Relic cryogenic features on cultivated interfluves and their impact on modern soil redistribution and gully erosion processes (Western European Russia)

Vladimir Belyaev[1], Katerina Garankina[1], Artem Gurinov[1], Nikolay Lugovoy[1], Alexandra Lisova[1], Anna Semochkina[1], Ilya Shorkunov[2], Irina Streletskaya[1], Elena Sheremetskaya[1], Sergey Kharchenko[1]
[1]Lomonosov Moscow State University, Moscow, Russian Federation. [2]Institute of Geography, Russian Academy of Sciences, Moscow, Russian Federation

Abstract

Widespread relic cryogenic features (RCF) in topography and soil structure beyond the present permafrost southern limits are observed in many areas of Europe (Pewe, 1966; Kolstrup, 1986; Jetchik and Allard, 1990; Bertran et al., 2014). It is generally accepted that most of those were formed under the most severe conditions of the last stage of the Late Pleistocene glaciation (Vandenberghe et al., 2014; Andrieux et al., 2016). Recent progress in studies of the RCF has been largely achieved due to latest development of the remote sensing (RS) techniques and especially increasing availability of high-resolution satellite imagery. By present time, morphological classification of RCF has been proposed (Velichko, 2015; Andrieux et al., 2016) and specifics of their zonal distribution more or less established for the Eastern European Plain (Velichko, 1982, 2015). Significant progress has also been achieved in investigations of role of RCF in structure of modern soils (Duchaufour, 1951; Makeev, 2009; Alifanov, 2010, Sycheva, 2012). Several problems still lacking detailed scientific considerations, namely relationships between different types of RCF and modern hillslope processes, soil degradation, sediment export from cultivated slopes into fluvial network.

The research reported here is concentrated on evaluating relationships between different types of the RCF and morphological and geochemical differentiation of soils, intensity and spatial distribution of soil erosion and deposition processes on cultivated slopes. Approaches employed include analysis of the RS data, application of several independent techniques for quantitative assessment of soil redistribution on cultivated slopes and in small catchments, geodetic DGPS surveys, airborne photo by unmanned aerial vehicles (UAV), morphological and geochemical investigation of soil properties and georadar surveys. Several case study sites with various combinations of relic cryogenic feature types, zonal soil types, morphological and morphometric characteristics of cultivated slopes, density and structure of stream network have been selected basing on examination of the RS data and reconnaissance field surveys. Two case study sites located in the Yaroslavl and Kursk Regions respectively have already been studied in more details. Detailed satellite images interpretation allowed distinguishing several types of RCF spatial patterns (similar to determined by Andrieux et al., 2016) including regular and irregular (by size and shape) polygonal networks with rounded outlines due to thermokarstic degradation of the wedges, striped grounds, transition zones between polygons and stripes and individual thermokarstic depressions. Ground control in combination with DGPS survey and detailed UAV photography allowed additional determination of RCFs prominent in the present-day microtopography or only in topsoil and vegetation color. It has been found that for the case study sites microtopographically-prominent RCF exert important influence on spatial pattern of overland flow, especially runoff concentration, and, therefore, on sediment redistribution within cultivated hillslopes. Present gully network also partly inherits downslope parts of polygonal or striped RCFs.