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The use of UAV-derived ultrahigh resolution data for the assessment of semiarid badland exposure to hazardous geomorphological processes: case of the Eastern Caucasus foothills

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Specific features of current semiarid landscape along the Eastern Caucasus foothills (so-called Dagestan extra-mountain region) are badlands formed on loess and clay deposits. The active piping, erosional and gravitational processes present a direct hazard for extensive grazing activities and infrastructure facilities accommodated here. The badlands topography is complicated with the abundance of diverse pseudokarst forms such as blind valleys, caverns, different sized and shaped sinkholes. Such typical patterns as chains of elongated sinkholes, marking the direction of underground flow along the bottoms of erosional forms, are rather distinguishable on satellite imagery with submeter spatial resolution. However, the real density and morphometric analysis of surface pseudokarst forms can be well mapped and analyzed only by means of remote sensing data with ultrahigh spatial and vertical resolution (about several decimeters). For the area in study we used UAV-derived data from 100 m altitude of survey to produced Digital Terrain Model (DTM) with resolution of 20 cm. The automatic extraction of DTM's for semiarid badland with sparse desert steppe vegetation was rather simple but there is obvious limitations of using UAV data for morphometric analysis of the badland were manifested in the formation of the so-called "dead zones" in case of the large and deep sinkholes. For a complete three-dimensional reconstruction of the badland topography, the terrestrial laser scanning data were additionally involved.

As a result of the analysis of the DTM with very high resolution, derived highly-detailed morphometric and hydrological models were built, reflecting the complex structure and genesis of the badland topography. Automatic identification and mapping of sinkholes reveal the prevalence of large sinkholes with a diameter of 5-15 m and a depth of 1-3 m along the erosional valleys for the study area. Along the slopes more smaller sinkholes forms (up to 0.3 m in diameter and up to 1 m in depth) were identified, the complex network of gullies and micro-terraces pattern were clearly reconstructed. Identification and mapping of sites with high susceptibility to current processes of different genesis was done: in particular, the identified closed catchment micro-basins are areas of predominance of piping processes, while the escarpments in the upper parts of the steep slopes of the badlands are most affected by erosional processes with formation of micro-gullies.

Under regular monitoring of piping, erosional and gravitational processes remodeling the badland topography, it is necessary to carry out multitemporal UAV surveys at low altitudes along with terrestrial laser scanning data. Such complex approach will make it possible to identify more reliably the current ratio of surface and groundwater runoff, and to early allocate and warn the hazardous geomorphological processes.