MORPHOLOGY AND CONTROLLING FACTORS OF LANDSLIDE CIRQUE GULLIES: A CASE STUDY FROM THE SPROGU GRAVAS NATURE MONUMENT (SE LATVIA)

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1. Introduction

Human-induced changes of landscape and the vegetation cover have been recognized in the majority of studies focusing on gully formation as one of the most important factors triggering the development of gullies throughout the world. However, detailed studies of singular erosion landforms in south-eastern Latvia, particularly those that are located on steep slopes of river banks modified by mass movement processes and presently found under forest, indicate that these gullies are not a geomorphic features resulting entirely from human agricultural activities. Such short, bottleneck-shaped gullies (Crosta, di Prisco, 1998), described in Latvia as landslide cirque or spring cirque gullies (Venska, 1982), can be found in deep river valleys and subglacial tunnel valleys in Latvia, but few studies have reported on their morphological characteristics and their origin.

This study investigates these landslide cirque gullies initiated via mass movement processes in the local case-study area of the river Daugava Valley in south-eastern Latvia. The objectives are (1) to determine the spatial distribution of these gullies, (2) to measure their morphological and topographical characteristics and (3) to interpret the factors that led to their development.

2. Study area

The investigation of landslide cirque gullies is performed in nature monument “Sprogu gravas” (the Nature Park “Daugavas loki”, Fig. 1.), located in the river Daugava Valley, SE Latvia.

Fig. 1. Location of the study site.

The average difference in local topography is about 25 to 35 m. The territory is characterised by a temperate semi-humid climate influenced by the westerlies. The mean annual precipitation varies mostly within 600 to 700 mm yr^{-1}; number of days with precipitation 100 to 120 d yr^{-1}; mean temperature in January from –7°C to –5°C; the mean temperature in July from +16°C to +17°C; recurrence interval of extreme rainfall events (more than 20 mm d^{-1}) is 10 years or more.

The study site is located within the most ancient part of the Daugava ancient valley, which is also the only such valley in Latvia with regard to its configuration, and has very unique scenery with 10 river bends. The present flow of the Daugava has begun to form as a proglacial spillway valley at the final stage of the last Weichselian (Vistulian) glacial event 15 to 13 thousand years ago. Later in the Holocene, it was modified by fluvial processes. The processes have created an open-air museum of geological objects with 1700 springs, large boulders, bedrock and interglacial peat exposures, hanging gullies, high Quaternary bluffs and glaciokarst sinkholes that other rivers do not have. “Sprogu gravas” is one of nature monuments, also listed in World Database on Protected Areas, Site Code: 172696 (http://www.unep-wcmc.org/wdpa/sitedetails.cfm?siteid=172696&level=nat). “Sprogu gravas” is featured by intricate topography, where landslide–gully complexes are formed by combination of gullying, landsliding and seepage erosion processes.

3. Materials and methods

During field studies, the depth, width, length, channel gradient and sidewall slope gradient of landslide–gully complexes were measured by standard geomorphological methods. Width and depth were measured several times along each gully in order to determine maximum values. Sidewall slope gradients were determined with a clinometer (type Suunto, error 0.005 m m^{-1}). At the same time morphology of gully channels, forms of cross-profiles and longitudinal profiles, as well as the type and intensity of geological processes in gullies were assessed. Position of landslide-cirque gullies was mapped with GPS (Trimble GeoXT). Because of a dense canopy of broad-leaved forests common in gullies, errors remained (a maximum error up to several metres) even after the differential correction. The spatial analysis and calculating of gully density was made by GIS ArcMap 9.0. Finally, principal geomorphological, geological, and hydrological factors which have affected formation of these landslide–gully complexes were studied.

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4. Results and discussion

In total, 20 short landslide cirque gullies and 3 large permanent gullies were mapped and surveyed. Landslide cirque gullies typically have bottleneck shape with cirque-like or amphitheatre-shaped sub-circular depression at the gully head and v-shaped cross-profile at the gully outlet. A large number of small springs (discharge less 0.05 l s^{-1}) and sapping signs, which can be observed at the bottom of landslides scarp, usually form small streams. This indicates that these landslide–gully complexes were initiated by seepage erosion.

Landslide cirque gullies are short (15 to 90 m), the depths of the incisions vary from 0.8 to 2 m and gully catchments are relatively small, from 0.29 ha to 1.22 ha. Taking into account volume of eroded sediment, they can be compared with ephemeral gullies. However, from ephemeral gullies they differ by step-like thalweg and steep longitudinal profile (inclination up to 20º - 25º) (Fig. 2.).

