RE-ACTIVATION OF EROSION PROCESSES IN PERMANENT GULLIES AS GEOMORPHIC RESPONSE TO EXTREME RAINFALL EVENT

J. Soms

Daugavpils University, Department of Geography, Daugavpils, Latvia
juris.soms@du.lv

Although many studies throughout the world have linked the triggering of gullying processes with changes of landscape and land cover resulting from human agricultural activities or with climate change induced seasonal variations in amount and intensity of precipitation, relatively few have focused on further development of gully channels, particularly in gullies presently found under forest. Such old gullies can be observed in many forests of northeastern Europe as well in Latvia, but the lack of obtained *in situ* scientific data does not allow seeking causal mechanisms of their current development and processes within these forms.

Despite the widespread opinion that vegetation cover controls erosion and increases slope stability within gully channels, occurrence of incisions and landslides in gullies under forest demonstrates possibility of the re-activation of geomorphic processes in such relatively stable fluvial forms. However, it is difficult to relate the development of channel incisions, sidewall erosion and mass failures directly to variations in land use and type of vegetation, most likely that obvious cause of these phenomenons is re-activation of erosion processes in permanent gullies as geomorphic response to extreme meteorological events, e.g. heavy rainfall or very intense snow melting.

Hence the geomorphological studies of changes in permanent gullies associated with re-activation of erosion let us (i) to understand better forcing-response mechanisms of small catchments to extreme events; (ii) to estimate the rates of sediment delivery intensification from gullies in response to climate change induced variations of precipitation amount and intensity; and (iii) to obtain knowledge about contemporary erosion events and their controlling factors as an important key to understanding the impacts of environmental change on the landscape.

In order to improve insights into these issues, the documentation of geomorphic response to extreme rainfall event in May 2005 has been carried out at that time by field study and morphometric measurements on channels affected by re-activation of erosion. Excessive precipitation that occurred in May 2005 caused sudden floods in many municipalities in Latgale region and was recognized as a local response to a particular episode of global climate change. At the same time this event triggered considerable re-activation of erosion and geomorphological changes in the permanent gullies within the river Daugava Valley, southeastern Latvia. These changes involved intensive channel incision, development of mass failures on gully sidewalls, colluvial sedimentation at gully outlets and substantial delivery of eroded material to the receiving river.

The specific objectives of the current study was (1) to obtain data *in situ* on distribution and morphometric characteristics of geomorphic features formed in gullies by re-activation of erosion, (2) to elucidate the meteorological and hydrological factors that led to their development, (3) to quantify the amount of material eroded during peak runoff, hence to estimate the environmental impact of runoff and erosion on water ecosystems.

Figure 1. Location of the study site

The study site (Figure 1) is located in the physiogeographic region - the Augsdaugava (Upper Daugava) Depression, which includes the River Daugava Valley, SE Latvia, and is defined by the geographic coordinates 55°54'33" N and 26°43'35" E. The Augsdaugava Depression crosses Baltic Morainic Ridge and separates the Latgale Upland from the Augszeme Upland, in the east it is connected with the Polatsk Lowland (Byelorussia). The main geomorphological element of the Augsdaugava Depression is the terraced valley of the River Daugava. Fluvial forms formed by gully erosion is widespread in this valley – more then 340 permanent gullies have been mapped within the valley stretch from Kraslava down to Naujene and total gully length per unit area in some places reaches 4.2 km km^{-2}.

The average difference in local topography is about 25 to 45 m. Geological structure is characterized by alternation of Pleistocene glacial till and glacifluvial deposits, in lower terraces covered by fine to medium alluvial sand and silt. The territory is characterized 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 studies of channel incision and mass failure processes associated to erosion re-activation in response to the extreme meteorological event in May 2005 were performed in one typical permanent gully under forest within the River Daugava Valley, i.e. Pescanij rucej.

