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

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Recent advances in technology may offer potential for using small unmanned aircraft systems (sUAS) for turfgrass management. Small UAS utilize remote sensing to measure plant canopy properties and diagnose plant stresses, and can cover areas the size of an 18-hole golf course much more quickly than conventional handheld or ground-vehicle-based platforms.

Our objectives were to: 1) evaluate ability of sUAS technology to detect drought stress in turfgrass across a gradient of irrigation regimes from well watered to severe deficit irrigation, and compare measurements with traditional (handheld) techniques; and 2) evaluate sUAS measurements of a golf course during the summer and fall.

A field study was conducted from 29 June to 31 August, 2015, on creeping bentgrass mown at 16 mm under a rainout shelter (Fig. 1). Six irrigation treatments began as 150, 125, 100, 75, 50, and 25% evapotranspiration (ET) replacement (overwatered to severely stressed). We hypothesized sUAS technology may detect overwatered as well as deficit irrigated turfgrass. However, after 3 weeks treatments were adjusted downward to 100, 80, 65, 50, 30, and 15% ET replacement (17 July), because no differences were evident among 75 through 150% ET and drought stress was negligible in all but 25 and 50% ET. 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 15 m within 3 hours of local solar noon. Images were processed using Agisoft PhotoScan Pro (Fig. 2), AgVISR, and ArcGIS (Figs. 3 and 4). Eight vegetation indices (combinations of NIR, green, and blue bands) and the three individual bands were evaluated for ability to detect 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).

By the end of the study, after 64 days of irrigation treatments, soil moisture was highest in 100 and 80% ET and declined steadily through 65%, 50% and 30% ET; soil moisture was similar between 30 and 15% ET (Fig. 5A). Turfgrass quality was similar, and quality was acceptable (> 6), among 100 through 65% ET, but quality declined thereafter and was unacceptable at 50 through 15% ET (Fig. 5B). Green cover was similar among the 100 through 50% ET treatments, but it declined rapidly at 30 and 15% ET (Fig. 5C). Significant bare soil was visible in 15% ET, and less so in 30% ET. Measurements with handheld NDVI detected no differences among the 100 through 50% ET plots (Fig. 5D). Among the 8 vegetation indices and 3 individual bands, the near infrared (NIR) band and GreenBlue vegetation index [(Green – Blue)/(Green + Blue)] were most sensitive, and the only ones that detected differences between 65% ET and the two highest irrigation levels (Figs. 5E and 5F; Figs. 3 and 4).

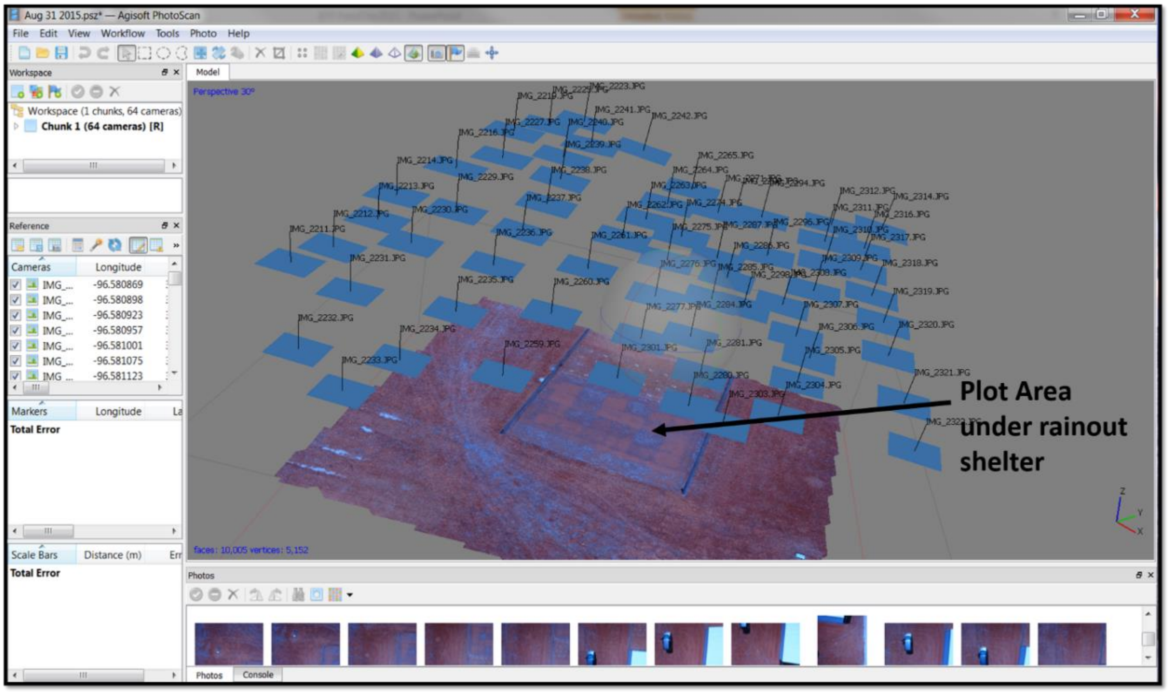
Preliminary measurements of a functioning golf course revealed interesting differences in fairways, tees, and greens between summer and fall. Additional research will be conducted in 2016 (Fig. 6).

