Progress Report Prepared for Turfgrass Research, Education, and Extension Endowment (TTREEE)

Date: December 2025

2024-2025 TTREEE and Potts* Endowments Funded Projects				
Title	PI	Co-PIs/ Collaborators	Amount	
Increasing species richness in Texas' lawns	P. Agustin Boeri	Ambika Chandra	$15,000.00	
Evaluating Artificial Turfgrass Sports Fields in College Station using Raman Spectroscopy	Manuel Chavarria	Aart Verhoef	$15,000.00	
Undergraduate Scholarship Proposal	Julie Howe		$8,000.00	
Development of molecular markers for cultivar identification and genetic differentiation in Zoysiagrass	Murukarthick Jayakodi	Ambika Chandra	$12,000.00	*partially funded by Potts
Calibration of a Portable L-Band Radiometer (PoLRa) for Accurate Soil Moisture Mapping on Golf Course Fairways	Madan Sapkota	Chase Straw, Benjamin Wherley	$5,010.00	*funded through Potts

CUMULATIVE TTREEE AWARDS AND FUNDING

Year	Awards	Total funded
2003	7	$31,874
2004	6	$30,850
2005	6	$25,150
2006	7	$30,650
2007	9	$41,600
2008	11	$91,934
2009	7	$55,000
2010	6	$50,000
2011	4	$36,000
2012	4	$44,275
2013	5	$33,300
2015	9	$45,500
2016-2017	6	$43,500
2017-2018	4	$37,000
2019-2020	3	$38,000
2020-2021	5	$51,000
2021-2022	6	$57,207
2022-2023	4	$32,000
2023-2024	4	$32,000
2024-2025	5	$55,010
TOTAL AWARDED	**114**	**$861,850**

Development of molecular markers for cultivar identification and genetic differentiation in Zoysiagrass

Murukarthick Jayakodi and Ambika Chandra

Zoysiagrass (Zoysia spp.) is a warm-season turfgrass valued for its resilience, low water requirements, and multi-stress tolerance. Most cultivars available in the market are vegetatively propagated and sold as sod. One of the major challenges with the production of high-quality and genetically pure sod is contamination with off-types arising from volunteer seed and/or viable plant parts either wind-blown or carried by farm equipment. Accurate identification of target cultivars from such contamination is essential for producing and maintaining clean certified sod. Currently, methods to identify off-types is based on visual assessment, which is qualitative in nature and difficult, especially for morphologically similar but genetically dissimilar off-types. In contrast, genetic testing using DNA markers provides a more accurate tool in the identification of such offtypes. We have recently identified a total of 80 haplotype specific variants and designed PCR markers using *Z. japonica* and *Z. matrella* species. Dr. Chadra has assembled a panel of 30 available cultivars (**Fig. 1**). We are now testing our markers to characterize similarity and dissimilarity between cultivars and species.

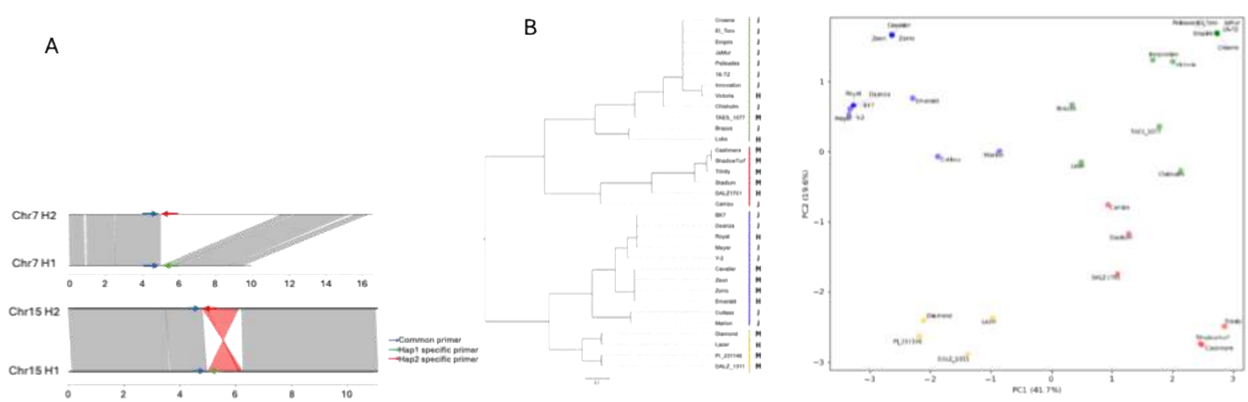


Figure 1. Development of new genotyping platform for zoysiagrass. A) new approach to develop PCR markers. B) genotyping and analysis (phylogeny and PCA) result of 30 zoysiagrass cultivars.