During field studies the depth, width, length, channel gradient and sidewall slope gradient of gully were measured by standard geomorphological methods. At the same time the type and intensity of geological processes in gully were assessed. Width and depth of newly formed incisions, as well as width and height of landslide scarps were measured by fiberglass tape several times in order to obtain values for calculating volume of removed material. Surveying of longitudinal profile of the channel incisions in the Pescanij rucej gully was done by an Leica digital level Sprinter 100M and Leica high-precision GPS model GX 1230 GG.

Sieve analysis by U.S. standart testing sieves (ASTM Standard E11) was performed to determine granulometric composition of sediments loaded in gully outlet. To estimate threshold velocities of peak runoff which caused entrainment and transportation of gravel pebbles (>10 mm), Hjulstrom curve was applied.

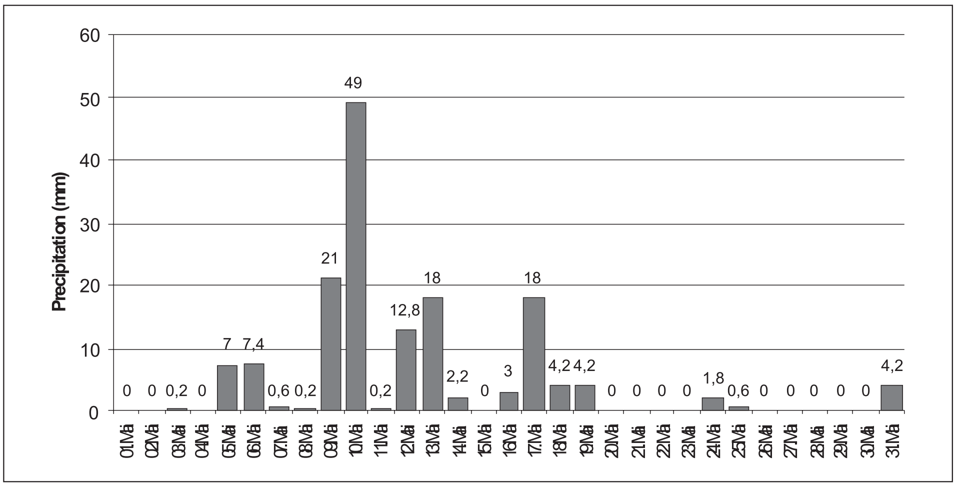

Figure 2. Precipitation sums in May 2005

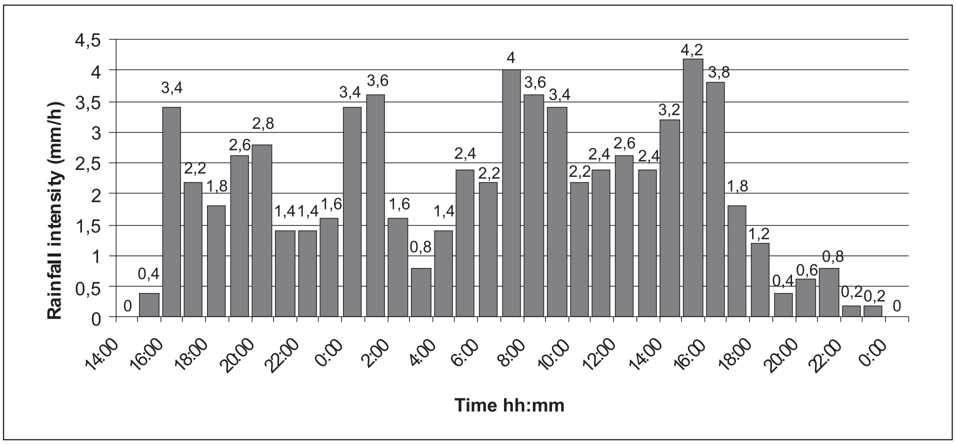

Figure 3. Intensity of rainfall, May 09.10.2005

In order to estimate the relationship between amount of precipitation and rainfall intensity on the one hand and formation of peak runoff in Pescanij rucej stream on the other hand, analyses of meteorological data registered by Vantage Pro 2 weather station was done.