Bullet Points:

- At the end of the study (31 Aug), no differences in turf quality were visible between the 100 and 65% ET treatments (Fig. 5B and 5C).

- However, soil moisture was less at 65% than 100% ET (Fig. 5A).
- The only measurements that detected differences in vegetative properties between 100 and 65% ET treatments on 31 Aug. were the NIR band and GreenBlue vegetation index (Fig. 3, 4, 5E, and 5F).
- This indicates using ultra-high resolution remote sensing with small UAS has potential to detect drought stress before it is visible to the human eye.
- Preliminary measurements of a functioning golf course revealed interesting differences in the turfgrass between summer and fall (Fig. 6).

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).



Cameras	Longitude
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IMG_...	-96.580898
IMG_...	-96.580923
IMG_...	-96.580957
IMG_...	-96.581001
IMG_...	-96.581075
IMG ...	-96.581123

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.

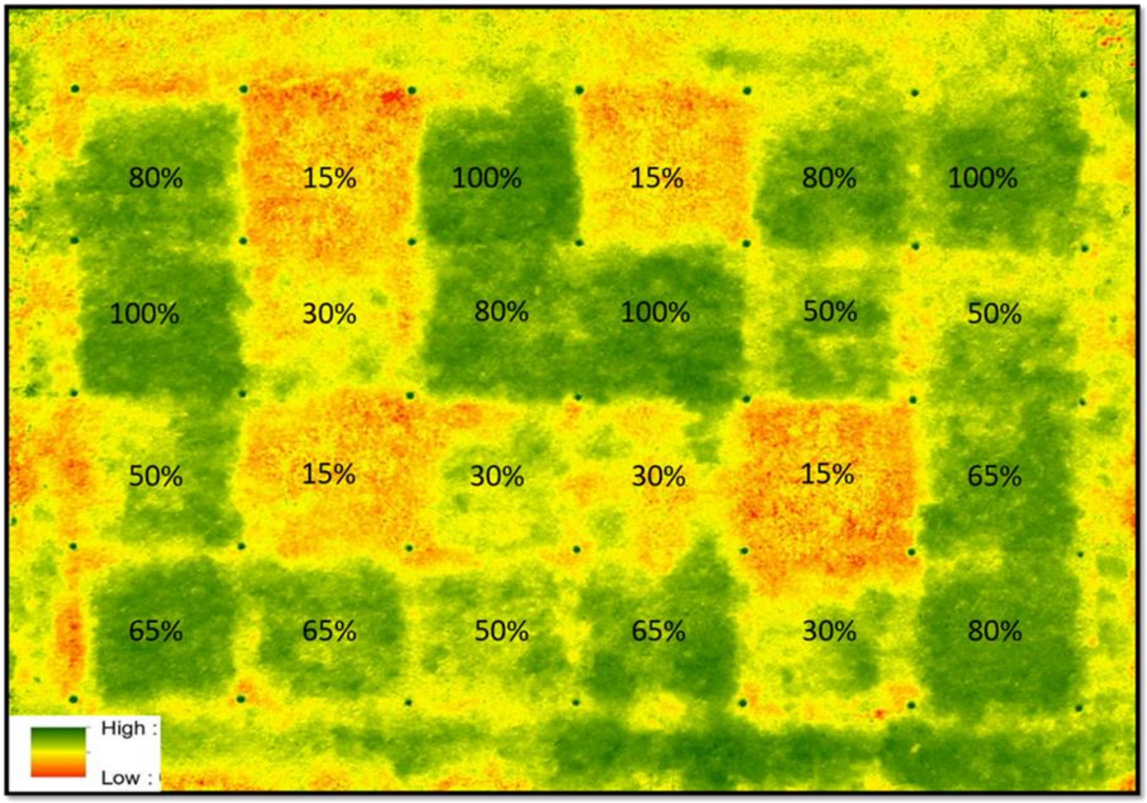

Figure 3. Color-enhanced image of plots in the near infrared (NIR) band. 31 Aug. 2015. Percentages denote ET replacement irrigation treatment. Dark green (high) indicates more turf biomass. Image created in ArcGIS.