Increasing species richness in Texas' lawns

P. Agustin Boeri and Ambika Chandra

In Texas, rising water demand due to population growth is compounded by climate change, recurring droughts, and increasing potable water costs, leading to municipal irrigation restrictions. Consequently, turfgrass rebate programs are likely to increase. For example, the North Texas Municipal Water District has prohibited "overseeding, sodding, sprigging, broadcasting, or plugging with cool-season grasses, or watering cool-season grasses, except for golf courses and athletic fields," as part of their 2024 water conservation efforts.

Objective: Overseeding with cool-season legumes presents an opportunity to fill the gap left by restrictions on cool-season turfgrass use. However, the performance and effects of this practice on warm-season turfgrass health in North Texas need further evaluation to ensure these plants benefit turfgrass. Therefore, the objective of this project is to evaluate the turfgrass response to legume overseeding under different management approaches.

Hypotheses

1. *Terminating legume plants before spring green-up will improve turfgrass summer performance by increasing dark-green color and overall quality.*
2. *Allowing natural transition may create competition that negatively affects turfgrass growth and recovery.*

Materials and Methods

Two studies are being conducted at the Dallas AgriLife Research and Extension Center, Dallas, TX, to evaluate winter legume overseeding in St. Augustinegrass and buffalograss. St. Augustinegrass represents a traditional residential lawn, while buffalograss represents a low-input turf or prairie model. White clover (WC), red clover (RC), birdsfoot trefoil (BT), and bluebonnet (BB) were selected based on previous work and their prominence in Texas.

Progress Report 2025

Both field studies were fully established according to the experimental designs. The legumes were plants on October 30, 2025. This date was selected based on historic recommendations, and weather patterns that included a drought in September and early October and relative warmer temperatures in Fall. All legume seeds were inoculated with the appropriate rhizobia to ensure nodulation and potential nitrogen fixation.

Following seeding, germination was observed in the buffalograss plots. At the time of reporting, germination had not yet been observed in the St. Augustinegrass field plots. These could be to differences in canopy density and temperatures. We expect to see emergence in St. Augustinegrass later in the season.

The greenhouse work established the materials needed for $\delta^{15}N$ evaluations. Plants grown in sand is a method to simulate an environment free of N for determination of B values. These plants will allow accurate calculation of nitrogen fixation contributions when field tissue samples are collected in summer 2026.

Baseline soil health assessments were completed for the St. Augustinegrass (Figure 4) and buffalograss (Figure 5) plots. Nitrogen forms were overall higher in St. Augustinegrass compared to buffalograss.

Soil Health Assessment

WATER EXTRACT		AVAILABLE NITROGEN LBS/ACRE		SOIL HEALTH		SOIL HEALTH	
Total Nitrogen, ppm N	27.6	Nitrate, Lbs/Acre	9	Soil Respiration, ppm CO_2C	64.7	Microbially Active Carbon, % MAC	36.5
Organic Nitrogen, ppm N	21.4	Organic Nitrogen, Lbs/Acre	39	Water Stable Aggregates (Mod), %	91	Organic C:N	8.3
Organic Carbon, ppm C	177	Organic Nitrogen Release, Lbs/Acre	39	*Includes 0.25-2 mm diameter sand grains*		Organic Nitrogen Release, ppm N	21.4
Ammonium, ppm NH_4-N	0.9	Organic Nitrogen Reserve, Lbs/Acre	< 0.01	Cover Crop Suggestion (Legume/Grass)	40%/60%	Organic Nitrogen Reserve, ppm N	0.0
Nitrate, ppm NO_3-N	5.22			Soil Health Calculation	12.64	NH_4:NO_3	0.2

