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Visual Understanding in Semantic Segmentation of Soil Erosion Sites in Swiss Alpine Grasslands

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Understanding the occurrence of soil erosion phenomena is of vital importance for ecology and agriculture, especially under changing climate conditions. In Alpine grasslands, susceptibility to soil erosion is predominately due to the prevailing geological, morphological and climate conditions but is also affected by anthropogenic aspects such as agricultural land use. Climate change is expected to have a relevant impact on the driving factors of soil erosion like strong precipitation events and altered snow dynamics. In order to assess spatial and temporal changes of soil erosion phenomena and investigate possible reasons for their occurrence, large-scale methods to identify different soil erosion sites and quantify their extent are desirable.

In the field of remote sensing, one such semi-automatic method for (semantic) image segmentation is Object-based Image Analysis (OBIA), which makes use of spectral and spatial properties of image objects. In a recent study (Zweifel et al.), we successfully employed OBIA on high-resolution orthoimages (RGB spectral bands, 0.25 to 0.5 m pixel resolution) and derivatives of digital elevation models (DEM) of a study site in the Swiss Alps (Urseren Valley). The method provides high-quality segmentation results and an increasing trend of total area affected by soil erosion (+156 +/- 18%) is shown over a period from 2000 to 2016. However, using OBIA requires expert knowledge, manual adjustments, and is time-intensive in order to achieve satisfying segmentation results. In addition, the parameter settings of the method cannot be easily transferred from one image to another.

To allow for large-scale semantic segmentation of erosion sites, we make use of fully convolutional neural networks (CNNs). In recent years, CNNs proved to be very performant tools for a variety of image recognition tasks. While training CNNs might be more time demanding, predicting segmentations for new images and previously unseen regions is usually fast. For this study, we train a U-Net with high-quality segmentation masks provided by OBIA and DEM derivatives. The U-Net segmentation results are not only in good agreement with the OBIA results, but also a similar trend for the increase of total area affected by soil erosion is observed.

In order to have a natural understanding of what in the input is “relevant” for the segmentation result, we make use of methods which highlight different regions of the input image, thereby

providing a visually interpretable result. We use different approaches to identify these relevant regions which are based on perturbation of the input image and relevance propagation of the output signal to the input image. While the former approach identifies the relevant regions by modifying the input image and considering the changes in the output, the latter approach tracks the dominant signal from the segmentation output back to the input image, highlighting the relevant regions. Although both approaches attempt to attain the same goal, differences in the relevant regions of the input images for the segmentation results can be observed.

Zweifel, L., Meusburger, K., and Alewell, C. Spatio-temporal pattern of soil degradation in a Swiss Alpine grassland catchment. Remote Sensing of Environment, 235, 2019.