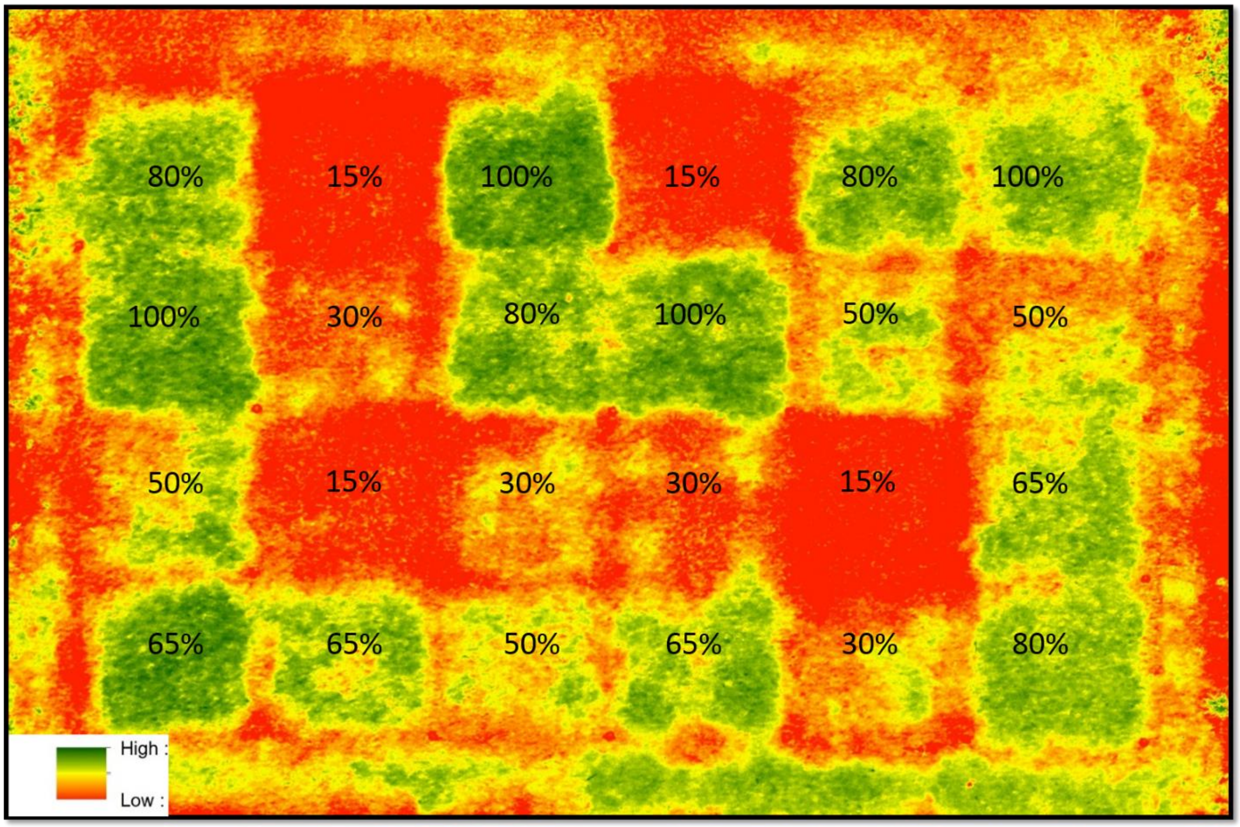

Figure 4. Color-enhanced image of plots in GreenBlue vegetation index [(Green-Blue)/(Green+Blue)]. 31 Aug. 2015. Percentages denote ET replacement irrigation treatment. Dark green (high) indicates more