Identification of Drought Stress in Turfgrass Using Hyperspectral and Multispectral Remote Sensing

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Introduction

Tall fescue (*Lolium arundinacea*) and bermudagrass (*Cynodon dactylon*) are the predominant turfgrass species in Californian urban landscapes. Advances in remote sensing may improve insight into turfgrass health, leading to better municipal irrigation management decisions during water restriction periods.

Objective

1. Verify qualitative differences in spectral signatures between deficit irrigation treatments
2. Explore and improve sensitivity of vegetative indices to drought stress

Materials and Methods

Turfgrass setup:

- 12 x 12 ft^2 plots established July 2017 in Parlier, CA
- Deficit irrigation began May 1, 2018
- 3 plot repetitions per treatment (Table 1)

	Tall fescue (TF)		Bermudagrass (BM)	
1.	80% ET	3 days/week	60% ET	3 days/week
2.	80% ET	2 days/week	60% ET	2 days/week
3.	65% ET	3 days/week	50% ET	3 days/week
4.	65% ET	2 days/week	50% ET	2 days/week
5.	50% ET	3 days/week	40% ET	3 days/week
6.	50% ET	2 days/week	40% ET	2 days/week

Table 1: Deficit irrigation treatments during experiment

Hyperspectral data collection:

- Instruments
  - Ocean Optics Flame-S (198-1032nm)
  - Ocean Optics Flame-NIR (937-1659nm)
  - 5 samples collected per plot
- 8 sampling dates

Multispectral data collection:

- Drone: DJI Matrice 210
- Camera: Micasense RedEdge (Blue, Green Red, Red Edge, NIR)
- 10 flight dates

Data analysis:

- Qualitative range selection to remove noisy spectra
- Data removed between 911nm -> 937nm for sensor spectral overlap
- Plot raw reflectance curves at each wavelength within a treatment

Preliminary modeling:

- Classify treatments with hyperspectral-derived vegetative indices using XGBoost (9-fold, cross-validation)