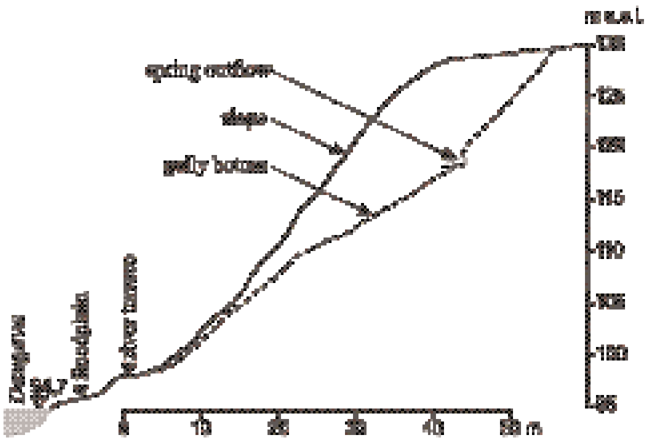

Fig. 5. Typical longitudinal profiles of landslide cirque gully.

In order to interpret the factors that led to their development, the Leopold and Maddock (1953) width–discharge relationship, extended on rills and gullies (1) (Nachtergaele et al., 2002; Torri et al., 2006) was applied:

$$W = 2.51\ Q^{0.412} \quad (1)$$

from which one gets:

$$Q = 0.1072\ W^{2.427} \quad (2)$$

Hence, it (2) let us to calculate discharge of spring outlets, which possibly forms these gullies. Calculation shows, that discharge have to be from 0.0058 $m^3\ s^{-1}$ (W = 0.3 m) to 0.0831 $m^3\ s^{-1}$ (W = 0.9 m). Comparison of data shows that calculated values is almost 2 orders as large as for the ones obtained by measurement of real spring discharges in-situ.

This fact can be explained by assumption, that gullies are not formed entirely by focussed groundwater seepage and spring outflow, but also by surface runoff concentrated in landslide cirques. On the other hand, channel gradient (>25 m m^{-1}), the effect of which in equations extended to rills and gullies (Nachtergaele et al., 2002; Torri et al., 2006) is considered negligible, obviously plays additional role in accelerated erosion in channels of landslide cirque gullies, despite the fact that these are similar to ephemeral gullies. Steep longitudinal profiles create favourable conditions for formation of micro-waterfalls due to collapse of colluvium in gully channel, which in turn invokes a variety of small scarp failures that intensify backward erosion.

5. Conclusions

The formation of bottleneck-shaped spring cirque gullies and landslide–gully complexes alongside the valley of river Daugava is determined mainly by the topographic indicators and geological structure. The latter is characterised by alternation of Pleistocene fine to medium glaciofluvial deposits covered by stony sandy clayey till. This type of lithostratigraphic sequence leads to an increase of erodibility and to the development of short gullies as the result of combination of the mass movement, surface run-off (incision process) and sub-surface run-off (seepage process).

Initiation of gully erosion in this case was determined by seepage and sapping, formation of landslides and up-slope development of spring cirques, which in their turn concentrate sub-surface run-off and lead to slumping.

In the river Daugava Valley, the most frequent cause of landslides is a change in groundwater conditions. This is caused by interference with natural drainage conditions after annual spring floods or by an increase in groundwater due to excessive rainfall. The presence of groundwater affects slope stability by increasing the effective weight of the saturated materials, creating appreciable pore pressure and tending to weaken soft Quaternary deposits and unconsolidated materials.

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References

Crosta, G., di Prisco, C., 1998. On slope instability induced by seepage erosion. *Canadian Geotechnical Journal 36*:1056– 1073.

Leopold, L.B., Maddock, T., 1953. The hydraulic geometry of stream channels and some physiographic implications. *U. S. Geological Survey Professional Paper 252*: 1–57.

Nature monument "Sprogu gravas" [Online, 12 February 2007], URL: http://www.unep-wcmc.org/wdpa/sitedetails.cfm?siteid=172696 &level=nat

Nachtergaele, J., Poesen, J., Sidorchuk, A., Torri, D., 2002. Prediction of concentrated flow width in ephemeral gully channels. *Hydrological Processes 16*:1935–1953.

Torri, D., Poesen, J., Borselli, L., Knapen A., 2006. Channel width–flow discharge relationships for rills and gullies. *Geomorphology 76*: 273-279.

Venska, V. 1982. Contemporary geological processes in the National Park "Gauja". In: *Contemporary exogenic geological processes and research methods*. LGU, Riga:139-159 (in russian).