turf biomass. Image created in ArcGIS.

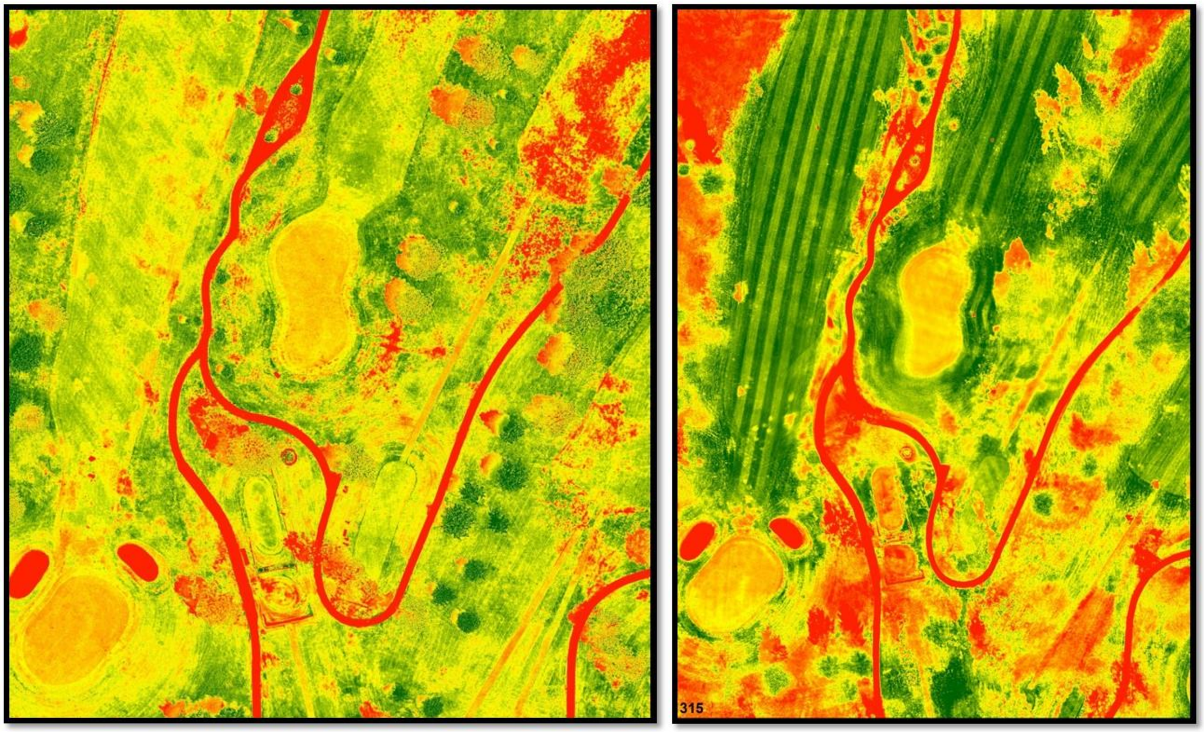

Fig. 6. Images of 3 partial fairways and 2 greens and tees on a functioning golf course in Manhattan, Kansas. Image on left was Aug. 3 and on right was Nov. 13

