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Drone-acquired structure-from-motion photogrammetry for high-precision measurements of biomass in semi-arid rangelands

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Covering 40% of the terrestrial surface, dryland ecosystems have a distinct vegetation structure that is strongly linked to their function. Recent global modelling studies have indicated interannual variations in semiarid ecosystem biomass accounts for ca. 40%-60% of interannual variations in atmospheric carbon dioxide concentrations. Empirical evidence is needed to validate these model predictions; however, existing survey approaches cannot provide sufficiently precise data at landscape-scale extents to quantify this structure appropriately. Using a small unpiloted aerial system (UAS) to acquire aerial photographs and processing using structure-from-motion (SfM) photogrammetry, three dimensional models were produced quantifying the vegetation structure of semi-arid ecosystems at seven areas of interest (AOI). This approach yielded ultrafine (<1 cm2) spatial resolution canopy height models over landscape-scales (10 ha), which resolved individual grass tussocks just a few cm3 in volume. Canopy height cumulative distributions for each AOI illustrated ecologically-significant differences in ecosystem structure over a grass- to shrub-dominated vegetation transition. Strong coefficients of determination (r2 >0.64) supported prediction of aboveground biomass from canopy volume. Canopy volumes, modelled biomass and carbon stocks were sensitive to spatial changes in vegetation community structure. We demonstrate the use of an inexpensive UAS and SfM photogrammetry to produce ultrafine-scale biophysical data products. The high-precision of this approach affords sensitivity to subtle differences in the biotic structure (and therefore function) of heterogeneous ecosystems subject to rapid environmental change, and has exciting potential to revolutionise the study of spatial ecology in ecosystems with either spatially or temporally discontinuous canopy cover.