Results

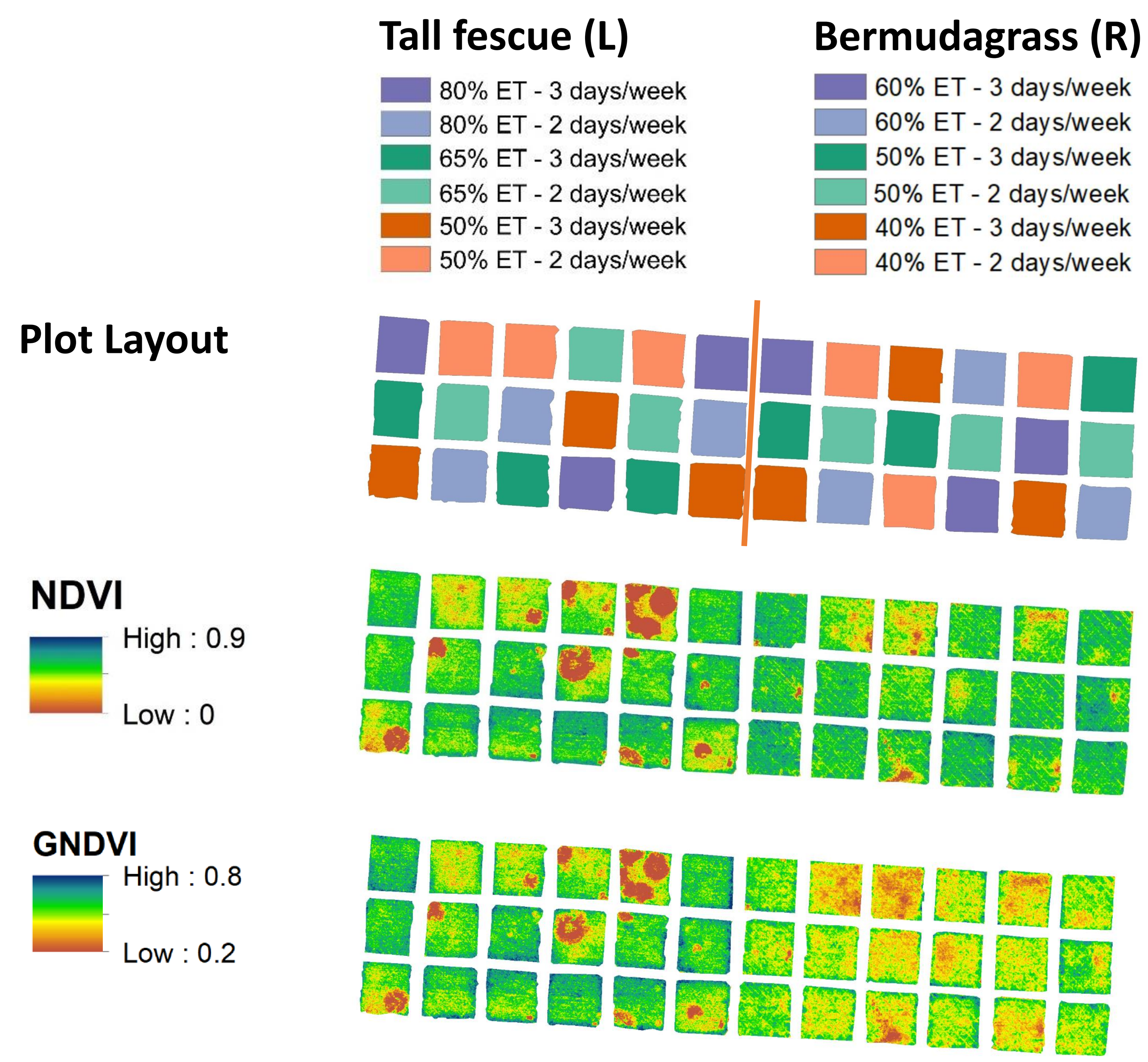

Figure 1: Normalized Difference Vegetative Index (NDVI), Green Normalized Difference Vegetative Index (GNDVI) rasters of plots on August 22, 2018

