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Quantifying suspended sediment, solutes and nutrients supply from small gully catchments under different runoff formation scenarios: a case study in SE Latvia

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Small headwater catchments which are drained by gullies have been recognized throughout the world as important sources of sediment and chemical pollutants transported to large rivers. Such gully catchments constitute the upper part of the hydrographic network in upland areas of northeastern Europe as well as Latvia, and therefore play an important role in the sediment flux processes from source to sink. Despite that, only some studies in Latvia have reported quantitative analysis of sediment and nutrient transfer from headwater catchments to the recipient water bodies. In turn, the lack of available scientific data does not allow to evaluate the impact of climate change on source-to-sink flux on the local scale.

In order to generate further insight into these issues, the studies were conducted in the period 2008 to 2009, during which time suspended sediment (*SS*), solutes (total dissolved solids or *TDS*) and nutrients (*N-tot* and *P-tot*) concentrations and their load from small headwater catchments located in the Daugava River Valley (southeastern Latvia) were examined during five different episodic runoff events, i.e. (1) runoff resulting from rain estimated as daily mean in autumn; (2) runoff resulting from the ordinary snowmelt in spring; (3) runoff resulting from an extreme snowmelt in spring; (4) runoff resulting from rain-on-snow event in winter and (5) runoff resulting from groundwater drainage in summer. Five closely located gully catchments were selected to estimate the relationship between amount of delivered *SS*, *TDS* and nutrients, on the one hand, and weather conditions which result in the formation of runoff in the gullies, on the other.

Considering that gully catchments under study are not gauged, discharges were measured directly during runoff events and data on suspended sediment concentration (C_{SS}) and *TDS* concentration (C_{TDS}) at the gully outlets were obtained. An average *SS* quantity discharged during a runoff event was calculated as a suspended sediment load (Q_{SS}; kg s^{-1}), which is the product of C_{SS} and gully stream discharge (Q). In order to get comparable values of Q_{SS} from gully catchments which differ in size, an area-specific daily Q_{SS} (kg ha^{-1} day^{-1}) was derived. Simultaneously with the estimation of Q_{SS}, data was collected about nutrients concentration, i.e. nitrate-N (C_{N-NO3}), total-N (C_{N-tot}), phosphate-P (C_{P-PO4}), total-P (C_{P-tot}). The data on solutes and nutrients load and area specific load from gully catchments was estimated in the way same as in case of Q_{SS}.

The obtained results indicate that the mean daily Q_{SS} from gully catchments under study varies from 43 to 585 kg day^{-1}, shortly reaching up to 8,000 kg day^{-1} during extreme runoff. The values of Q_{TDS} vary from 4.64 to 1,080 kg day^{-1}, the lowest values of it, similar to Q_{SS}, were measured during the groundwater drainage phase in summer. The calculated nutrient load yields the delivery of 0.03 to 1.2 kg day^{-1} of *N-tot* and 0.001 to 0.53 kg day^{-1} of *P-tot* by temporary gully streams to the Daugava, whereas an extreme runoff can shortly generate the loads up to 9.84 kg day^{-1} of *N-tot* and 6.74 kg day^{-1} of *P-tot*. Fluctuations of *SS*, *TDS* and nutrient output depend on runoff formation weather conditions, the highest measured values correspond to the runoff during snowmelt in spring, the lowest – during the dry season in summer. However, maximal supplies are very responsive to extreme runoff events, which occur over short time spans due to a small size of gully catchments and quick transfer of water, leading to a strong underestimation of loads when using statistical methods based on the mean monthly concentration. It is also necessary to specify that presence of boulders in gully bed plays an important role in additional mobilization of sediments due to formation of very turbulent flow, triggering the bank erosion and slumping of the gully walls.