Soil pH 1:1	BpH Modified WDRF	Soluble Salts 1:1 mmho/cm	Excess Lime Rating	Organic Matter LOI %	Phosphorus	Ammonium Acetate				Sulfate M-3 ppm	DTPA-Sorbitol					$CaNO_3$ Chloride ppm Cl	Sum of Cations me/100g	% Base Saturation				
					M-3	K ppm	Ca ppm	Mg ppm	Na ppm		Zn ppm	Fe ppm	Mn ppm	Cu ppm	B ppm			H	K	Ca	Mg	Na
7.2	6.8	1.63	NONE	5.4	38	337	1696	151	141	36.9	1.44	13.3	3.3	0.72	--	--	12.8	12	7	66	10	5

Figure 4. Soil health report St. Augustinegrass.

Soil Health Assessment

WATER EXTRACT		AVAILABLE NITROGEN LBS/ACRE		SOIL HEALTH		SOIL HEALTH	
Total Nitrogen, ppm N	12.9	Nitrate, Lbs/Acre	1	Soil Respiration, ppm CO_2C	38.9	Microbially Active Carbon, % MAC	32.6
Organic Nitrogen, ppm N	11.3	Organic Nitrogen, Lbs/Acre	20	Water Stable Aggregates (Mod), %	92	Organic C:N	10.5
Organic Carbon, ppm C	119	Organic Nitrogen Release, Lbs/Acre	20	*Includes 0.25-2 mm diameter sand grains*		Organic Nitrogen Release, ppm N	11.3
Ammonium, ppm NH_4-N	0.9	Organic Nitrogen Reserve, Lbs/Acre	< 0.01	Cover Crop Suggestion (Legume/Grass)	50%/50%	Organic Nitrogen Reserve, ppm N	0.0
Nitrate, ppm NO_3-N	0.72			Soil Health Calculation	7.94	NH_4:NO_3	1.2

Soil pH 1:1	BpH Modified WDRF	Soluble Salts 1:1 mmho/cm	Excess Lime Rating	Organic Matter LOI %	Phosphorus	Ammonium Acetate				Sulfate M-3 ppm	DTPA-Sorbitol					$CaNO_3$ Chloride ppm Cl	Sum of Cations me/100g	% Base Saturation				
					M-3	K ppm	Ca ppm	Mg ppm	Na ppm		Zn ppm	Fe ppm	Mn ppm	Cu ppm	B ppm			H	K	Ca	Mg	Na
6.8	6.9	0.18	LOW	4.2	17	388	5694	173	87	9.9	1.75	3.2	1.0	0.24	--	--	32.8	5	3	87	4	1

Figure 5. Soil health report buffalograss.

Over the coming months, the project will transition into the measurement and monitoring phase. Seasonal vegetation composition assessments will begin using the 1 × 1-m quadrat grid, and monthly digital image collection will document turf quality, canopy color, and groundcover interactions. Chlorophyll readings, NDVI measurements, and soil moisture monitoring will be initiated once winter transitions to active growth in spring. Hydraulic conductivity measurements will be taken during summer 2026.

Overall, the project is on schedule. The field plots have been established, soil baselines have been collected, greenhouse materials for nitrogen-fixation calculations are in place, and germination has been successful in buffalograss and the greenhouse system.

Tittle: Evaluating Artificial Turfgrass Sports Fields in College Station using Raman Spectroscopy

Ashton Franks, M.S.**,** Manuel R. Chavarria, Ph.D.**, and** Aart Verhoef, Ph.D.

Introduction: As artificial turf fields and playgrounds become more common in Texas, especially in communities facing water shortages, concerns are growing about their potential environmental and health impacts. Although synthetic turf is often viewed as a low-maintenance alternative to natural grass, Texas's intense heat, high UV exposure, and variable weather can accelerate the breakdown of turf fibers and infill materials. This degradation may release harmful chemicals, including per- and polyfluoroalkyl substances (PFAS), into surrounding soils and groundwater.

