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3-D reconstruction of the retention volume of a montane reservoir using UAV photogrammetry, aerial LiDAR and field survey

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The small reservoirs in the European montane landscape, which were built in past centuries for various purposes, represent specific cultural and technical heritage but also object with potential for mitigating the emerging impacts of climate change, namely, the course of flooding or droughts. However, the frequent lack of technical data on these historical structures, including their storage volume and flooded areas, prevents their consideration in water management.

We have used unmanned aerial vehicles (UAVs) to perform a detailed 3-D reconstruction of the abandoned montane reservoir of Rokytka, located in Sumava Mountains, Czech Republic, Europe. The reservoir of an area of 2,6 ha and a mean depth of 3 meters was built in a montane peatland area for timber flowing in the beginning of 19th century and since 1950′s is not in operation but has preserved dike structure.

The UAV imaging was done by the DJI Inspire 1 Pro platform, equipped with the Zenmuse X5 camera at flying altitude of 90 meters. The photogrammetric reconstruction of 492 source images resulted in the 3-D model of the reservoir basin with a spatial resolution of 2 cm per pixel. The reliability of the UAV-based model was tested by comparing the results with the elevation models derived from geodetic field survey using a total station and from conventional elevation data from the recent aerial LiDAR scanning. Based on these data sources the bathymetric models were constructed to calculate the reservoir volume and flooded areas for different water levels, corresponding to recent and design flood levels. The results were compared to the historical estimates of the reservoir parameters found in the literature.

Bathymetric reconstruction of the reservoir properties based on high-resolution UAV data revealed significant underestimation of the reservoir storage volume in the assessments based on aerial LiDAR data or in historical estimates. The actual full reservoir capacity of 54 thousand m3, calculated from the UAV-based model significantly overpasses the volume estimates, commonly considered for the water management purposes until present.

The key contribution of the UAV-based imagery is mostly the ability to reliably reconstruct the fine structures in the shallow reservoir basin from the ultra-high resolution 3D model. In the conditions of flat topography, the inaccuracies, resulting from generalizations, stemming either from the use of the conventional elevation data from the aerial LiDAR scanning or from the field surveying, may lead to the large underestimations of the structure volume, especially at low levels of flooding.

The study results have demonstrated the high potential of the UAV technology as a rapid and reliable survey tool, able to increase the quality of information on historical landscape structures, that are applicable for mitigation of hydrological extremes in montane areas.