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The application of land morphology and lithology information optimizes remote sensing badland mapping using Landsat 8 and Sentinel 2 imagery in a heterogeneous regional setting, the upper Llobregat basin (Catalan Pyrenees)

Mariano Moreno de las Heras and Francesc Gallart

Surface Hydrology and Erosion group, Institute of Environmental Assessment and Water Research (IDAEA), Spanish Research Council (CSIC), Jordi Girona 18, 08034 Barcelona, Spain

Badlands are highly erosive landforms carved in soft bedrock (e.g. mudstones, marls and shales) with little or no vegetation. Despite representing, in general, minor catchment fractions, badlands can contribute much of the total sediment transported within the river networks, largely affecting channel and floodplain dynamics, as well as freshwater ecosystems. Basin management in areas affected by these erosion hotspots requires accurate badland identification and mapping on the broad regional scale. Supervised classification of land features using remotely sensed imagery can provide satisfactory results for screening and quantitative analysis of barely covered, eroded areas. However, badland detection applying remote-sensing classification can be affected by the low separability of their spectral signatures in heterogeneous landscapes. We tested the accuracy of badland identification using remote sensing spectral information (from Landsat 8 OLI and Sentinel 2 instruments) and complimentary land morphology and bedrock lithology data over the upper Llobregat basin (Catalan Pyrenees, NE Spain), a 500 km2 mountain region spotted by (less than 1% of the terrain) mudstone and marly badlands. Maximum likelihood (supervised) classification of badlands using Sentinel 2 spectral information (10 bands, 10-20 m resolution) improved the results obtained by applying Landsat 8 OLI imagery (7 bands, 15-30 m resolution). The use of spectral information alone, however, resulted in poor results due to the low signature separation for badlands and other barely covered areas. The use of complimentary information on landscape morphology (i.e. slope gradient and surface roughness maps derived from a 2-m LiDAR digital elevation model) increased the separability of badlands, riverbeds and degraded areas without badland morphology, while the use of lithology masks derived from digital information of the regional geological setting optimized the discrimination of badlands and hard rock outcrops, maximizing the efficiency of the classifications. Overall, our results stressed the application of combined remote sensing imagery with auxiliary land morphology and lithology information for accurate detection of badlands in regional settings with heterogeneous land features.