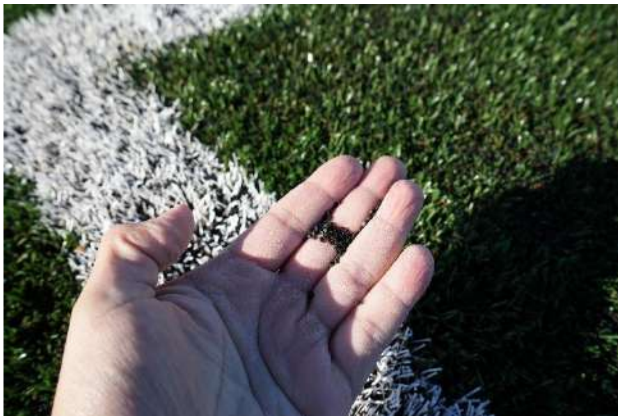
Recent findings highlight the scope of the issue. A Yale University study identified 306 chemicals in crumb rubber infill, including 197 with carcinogenic properties, while 207 remain unlisted in EPA databases, revealing critical gaps in toxicological understanding (Perkins et al., 2019). Yet most existing studies were conducted in cooler climates and indoor environments, leaving major questions about how artificial turf behaves under Texas's harsher conditions.

Materials and Methods: Field samples were collected during spring 2025 from artificial turf soccer and American football fields, as well as playground rubber surfaces, in College Station, Texas. After collection, samples were analyzed using Raman Spectroscopy (Resolve, Agilent Technologies, Santa Clara, CA).

Minimal sample preparation was required. For each material:

- Three aliquots per sample were scanned as replicates.
- Crumb rubber samples were placed in 5 mL vials and analyzed using *Vial Holder* mode.
- Artificial leaf fibers and rubber mulch samples were analyzed using *Surface Scan* mode.
- Rubber mulch was separated by color before scanning.

Raw spectra were downloaded and replicate scans were averaged to improve precision. Spectra were examined for clarity and compared to known PFAS reference peaks (Kumar et al., 2025).






Results: *These results are preliminary and currently undergoing further analysis.*

Spectral comparisons between the collected samples and published PFAS reference spectra revealed multiple peak matches indicating the possible presence of PFAS compounds. Consistent peaks at 376 cm^{-1} and 727 cm^{-1} aligned with PFOA, while additional peaks at 393, 608, and 778 cm^{-1} corresponded to PFBA and PFHpA. Artificial turf fiber samples from Penberthy, the Indoor Football Facility, and Veterans Park showed the strongest correlations, with high-intensity signals closely matching PFAS reference peaks. In contrast, crumb rubber infill samples from Penberthy and Veterans Park displayed only weak to moderately weak correlations, with minor PFAS-related peaks that were far less intense, and strong PFAS signals were largely absent. Rubber mulch samples from playgrounds showed patterns similar to the leaf fibers, with all colors exhibiting strong correlations and the highest peak intensities among all materials tested, suggesting these samples may contain comparatively higher levels of PFAS.

