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Sentinel-2-based fractional cover time series reveal drought impacts on Central European grasslands

Droughts had severe impacts on Central European grassland ecosystems in the last years. Sentinel-2 time series offer great potential for intra-annual monitoring of grasslands during such drought conditions with increased spatial and temporal resolution. NDVI time series have been demonstrated to be well suited to monitor grassland dynamics during drought (Reinermann et al., 2019) and to derive proxies for agricultural management across large areas (Griffiths et al., 2020). However, the interpretation of vegetation index-based times series is limited to a broad measure of greenness in a dimensionless unit. Time series representing percent cover estimates of photosynthetic vegetation (PV), non-photosynthetic vegetation (NPV) and soil provide a more comprehensive picture of grassland dynamics in interpretable quantitative units. Yet, the value of such fractional cover time series at annual or seasonal intervals have only been demonstrated for analyzing degradation processes or grazing pressure in natural grasslands systems (e.g. Guerschman et al., 2009). In this study, we therefore quantified drought effects for grasslands in northeastern Germany based on a fractional cover time series that was derived through unmixing of all available Sentinel-2 data from 2017 to 2019. The Sentinel-2 data were pre-processed using the open-source Framework for Operational Radiometric Correction for Environmental monitoring (FORCE; Frantz, 2019). Unmixing was based on regression modeling, i.e., we then trained an ensemble of Support Vector Regression (SVR) models with synthetically mixed spectral signatures (Okujeni et al., 2017) of PV, NPV and soil. By applying the SVR models to each available Sentinel-2 acquisition, we obtained intra-annual time series of PV, NPV and soil fractional cover from 2017 to 2019. Our results showed that PV cover was estimated with the highest accuracy (MAE = 7%) while agreement to the reference was slightly lower for soil and NPV cover (MAE = 10.1% and MAE = 15.6%, respectively). From the fractional cover time series, we calculated the Normalized Difference Fraction Index (NDFI), which contrasts NPV and soil relative to PV fractional cover. Confirmed by meteorological (SPI03, SPEI03) and soil moisture (SMI) drought indices, the NDFI tracked different drought severities in 2018 and 2019 very well. Investigating the beginning, duration, impact, and end of drought effects, we found a high spatial variability of these metrics related to land management and site-specific growing conditions. Combining the NDFI drought metrics with a soil type map revealed e.g. a higher drought resistance of grasslands on Gleysols and Histosols compared to grasslands on less productive, sandy Cambisols. Our study confirms that the high spatial and temporal resolution of Sentinel-2-based fractional cover time series enables a detailed understanding of grassland vegetation dynamics during drought conditions.

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