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Evaluating small unmanned aircraft systems for detecting turfgrass stress with an emphasis on drought

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Our objectives were to: 1) evaluate the utility of using ultra-high resolution remote sensing sensors mounted on small unmanned aircraft systems (sUAS) to detect early drought stress in turfgrass, before it is visible to the naked eye; and 2) compare sUAS remote sensing measurements with traditional techniques conducted at ground level.

The second year of a field study was conducted from 1 July to 29 August, 2016, on creeping bentgrass mown at 16 mm under a rainout shelter (Fig. 1). Six irrigation treatments were applied to create a gradient of irrigation regimes from well-watered to severe deficit irrigation, including 100, 80, 65, 50, 30, and 15% evapotranspiration (ET) replacement (well-watered to severely stressed). Measurements were taken weekly with a Canon S100 digital camera, modified to include near infrared (NIR), green, and blue bands. The camera was mounted on a S800 EVO hexacopter flown at 25 m above ground level within 3 hours of local solar noon. Images were processed using Agisoft PhotoScan Pro (Fig. 2) and AgVISR. Eight vegetation indices (VI; combinations of NIR, green, and blue bands) and each of the three individual bands were evaluated for their ability to detect early drought stress. Additional measurements included soil moisture (7.5 cm depth; FieldScout TDR 300), visual quality, percentage green cover (digital image analysis); and NDVI (handheld FieldScout 1000 and handheld Holland Scientific RapidSCAN CS-45).

Results from the first year (2015) indicated the near infrared (NIR) band and the GreenBlue VI [(Green-Blue)/(Green+Blue)] detected drought stress in turfgrass before it was visible (data not shown). On 7 July, 2016, 7 days after initiation of irrigation treatments, soil moisture had already declined and was significantly less at 30 and 15% ET than at 100% ET (Fig. 3A). However, on the same day turfgrass quality remained acceptable (≥ 6) and similar among all ET treatments (Fig. 3B). Percentage green cover was also similar among ET treatments (Fig. 3C). No differences in NDVI were detected among ET treatments with the handheld FieldScout 1000 (data not shown), but the RapidSCAN CS-45 indicated lower NDVI at 15% than at 100% ET (Fig. 3D). Among the 8 vegetation indices and 3 individual bands utilized with the sUAS, the NIR band, GreenBlue VI, Enhanced 1 VI [(NIR+Green-2Blue)/(NIR+Green+2Blue)], and Enhanced 2 VI [(NIR+Green-Blue)/(NIR+Green+Blue)] detected differences between 100% ET and the two lowest irrigation levels on 7 July, which was the same trend as soil moisture (Figs. 3E to 3H, 3A). Interestingly, the trends in visual quality and percentage green cover one week later (15 July) were similar to soil moisture and the aforementioned VIs on 7 July. Namely, visual quality and percentage green cover were lower at 15 and 30% than at 100% ET (Figs. 3 and 4). This indicates ultra-high remote sensing mounted on sUAS detected drought stress in the turfgrass canopy at least 8 days before it was visible to the naked eye.

Bullet Points:

- Seven days after initiation of ET treatments (7 July), no differences in turf quality or percentage green cover were evident among ET treatments (Fig. 3B and 3C).
- However, soil moisture was less at 15 and 30% than 100% ET (Fig. 3A).

- On the same day (7 July), the NIR band and the GreenBlue, Enhanced 1, and Enhanced 2 vegetation indices detected differences in vegetative properties between 100 and 15/30% ET treatments (Fig. 3E to 3H) (same trend as soil moisture, Fig. 3A).
- Trends observed on 7 July in these vegetation indices and the NIR band were predictive of visual quality and percentage green cover 8 days later, on 15 July (Figs. 3 and 4).
- Ultra-high resolution remote sensing with small UAS detected drought stress at least 8 days before it was visible to the human eye.

Figure 1. Aerial view of creeping bentgrass plots (top, highlighted with black border). Precipitation was excluded from plots by an automated rainout shelter (inset A), which covered plots during rainfall. This allowed precise irrigation amounts to be applied to individual plots (inset B).

