at least their end parts) were filled up by farmers using heavy machinery (bulldozers). Traces

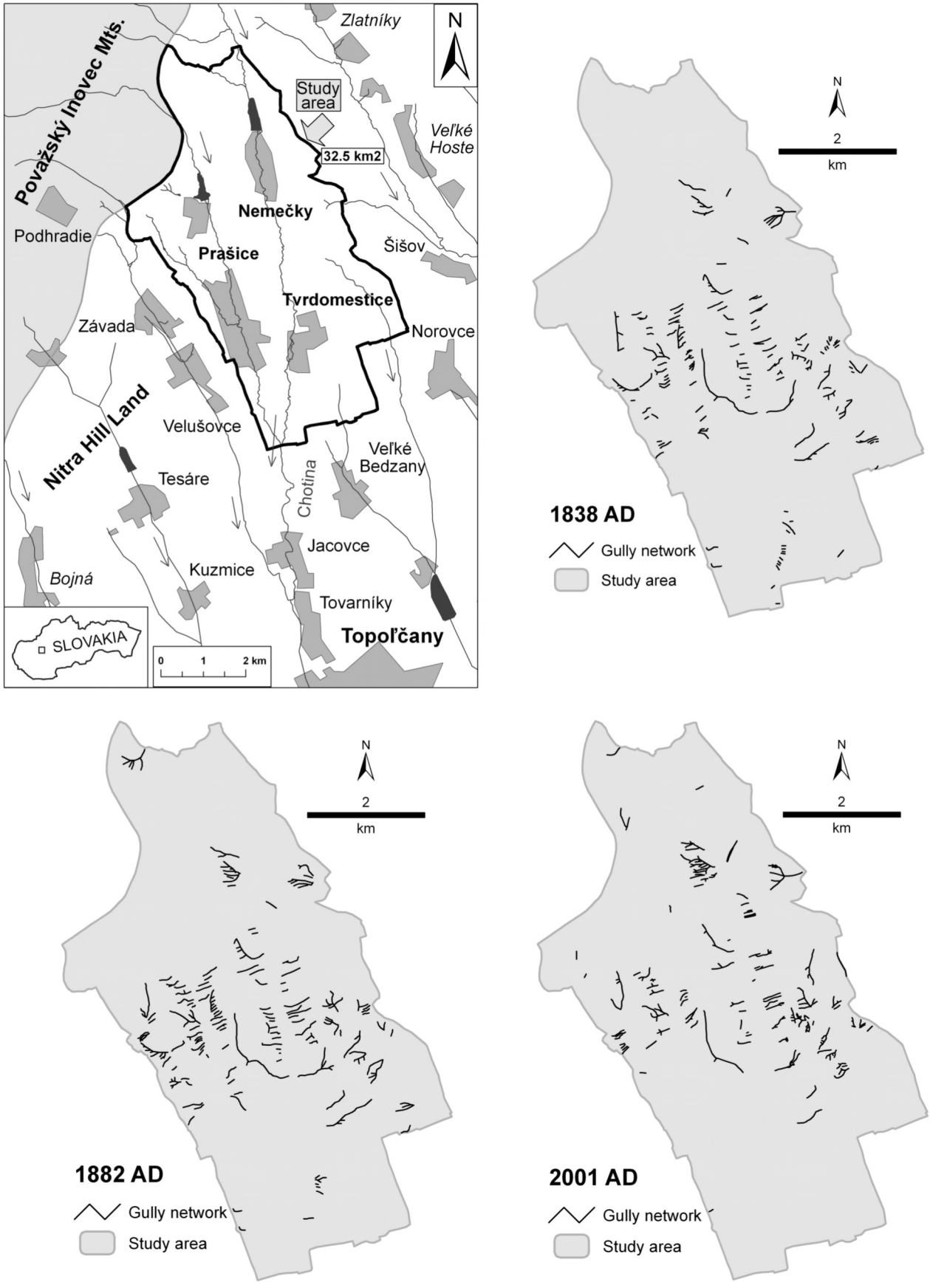

Fig. 1. Situation map displaying the study area as a part of the Nitra Hill Land near the Považský Inovec Mts. and evolution (status) of the permanent gully network regarding to the years 1838, 1882 and 2001

of the former gullies, however, have remained in relief as shallow longitudinal depressions which were after the operations agricultural re-used. These shallow *artificial* dells give now rise to concentration of runoff which results in creation of ephemeral gullies. Despite the overall decrease in the density of gullies comparing the maps from the 1882 and 2001, an increase in the length of permanent gullies was recorded in a few cases. In addition, it is possible to see examples of active gullies on aerial photographs from 1955 (before collectivization) whereas those sites were later forested or recultivated (according to the aerial photographs from 1970, 1976 and 2002).

Analysis of historical written sources

There are a few written documents describing directly historical gully erosion in the study area and its surroundings which are related to the years 1770, 1783, 1817, 1843 and 1956. Chronologically, the first report is a part of letter of vassals addressed to representatives of aristocracy dated to the April 15th, 1770 in which the residents of five villages (in surroundings of the study area in distance of about 15 km) were complaining that their: "fields are poor, full of gullies and covered by loam and weed and the most by stones" (Horváth 1955).

The reports from the years 1817 and 1843 are also parts of the letters of complaints (according to the same reference). People from Tvrdomestice (study area) are writing on March 16th, 1817 that: "their parish is miserable and the pastures are not sufficient for the cattle feeding and they need wicker to block gullying". On May 28th, 1843 a letter was sent from the village Bojná (distance to study area of about 6 km) in which is also mentioned the problem of gully erosion: "the fields are covered by gravels and affected by gullies caused by heavy rains and too much water". Maps of the 2nd Military Survey of 1838 show a dense gully network in Bojná, and the gullies were not delineated on the maps from 1783. Both sources thus probably confirm the rapid creation and development of permanent gullies in that place and time.

