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Spectral mixture analysis to quantity winter wheat (Triticum aestivum L.) damage caused by hailstorms

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Extreme weather events such as hailstorms represent a threat to crops, causing both economic and food supply losses. Hailstorm intensity is likely to increase in the future pushing more farmers to purchase crop insurances to prevent related economic losses. Currently, insurers mostly rely on field inspectors for crop damage assessments, which can build up limitations such as: (i) partial subjectivity in damage estimations; (ii) inaccuracies in wide-area assessments; (iii) difficulties in accounting for damage spatial variability. Sensors mounted on UAVs (Unmanned Aerial Vehicles) and satellites can fulfill these requirements when coupled with advanced spectral analysis techniques, such as spectral mixture analysis (SMA). In this experiment we applied SMA on UAV hyperspectral images to quantify dead-and-alive organs during the growth of winter wheat (*Triticum aestivum* L.) and estimate yield loss due to hail damage. The experiment was conducted on a 17-ha field located in the surroundings of Venice (NE Italy). The experiment involved four simulated hail treatments (null, low, medium and high damage) at three plant growing stages (flowering, milky and over-ripe). Treatments were in triplicate for a total of 30 plots, nine sized 60x60 m and 18, 20x20 m. Damages were inflicted using a prototype specifically designed at the University of Padova, consisting of a rotating pole with whips attached and positioned on the back of a tractor. Damage intensity was adjusted with the aid of insurance field inspectors. A UAV M600 Pro (DJI, Shenzhen, China) was equipped with a nanohyperspec (400-1000 nm) camera (Headwall, Boston, USA). Pixel ground resolution was about 0.04 m. UAV surveys were performed after each damage, leaving a period of 7-10 days to the crop for developing a detectable morphologic and physiologic response (e.g., leaf drying, development of necrosis). At each flight, crop samples were collected, and pure spectral signatures of dead and alive stems, leaves and spikes were analyzed using an ASD Fieldspec 4 (Malvern Panalytical Ltd, Malvern, UK) in proximal sensing configuration. SMA algorithm was run on UAV imagery by selecting endmembers composed of intact green plant organs, bare soil and dead spikes, thus allowing for differentiation between damaged and undamaged vegetation. Results showed that increasing yield loss due to hail damage intensity was associated with an increasing number of dead spikes. Proximal-sensed hyperspectral signatures highly differentiated between undamaged and damaged vegetation, especially in the red-edge and chlorophyll absorption (~ 680 nm) regions. In this context, the SMA

technique was promising for disentangling dead spikes from alive organs, aiding the area-damaged classification and allowing hyperspectral imagery for a direct estimate of yield losses.