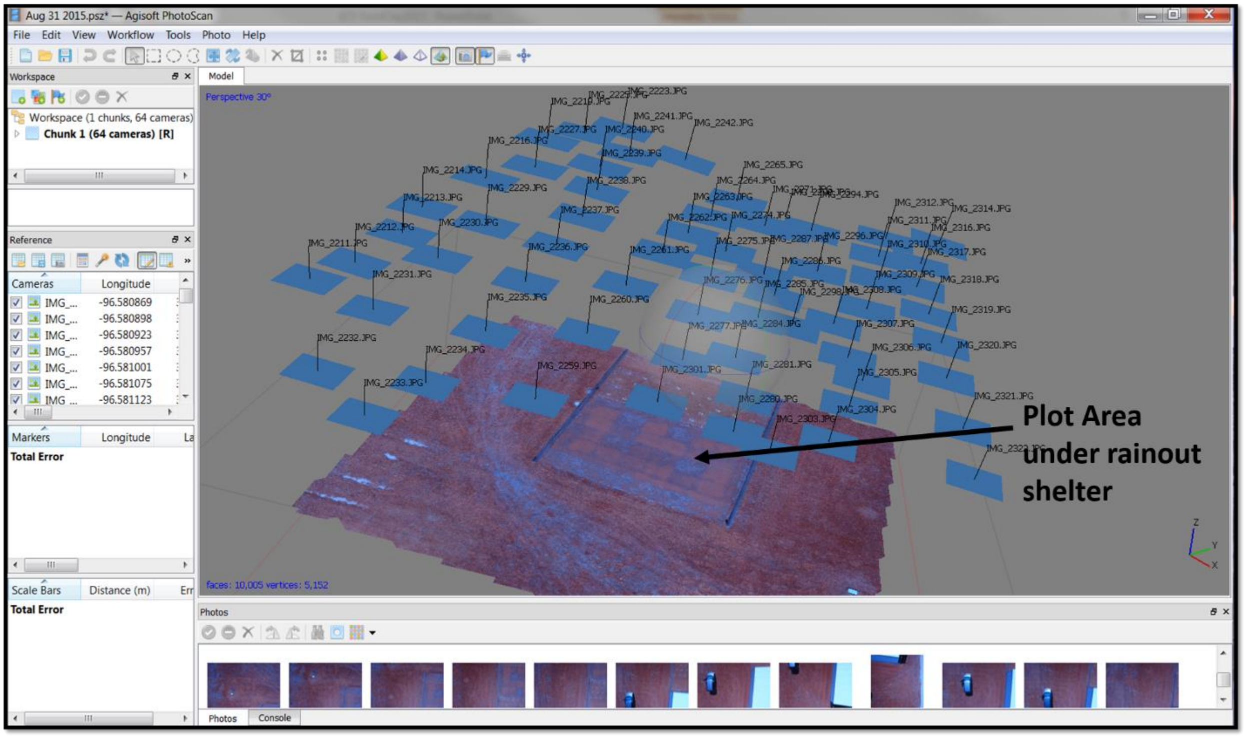


Figure 2. Building a model of the plot surface area using digital images taken from sUAS. Blue squares indicate position of camera during flyover of plots. Multiple images were "stitched" together to minimize angle effects and create an orthomosaic image, from which vegetation indices were developed.