Transition source between the written and cartographic documents are formal remarks on maps. Remarks of the 1st Military Survey from 1783 contain information which are relevant to troops transport. In the case of villages Veľké Hoste and Zlatníky (neighboring to Nemečky and Tvrdomestice) a presence of "many gullies which are almost everywhere deep and very steep" is mentioned in the remarks. This fact demonstrates the significance of the gully network in that time and space as is evidenced by the map itself.

The written report from the mid-20th century concerns the rural zone of the village Prašice. According to Gam (1956) a presence of "fresh gullies" was recorded that could be confirmed also by aerial photographs from 1955.

Discussion: the cause of gully formation

According to Morgan (1995), gullies are almost always associated with accelerated erosion and therefore with landscape instability. The main cause of gully formation is too much water, a condition which may be brought about by either climatic change or alteration in land use. Different formation of gullies in time at small area may indicate the presence of several factors (sub-factors). However, none of them can be considered as definite. It is just naming the possible ones.

A special example of this can be found in the study area where a different formation of gullies is recorded on opposite slopes of one particular valley, even within only one side of the valley. While the left side of the valley between the villages Nemečky and Tvrdomestice is according to the maps of 1783 dissected by several gullies, on the right side except two sites there are no more gullies. There are many new delineated gullies on the maps of 1838 and according to these maps a basic network of the landforms seems to be completed at this time.

The question is what is the cause of different development? The first answer might be the questionable trustfulness of the maps from 1783 or the fact that the gullies were not too large or deep to be a block for troops' transit. If there were actually no gullies at that time there might be several following possible causes. In terms of physical-geographical conditions the two slopes have slightly different characteristics. The right side slopes are less steep but longer. The left side slopes, oppositely, are steeper but shorter. Geologic cover is built mainly by loess on the right side, on the left side by aeolian-deluvial sediments (loess loams with loess and gravels).

According to the maps from 1783 the whole assessed area was used as agricultural land, mostly cropland. The difference in land use pattern becomes as another possible factor, possibly in combination with certain socio-economic conditions. As an example, annual changes in agricultural management by three-field (crop) system which was common way of the land management at that time and place might appear. The essence of the system was a division of an area into three approximately equal parts, with one part with winter rye (in Slovakia), second with spring barley and third part remained as a fallow during one year (the fallow was used as a common pasture for cattle; Horváth 1963). No vegetation cover during autumn and early spring might lead to an increase in volume and speed of runoff. The use of short-term pasture might also influence the

concentration of runoff due to presence of cattle trails.

Elsewhere in the study area, it is possible to see other facts. A lot of gullies displayed on the maps from 1783 are situated in sites of former vineyards. According to historians, viticulture in Slovakia suffered during the wars and internal disturbances at the turn of the 17th and 18th century, while much of the vineyards were desolated (Horváth 1963). Desolating of vineyards could be connected with the formation of the landforms. Gully erosion could directly causes degradation of vineyards, but from the other point of view, the abandonment of vineyards could cause the sites more vulnerable to erosion.

A demographic characteristics is remarkable in the study area (Prašice case) at the end of the 17th and during the first half of the 18th century. At first a decrease of population by two thirds occurred during the 17th century compared to the 16th century and then a five-fold increase (!) in number of population was recorded during the first half of the 18th century (Lukačka 1995). This had to be reflected in the intensity of land use.

Comparing of gullying in the study area in the past and present may also point to the human factor – factor of technical human availabilities. The formation of deep and large gullies seems to be stopped at present-time. It reflects the possibility, respectively impossibility to do some arrangements to block gullying in historical and current times, for example, recultivation of damaged areas (heavy mechanisms now vs. a wooden plough in the 18th century) or introduction of land drainage melioration, no tillage management etc. It may point indirectly to the fact that the factor of climate might not be a decisive factor in forming of *permanent* gullies.

However, along the above mentioned possible land use changes as factors during the 18th and 19th century they are also recorded increased rainfall activities during these periods. For the Czech Lands (there is absence of papers dealing with the reconstruction of climate in Slovakia before the 2nd half of the 19th century) there was an occurrence of significant precipitation years from 1763 to 1804 including "very wet period" of 1795–1804 (Vašků 1999). According to this source there were another wet fluctuations during the 19th century, particularly 1811–1812, 1815–1817, 1827–1833 (including "extreme" years 1828–1829), 1836–1839, 1890–1891 and 1894–1901.

Conclusions

The study area represents a remarkable place to assess the development of permanent gullies. Using the analysis of maps (aerial photographs) and written sources an erosion activity of gullies can be found in the territory approximately between the seventies of the 18th century to the sixties of the 20th century. Starting in the 1970s a number of parts of the landforms as well as in few cases the whole gullies themselves have been filled up by farmers (heavy mechanisms) when at the same time an increased control of expansion of permanent gullies has begun (via afforestation, protection of gully heads by setting shrubs etc.). However, formation of ephemeral gullies occurs in shallow linear depressions which are results of the filling up processes. A list of several possible causes or sub-causes of formation of permanent gullies has been shown in the study. Beyond the two main causes as climatic change and alteration in land use also conditions, such as agricultural system, different land use pattern (cropland – pasture – vineyards), demographic characteristics or level of human society development may play partial roles.

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