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Cycles of gully incision and infill in agricultural landscapes of Central European Russia: natural and anthropogenic factors

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Gullies are traditionally considered as one of the most active landforms in agricultural areas. In many places gully erosion leads to massive loss of fertile soil, decline of areas available for cultivation and a number of other land use complications. In addition, gullies in many cases act as the most effective runoff and sediment routing pathways, promoting better connectivity and increasing sediment delivery from cultivated hillslopes into fluvial network. Hence, gully network development may also cause significant detrimental off-site effects, including small river degradation, reservoir siltation, particle-bound pollutants concentration, etc. On the other hand, this process is often not progressive and unidirectional, but rather includes cycles of incision and head retreat alternating with infill periods. Understanding this dynamics and knowing its control factors may help to predict the future process trends for different climate and land use change scenarios, save fragile soil and water resources and design sustainable agricultural activity in changing environment.

We analyzed five different small river basins in Central European Russia to investigate the cycles of gully growth and infill. The main approach was to acquire gully network structure from topographic maps or by manual visual interpretation of satellite images. A set of topographic maps was used to map the spatial structure of gullies over the case study areas for several time intervals from mid XIX century to the end of XX century. In addition, recent satellite images were used to investigate the up-to-date (2018-2019) gully network structure and distinguish its possible latest changes related to climate or land use changes.

It is common to consider agriculture as the main factor of gully erosion activation in this area. We found that land use changes over the last 150 years lead not only to erosion rates shifts, but to incision and infill cycles. Besides, morphometric parameters of individual gullies, spatial patterns of gully network and gully density within different catchments strongly depend on local topography. Particularly important controls are topographic ranges, long profile and planform shapes of catchment slopes. Recent studies also showed that planform structure of upper parts of gully network (especially small tributary gullies of larger gully systems), as well as smooth slope depressions and periodically formed ephemeral gullies on cultivated hillslopes are in many cases strongly related to relic cryogenic features (RCF) of the Late Pleistocene cold stages. Evidence of partly infilled gullies incised into the RCFs such as ice or ice-ground wedge pseudomorphs are

widely observed both on satellite and airborne images and in natural (undercut gully or small valley banks) or anthropogenic (quarries) exposures.

Interaction of climatic impact, intrinsic gully headcut retreat threshold and recent land use changes determine modern gully network conditions. The main presently observed tendency is stabilization or gradual infill of most of the small- and medium-sized gullies by sediments transported by sheet wash, rill and ephemeral gully erosion from arable fields. At the same time, small discontinuous bottom gullies are developed in larger gully systems.

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