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Integrating Multi-Sensor and Multi-Platform Technologies for Enhanced Assessment of Spectral Indices and Phenological Dynamics in a Seasonal Tropical Dry Forest

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The Seasonal Tropical Dry Forest (STDF) known as Caatinga occupies approx. 10% of the Brazilian territory. Its vegetation exhibits rapid phenological responses to rainfall resulting in corresponding increases in gross primary productivity and biomass production. Determining the timing of the start and end of the growing season is very important to ecosystem studies and to precisely quantify the carbon balance. Satellite-derived vegetation indices have been widely used to capture the vegetation dynamics in response to fluctuating environmental conditions. However, the spatial and temporal resolution of these indices cannot capture fine vegetation features and phenology metrics in a highly biodiverse and heterogeneous environment such as the Caatinga. On the other hand, phenocameras have been successfully used for this particular purpose for tropical and dry ecosystems. Complementarily, proximal spectral response sensors (SRS) have been used to allow computation of vegetation indices as phenology proxies. Due to their ability to capture high spatial resolution imagery, Unmanned Aerial Systems (UAS) or drones, can deliver an excellent spatial and a very good temporal resolution for diverse detailed vegetation studies. In this context, the objective of this study was to verify whether multi-sensor and multi-platform technologies provide an enhanced assessment of spectral indices and phenological dynamics of the Caatinga. The field campaign occurred in a pristine area of caatinga vegetation, located at the Legal Reserve of Caatinga, Embrapa Semi-Arid, Petrolina, Brazil. Indices for detecting phenology dynamics were obtained using multi-spectral cameras installed on unmanned aerial vehicles (UAV), field spectral response sensors (SRS), phenocameras (digital RGB cameras) and MODIS satellite data (visible and near infrared) from 2020 to 2023. Environmental driving data were measured via instrumentation

installed on a flux tower. Standard statistical measures, including correlation coefficients were employed to verify the relationship observed on Normalized Difference Vegetation Index (NDVI), Photochemical Reflectance Index (PRI), and Green Chromatic Coordinate (Gcc) determined by different sensors and platforms. We observed a substantial and fast increase in Gcc, NDVI and PRI immediately after rainfall events. The sensitivity of NDVI and PRI to changes in vegetation can vary depending on factors such as vegetation greenness, overall plant health, and stress responses according to the environmental conditions of the study area. Particularly during the dry season, indices derived from higher spatial resolution sensors consistently showed lower NDVI values compared to those obtained from proximal spectral response sensors (SRS) and drones. Our observations indicate that the representation of vegetation captured by satellites and drones aligns well with the data obtained from phenocamera and proximal SRS platforms. The combination of high temporal resolution provided by SRS and phenocameras resulted in improved and more reliable indices that will be indispensable for evaluating the response of Caatinga vegetation to current and future conditions.

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