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Monitoring Mediterranean grass phenology from digital terrestrial camera and Sentinel-2 vegetation indices in an oak-grass savanna ecosystem

Maria P. González-Dugo¹, **Pedro J. Gómez-Giraldez**¹, María J. Pérez-Palazón², and María J. Polo²

¹IFAPA, Institute of Agricultural and Fisheries Research, Córdoba, Spain (mariap.gonzalez.d@juntadeandalucia.es)

²Andalusian Institute for Earth System Research, University of Cordoba, Córdoba, Spain

Annual grasslands are an essential component of Mediterranean oak savannas, the most extensive agroforestry system in Europe, as the primary source of fodder for livestock and wildlife. Monitoring its phenology is key to adequately assess the impacts of global warming on different time scales and identify pre-critical states in the framework of early warning decision making systems. The natural variability of the climatic-hydrological regime in these areas and the usually complex spatial patterns of the vegetation, with sparse distribution and multiple layers, encourage the exploitation of available data from remote sensing sources. This work presents an assessment of vegetation indexes (VI) from Sentinel-2 validated against field data from terrestrial photography in an oak-grass system in southern Spain as a multi-approach method to monitor phenology in grass pastures. The analysis also has provided an insight into the links of the phenology dynamics with hydrological variables under these conditions.

From December 2017 to May 2019 a quantitative value of grassland greenness was computed using the Green Chromatic Coordinate (GCC) index. The phenological parameters of the start of the season (SOS), the peak of the season (POS) and end of the season (EOS) were extracted using the 50% amplitude method and confirmed using field photography. These values were compared with those provided by eight VI's derived from Sentinel-2 (NDVI, GNDVI, SAVI, EVI, EVI2, MTCI, IRECI and S2REP) and the difference in days between the key phenological dates were estimated. The results showed that for annual grasslands NDVI was the index providing estimations closest to those of ground GCC, with differences below 10 days for all phenological dates and the best correlation with GCC values ($r = 0.83$, $p < 0.001$). None of the VIs using bands in the red-edge region have improved the NDVI results. Two of them, MTCI and S2REP, followed a different trend than the rest of explored indices, presenting a high temporal variability. The high diversity of species, typical of Mediterranean grasslands, might explain the high variability observed in these values. However, the third index using red-edge bands, IRECI, presented a high correlation with GCC. In this case, the index was designed to focus on the chlorophyll content of the canopy instead of the leaf scale addressed by S2REP. The influence of the vegetation ground coverage and foliage density is then higher and more similar to the broad-band indices. GNDVI also provided good general results. Soil moisture (SM) time-series were also used to estimate phenology and have presented a good agreement with GCC in SOS and EOS estimations, with SM reaching threshold

values a few days before greenness ones, as measured by GCC. However, SM was not a good indicator of the POS, presenting significant biases with respect to GCC estimations.