Finally, principal meteorological and hydrological factors which have affected formation of these geomorphic features were studied.

Spring of 2005 was extraordinary from meteorological view point because climatic long-term mean values of precipitation and rainfall intensity were exceeded several times (Figure 2, 3), triggering floods in SE Latvia and re-activation of erosion processes in stream channels. Field studies of erosion rates and granulometric composition of sediments loaded in gully outlet allow to evaluate the mechanisms of threshold runoff generation and sediment production and to estimate the potential values of eroded material.

Obtained results show that in some days storm rainfall intensity (up to 4.2 mm h^{-1}) exceeds infiltration capacity 1.2 to 2 times and overrun threshold which triggers Horton overland flow. Taking into account that soil and top part of subsoil deposits became saturated by previous rainfalls, in addition saturation overland flow was produced too. Combination of these factors leads to quick transfer of precipitation from gully catchments to channels, concentration of waterstreams and saltatory increasing of bed and sidewall erosion.

Studies conducted *in situ* show that gully channel at Pescanij Rucej gully head and middle part due to erosion was deepened from 0.8 to 1.1 m, but at the gully outlet channel was filled with poorly sorted sediments (mainly consists of fine sand and silt) layer up to 0.7 m thickness. Total amount of material eroded just in this gully channel could be estimated as 175 to 200 m^3 or approximately from 280 to 320 t. Granulometric analysis of sediments demonstrate that dominant part of accumulated colluvium within gully channel is 0.5-2 mm fraction, however 10 – 12% of it consists of gravel, pebbles and even cobbles.

Analysis of granulometric data by Hjulström (1935) curve shows that presence of theses rather big particles (d > 50 mm) in deposited layers can be explained by threshold stream velocities near 8 m s^{-1}. Such high stream velocities could not develop in gully directly as the result of runoff, but due to natural damming of gully by landslides, when impounded pond water level rises and breaches the dam, hence triggering rapid release of the impounded water into gully channel and causing significant downcutting. Development of shallow landslides in response to excessive precipitation and meteorological extreme was caused by incision of gully channel and sidewall erosion process which leads to steepening of slopes and removing of foot of slope, hence increasing instability of sidewall and creating favorable conditions for mass failures. In addition, rainfall over extended periods with a moderate intensity causes a response in the forming of a landslide by increasing the effective weight of the saturated material, creating appreciable pore pressure and tending to weaken soft Quaternary deposits and unconsolidated materials.

Taking into consideration that total amount of precipitation in May 2005 was unusually high, it is concluded that similar events are likely to recur several times a century. However, modeling of global warming shows that climate change is likely to make extreme rainfall events more frequent in Baltic region. Such changes of climate factors and hydrological regime will relate to all elements of fluvial systems, therefore these changes certainly will trigger increasing of runoff and intensification of accelerated erosion by water in gullies. In its turn, the intensification of erosion caused by extreme rainfalls will re-arrange existing equilibrium of geomorphic erosion/accumulation processes, first of all, in small catchments of zero-order, and will increase sediment and nutrient transferring from adjacent territories to receiving streams. At the same time shortened return periods of extreme rainfalls and increasing amount and duration of precipitation in summer will intensify erosion and increase sediment load transfer through gully channels due to more frequent formation of peak discharge runoff. This tendency has negative effects on fluvial ecosystems through excessive siltation, increased turbidity and eutrophication of receiving river. Finally, it is obvious that geomorphic responses to extreme meteorological events need to be analyzed with a long-term perspective of climate change at local and regional scale.

Acknowledgements

Part of the work reported in this presentation was financially supported by the ESF grant from the project 2005/0135/VPD1/ESF/PIAA/04/APK/3.2.3.2/0032/0065 and the National research program KALME.