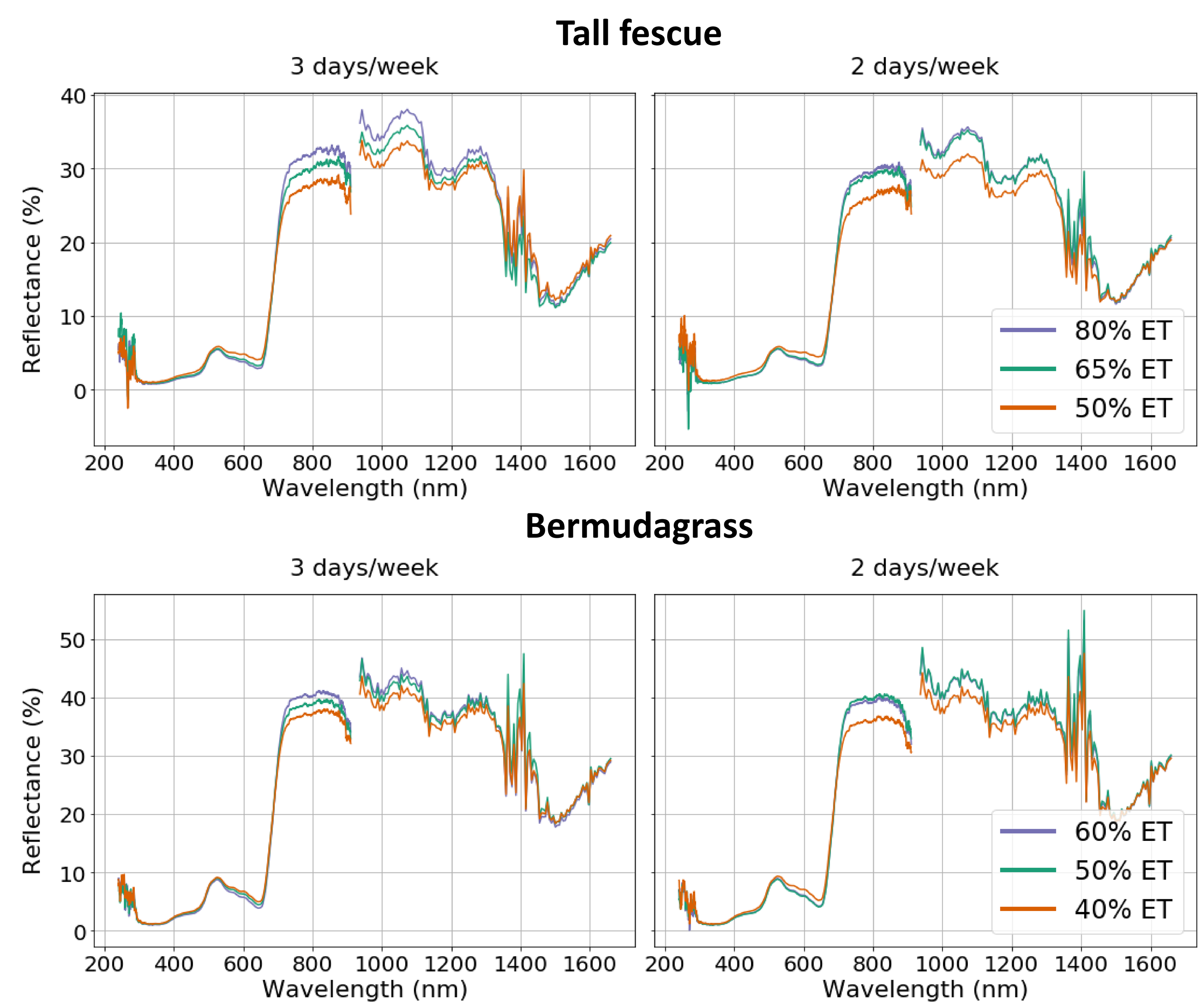

Figure 2: Raw reflectance spectral signature on August 22, 2018. Each treatment is an average of 15 samples.

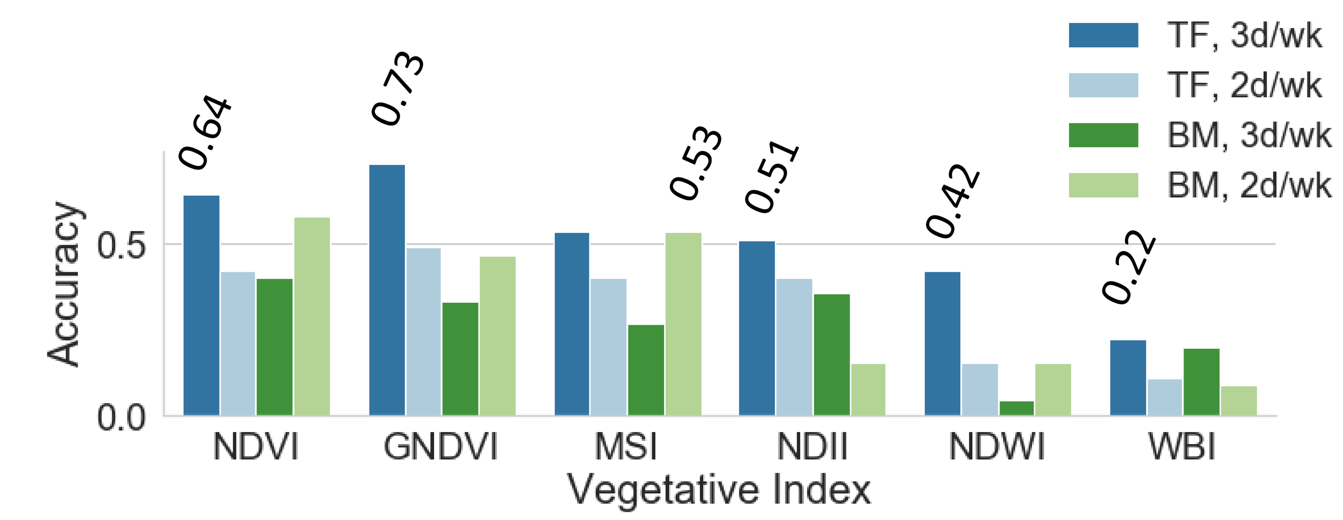

Figure 3: Accuracy of classification model
Input features: One VI calculated on August 22, 2018
Class Label: Deficit irrigation treatment per species, per irrigation frequency

Vegetative Index		Equation
Normalized Difference Vegetative Index	NDVI	$\frac{\rho_{840} - \rho_{668}}{\rho_{840} + \rho_{668}}$
Green Normalized Difference Vegetative Index	GNDVI	$\frac{\rho_{840} - \rho_{560}}{\rho_{840} + \rho_{560}}$
Moisture Stress Index	MSI	ρ_{1599}/ρ_{819}
Normalized Difference Infrared Index	NDII	$\frac{\rho_{819} - \rho_{1649}}{\rho_{819} + \rho_{1649}}$
Normalized Difference Water Index	NDWI	$\frac{\rho_{857} - \rho_{1241}}{\rho_{857} + \rho_{1241}}$
Water Band Index	WBI	ρ_{970}/ρ_{900}

Table 2: Hyperspectral vegetative indices used in preliminary modeling

Discussion

Hyperspectral analysis:

- Clear qualitative distinction between irrigation treatments within the first month of deficit irrigation trials
- Turfgrass irrigated 3 days/week vs. 2 days/week have similar spectral signatures

Multispectral analysis:

- Disease seen in flight dates, affecting VI in deficit irrigation experiment

Classification analysis:

- NDVI and GNDVI are generally good predictors for classification on tall fescue, cluing in to relevant spectral bands for drought stress
- Improvement in classification accuracy after several months of deficit irrigation

Conclusion

- Qualitative differences can be seen on some deficit irrigation treatments but may be affected by the period between irrigation, sampling date, and disease present