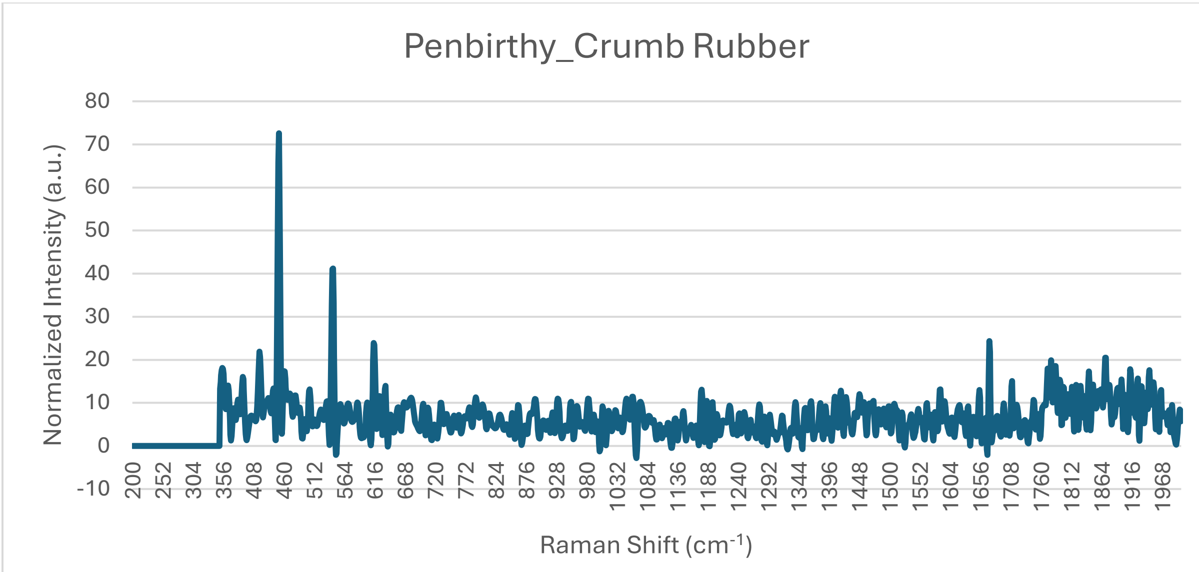
Comparison of published PFAS peaks and the measured samples shows compelling matches at several peaks. Peaks at 376 cm^{-1} and 727 cm^{-1} were consistently found in the field samples and match that of PFOA. Peaks at 393, 608, and 778 cm^{-1} were also identified in the field samples and match that of PFBA and PFHpA. Based on the peaks identified above, a correlation could be made between the likelihood of PFAS compounds existing within the sample.

