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A deep-learning approach for multi-temporal savannah woody vegetation density assessment with Earth Observation data

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Bush encroachment in African savannahs has been identified as a land degradation process, mainly due to the detrimental effect it has on small pastoralist communities. Mapping and monitoring the extent covered by the woody component in savannahs has therefore become the focus of recent remote sensing-based studies. This is mainly due to the large spatial scale that the process of woody vegetation encroachment is related with and the fact that appropriate remote sensing data are now available free of charge. However, due to the nature of savannahs and the mixture of land cover types that commonly make up the signal of a single pixel, simply mapping the presence/absence of woody vegetation is somewhat limiting: it is more important to know whether an area is undergoing an increase in woody cover, ever if it is not the dominant cover type. More recent efforts have, therefore, focused in mapping the fraction of woody vegetation, which, clearly, is much more challenging. This paper proposes a methodological framework for mapping savannah woody vegetation and monitoring its evolution though time, based on very high-resolution data and multi-temporal medium-scale satellite imagery. We tested our approach in a South African savannah region, the Northwest Province (>100,000 km2), 0.5m-pixel aerial photographs for sampling and validation and Landsat data. We first mapped presence/absence of woody vegetation using samples selected over 5x5 km aerial photo subsets acquired between 2009 and 2013 and a Random Forest classifier. We then used these estimates to train a U-Net Convolutional Neural Network to produce fractional woody cover estimates from a series of spatio-temporal variability metrics derived from all available Landsat data in the five years between 2009 and 2013. The model was then applied to other epochs of Landsat metrics, centred around 2016, 2006, 2001, 1998, 1993, and 1988. The multi-temporal fractional woody cover maps were also used to derive estimates of fractional woody cover change over the three decades of the study period. We identified areas that had undergone a constant increase in woody cover density through the 6 epochs, and others that saw a net increase in woody cover density from 1988 to 2018. These hotspots of woody cover densification, or encroachment, that our methodology was able to identify, should be the ones that mitigation measures are directed to, in order to prioritise action and limit the extent and damage caused by this form of savannah land degradation.