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Identifying soil degradation in Swiss alpine grasslands using different machine learning approaches

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Soil erosion occurs on alpine grasslands due to the extreme prevailing topography, climate conditions and/or land use and management. Aside from geological, morphological and anthropogenic factors making certain regions more susceptible, soil erosion is also triggered by prolonged precipitation events, snow gliding and avalanches. Climate change is predicted to have a pronounced impact on these triggering factors in the alpine region. Together with changing land-use practices, increased soil erosion rates are expected. As such, mapping different soil erosion features in space and time is very crucial.

To better understand the spatial and temporal developments of soil degradation we use high-resolution aerial images taken between 2000 and 2016 to identify eroded areas in the Urseren Valley (Canton Uri, Swiss Central Alps). We compare the results of object-based image analysis (OBIA) to the results of deep learning algorithms.

OBIA is a state of the art, semi-automatic method commonly applied in the field of geoscience when mapping visible elements on remotely sensed images. The semi- automated workflow profits from the high spatial resolution of the orthophotos (0.5 - 0.25m) and takes into account spectral, spatial, contextual and textural image properties as well as accompanying information gained from digital elevation models. However, the method is labor intensive and, because manual corrections are required, might be biased. Expert knowledge is therefore a necessity at every working step to produce quality results.

For the deep learning approach we use convolutional neural networks (CNN) with the ResNet-152 architecture as well as fully-convolutional networks with the U-Net architecture. The algorithms are trained on a dataset consisting of manually mapped erosion sites. CNN achieves good results for object recognition tasks and can be used to identify the relevant properties or features to distinguish eroded sites from other areas. Leveraging the aforementioned resources, the manual labor and required expert knowledge in identifying eroded sites can be reduced.

OBIA yields results with very precise boundary delimitations of the eroded sites. CNN results are not quite as precise, however the method is capable of producing probabilities for every pixel. Probability thresholds can be set to higher or lower confidence levels, depending on the application needs. The quicker production time can be used for larger scale assessments (e.g. alpine-wide analysis).

By analysing a time series consisting of several images, we can identify growing and recovering erosion sites. For the entire valley, we confirm an increasing trend in eroded areas between 2000 and 2016. Spatial analysis reveals a high dynamic within the catchment, highlighting areas especially prone to erosion.