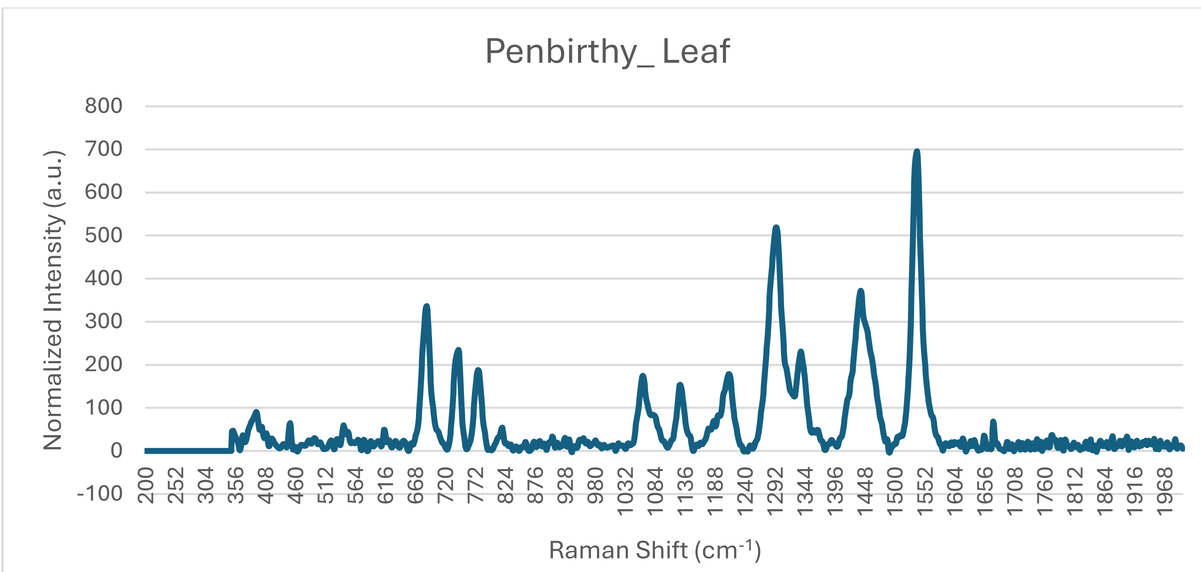
Interpretation and Next Steps

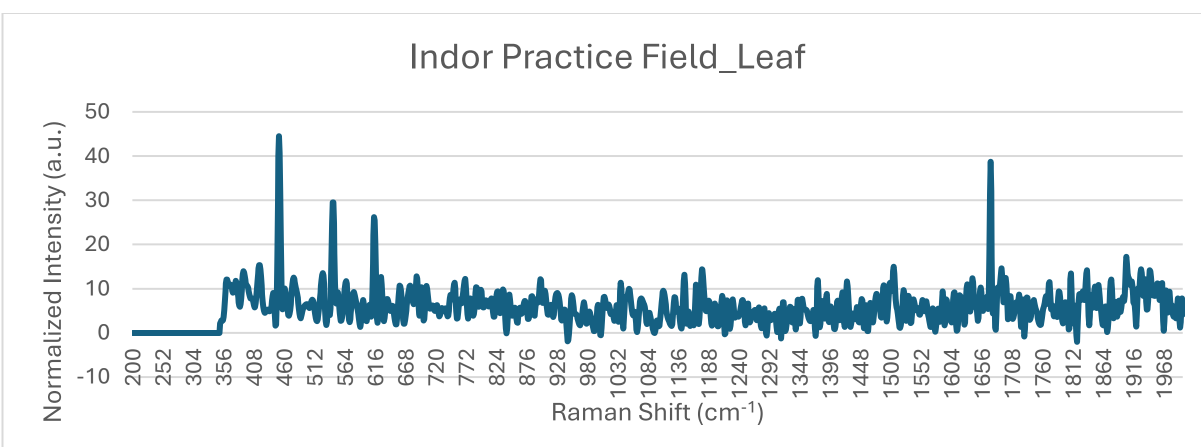
These preliminary spectroscopic results indicate that PFAS compounds may be present in artificial turf fibers and playground rubber mulch in College Station, with weaker signals observed in crumb rubber. However, Raman spectroscopy alone cannot provide definitive chemical identification.

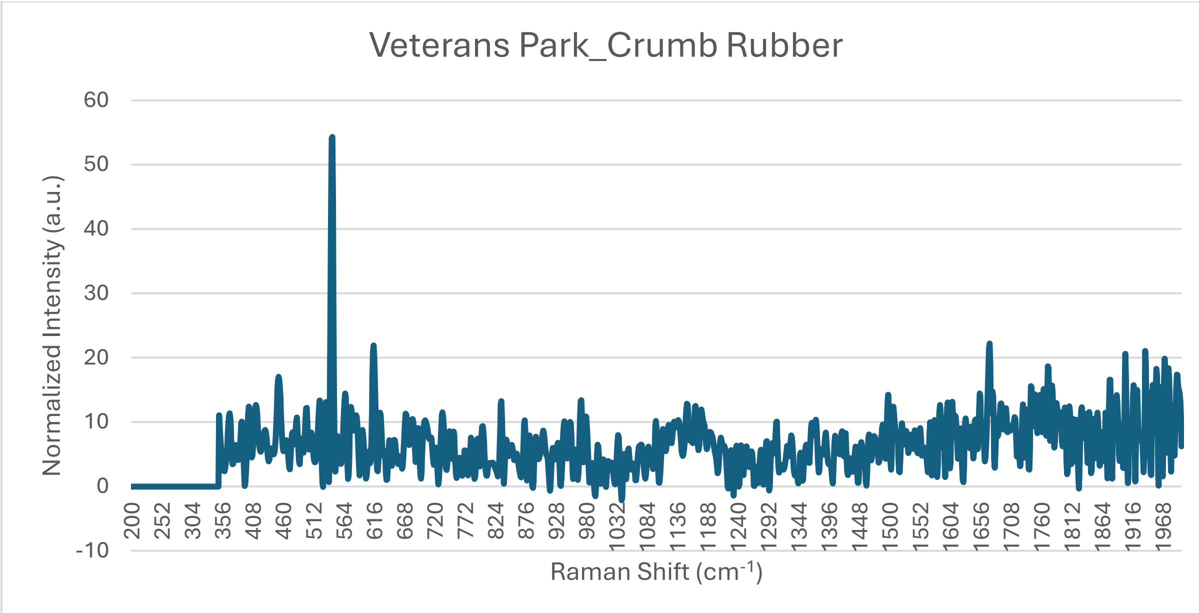
To confirm these findings, more precise analytical techniques (e.g., LC-MS/MS, GC-MS, targeted PFAS assays) will be necessary. These next steps will help verify the presence and concentration of PFAS compounds and strengthen understanding of chemical behavior in artificial turf systems under Texas environmental conditions.

