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Semi-automated detection of gully slivers from a Digital Surface Model in rough agricultural terrain

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Gully erosion is regarded as one of the worst land degradation processes in the world. Rapid identification of the location of gully features is urgently required, to aid in recognizing regions where gully erosion is prominent. Manual digitizing of gully features is both time consuming and prone to bias. Generating semi-automated or automated workflows to detect gully erosion allows quick and unbiased mapping of gully features over large extents.

In the Sandspruit catchment, South Africa, contour banks with a combined length of approximately 25000km have been constructed to mitigate soil erosion. Gullies are now mostly confined to narrow slivers in the natural vegetation, fynbos and Renosterveld, between agricultural fields. The morphological similarity and proximity of contour banks and gullies in this region provides a good test site to evaluate whether a semi-automated detection workflow could map gullies in complex, rough agricultural terrain.

Here, a Digital Surface Model (DSM) with a spatial resolution of 2m was used to test a semi-automated detection workflow in a Geographical Information System (GIS) environment. Two main building blocks were generated from the DSM: 1) a normalized DSM, created by subtracting a convolved mean DSM with a designated filter size from the original DSM, and 2) local slope generated from the normalized DSM. Subsequently, using expert knowledge, mapped gully polygons were refined and smoothed, by threshold determination, masking features not related to drainage, and pixel-based growing and shrinking. The semi-automated workflow was completed for two different spatial resolutions: 1) the native 2m-resolution and 2) a 0.5m-resolution DSM, upsampled without producing artificial values from interpolation methods. A GeoEye-1 image with a spatial resolution of 0.5m was included at the backend of the workflow as an additional step, to test whether gully mapping from using terrain attributes only, could be improved upon.

Gully detection from terrain attributes only, achieved an overall accuracy of 0.68 (0.5m DSM) and 0.74 (2m DSM) with kappa values ranging from 0.36 (0.5m DSM) and 0.35 (2m DSM). The upsampled 0.5m DSM performed worse than the native 2m DSM due to increased noise detection. Although reasonable performance was obtained from the 2m DSM, issues encountered include: 1) vegetation that caused some inaccuracies in gully boundary delineation and discontinuities along gully channels and 2) false positive detection of contour banks. The addition of the GeoEye-1 image increased overall accuracy to 0.79 and kappa value to 0.5, mostly because of the elimination of false positives in agricultural fields.

The accuracy statistics indicate that the semi-automated detection workflow developed here shows promise as a tool to detect gully erosion on a catchment scale. Furthermore, due to the workflow being built upon the distinct morphology of gully features, it could be transferable to other regions that are dissimilar to the Sandspruit catchment. The transferability of the workflow should be tested in future, in addition to how accuracy would be affected if the DSM were substituted with a Digital Terrain Model (DTM) of similar spatial resolution.