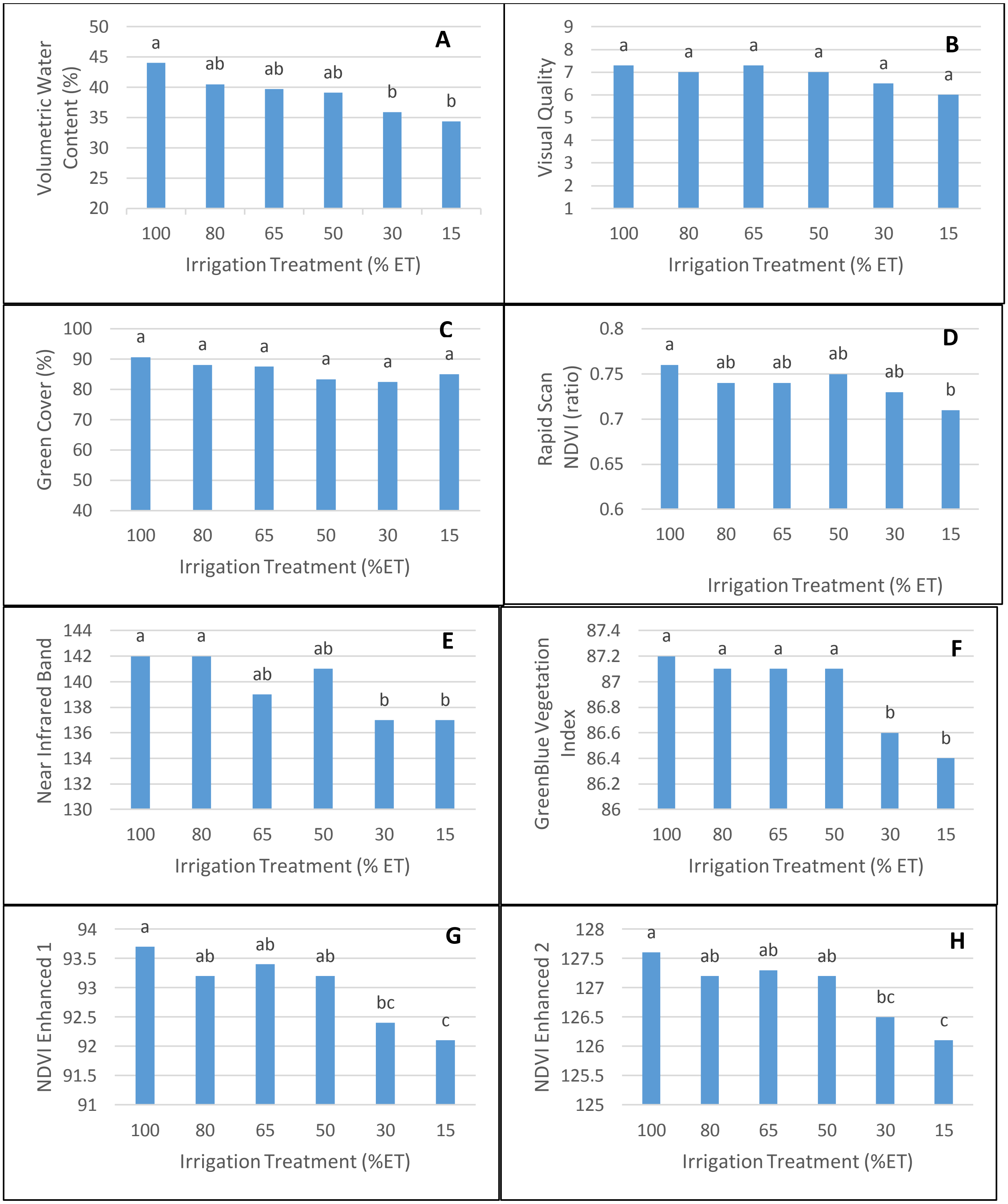
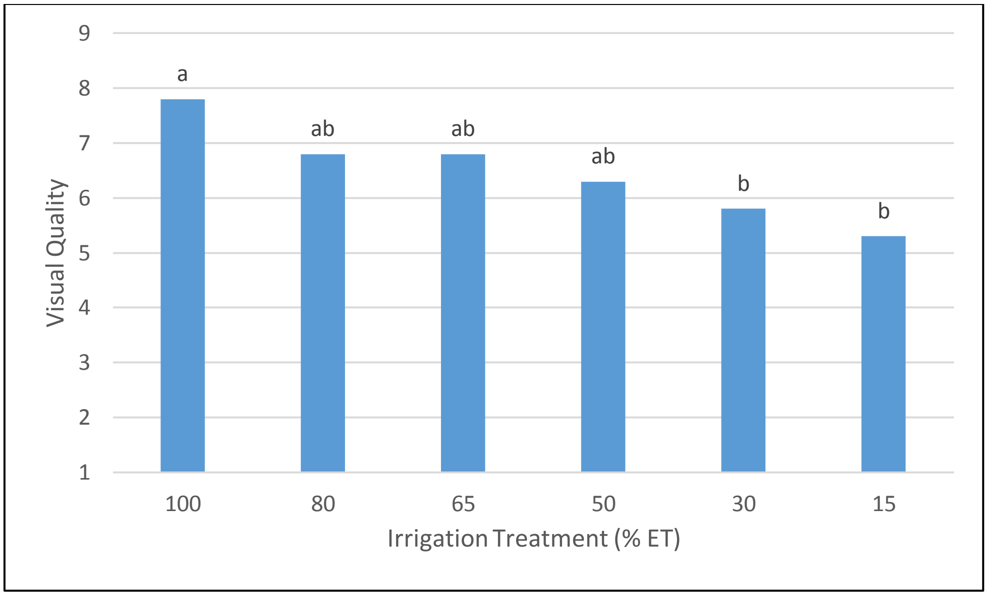