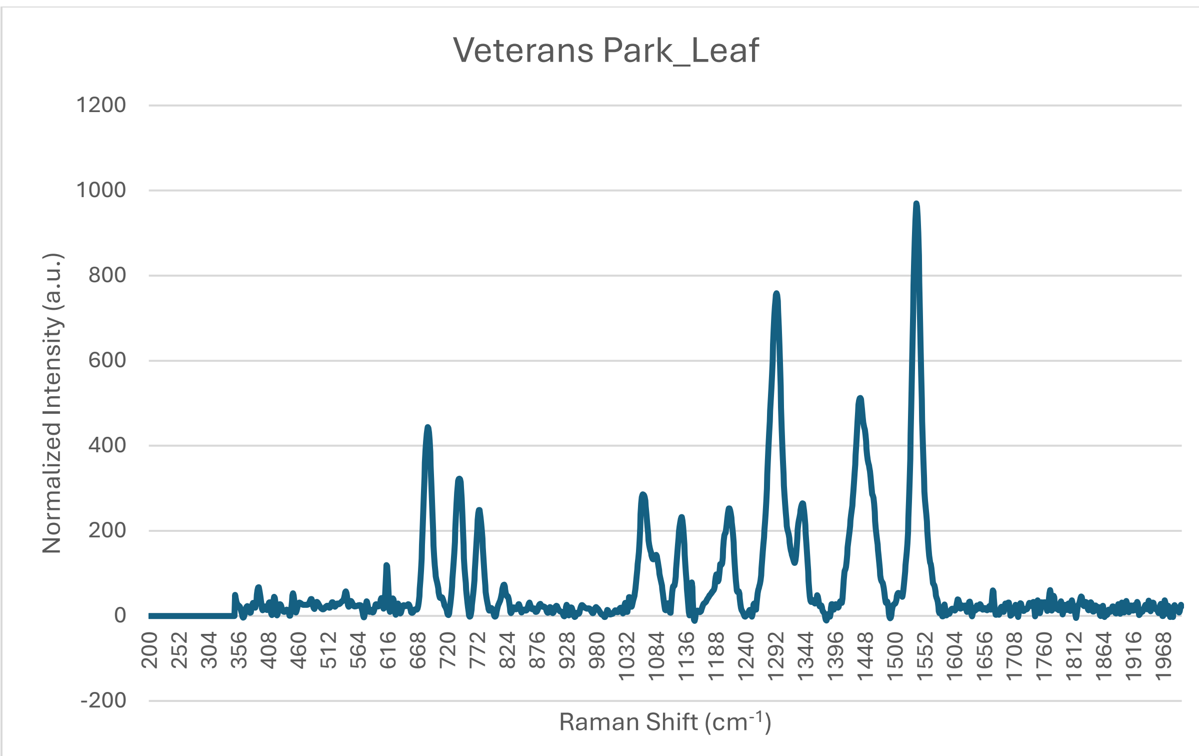
Kumar, A., J. Rothstein, Y. Chen, H. Zhang, and Y. Zhao. (2025). Experimental Raman spectra analysis of selected PFAS compounds: Comparison with DFT predictions. *Journal of Hazardous Materials*. https://doi.org/10.1016/j.jhazmat.2025.138704