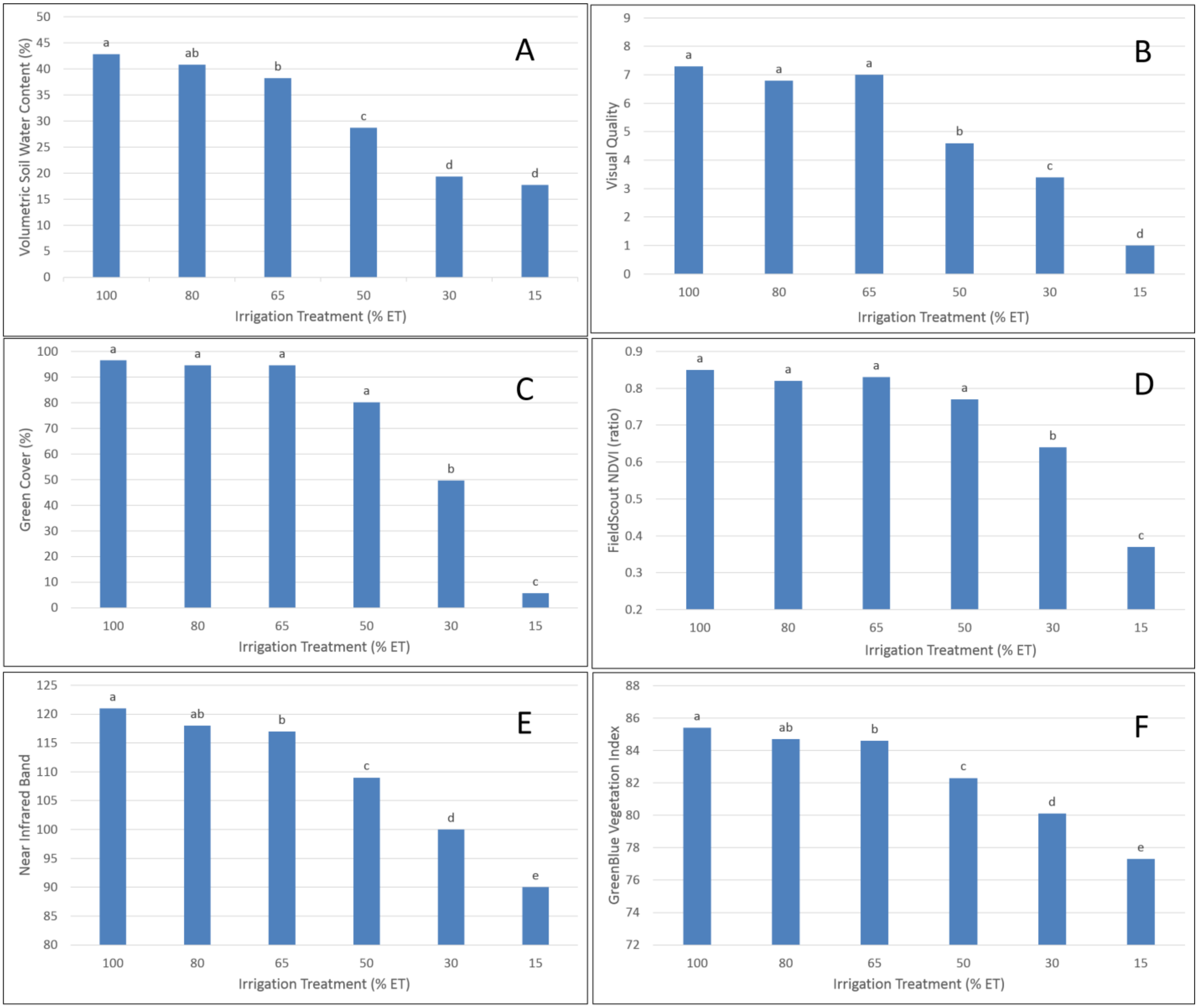

Figure 5. Measurements on the final day of the study of volumetric soil water content (A); visual quality (B); percentage green cover (C); NDVI with handheld instrument (D); near infrared (NIR) with modified digital camera mounted on sUAS (E); and GreenBlue vegetation index obtained with modified digital camera mounted on sUAS (F).