Figure 3. Measurements on 7 July (7 days after initiation of irrigation treatments) of volumetric soil water content (A); visual quality (B); percentage green cover (C); NDVI with handheld instrument (D); near infrared (E); GreenBlue vegetation index (F), Enhanced 1 vegetation index (G); and Enhanced 2 vegetation index (H); D through E were obtained from modified digital camera mounted on the sUAS.



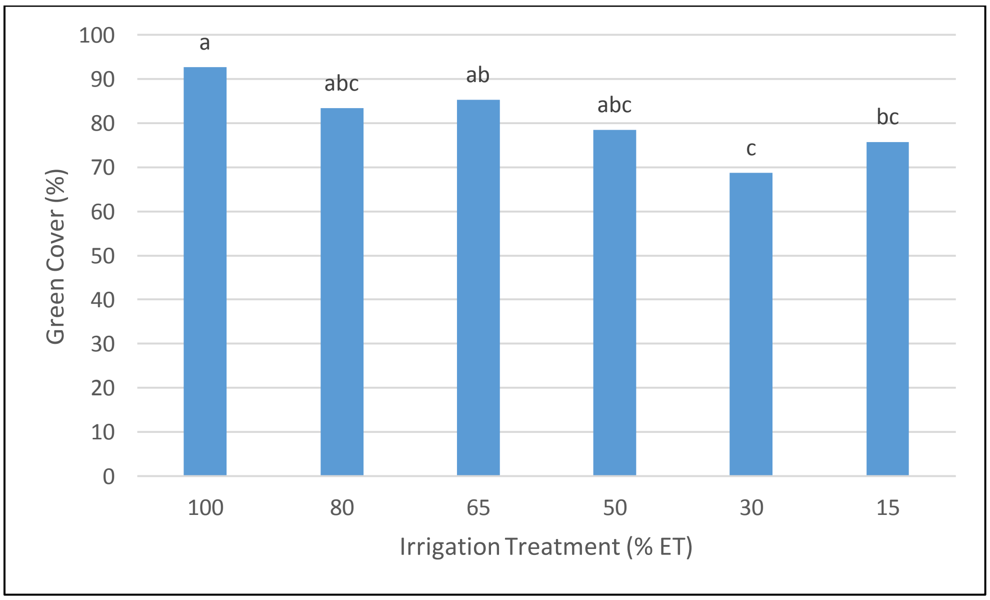


Figure 4. Measurements on 15 July (15 days after initiation of irrigation treatments) of visual quality (top); and percentage green cover (bottom). Trends were similar to soil moisture, near infrared band, and GreenBlue vegetation index 8 days earlier (7 July), indicating they were good predictors of visual quality and percentage green cover.