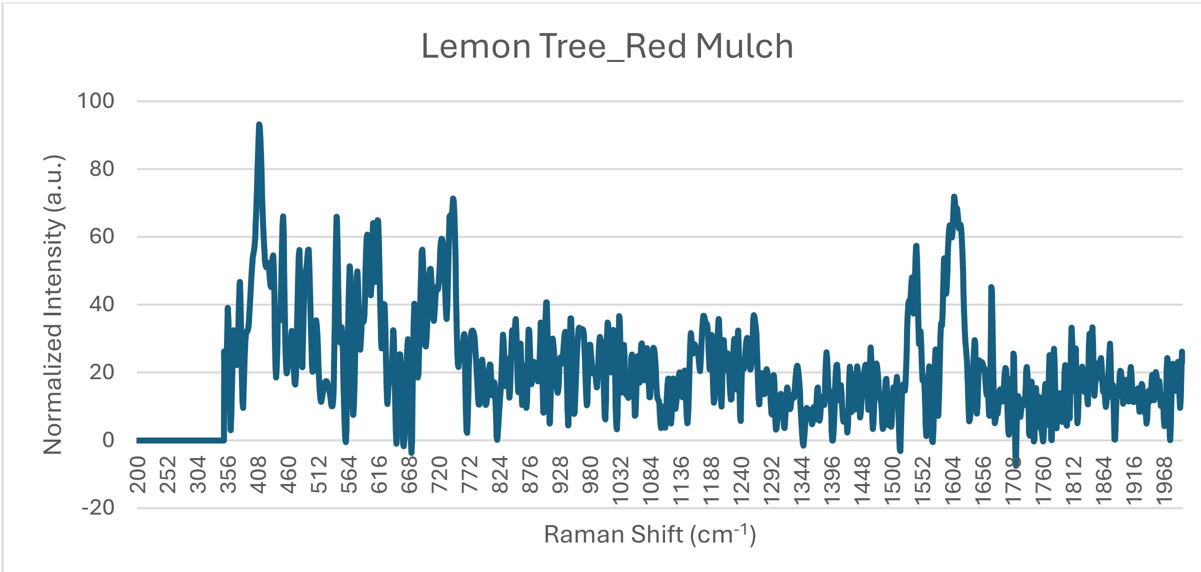

Penbirthy_Crumb Rubber
Normalized Intensity (a.u.)
Raman Shift (cm-1)

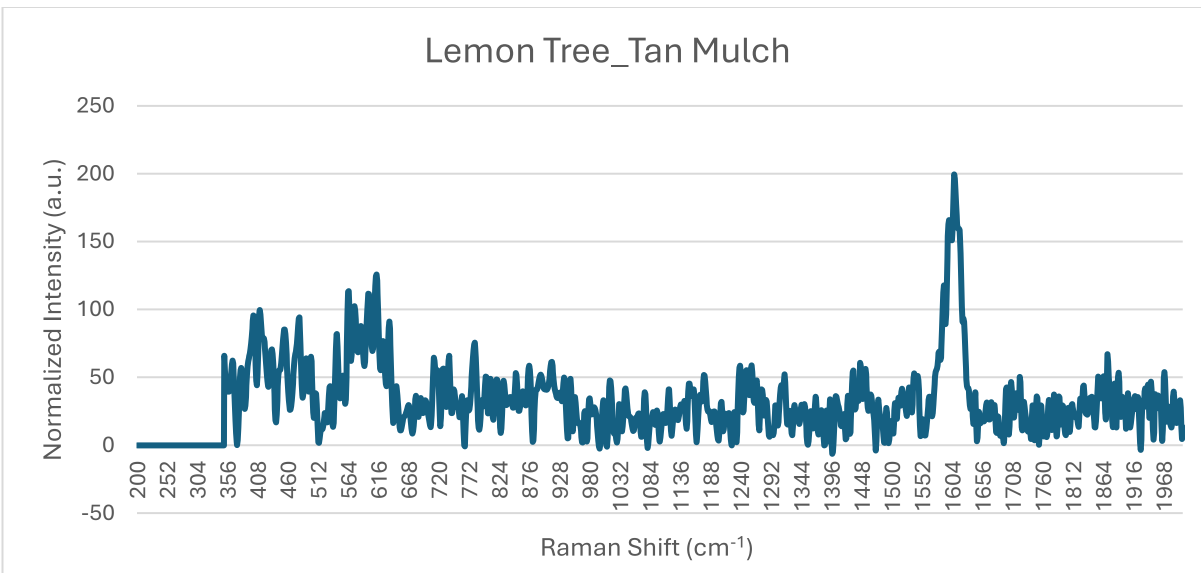

Penbirthy_ Leaf
Normalized Intensity (a.u.)
Raman Shift (cm-1)

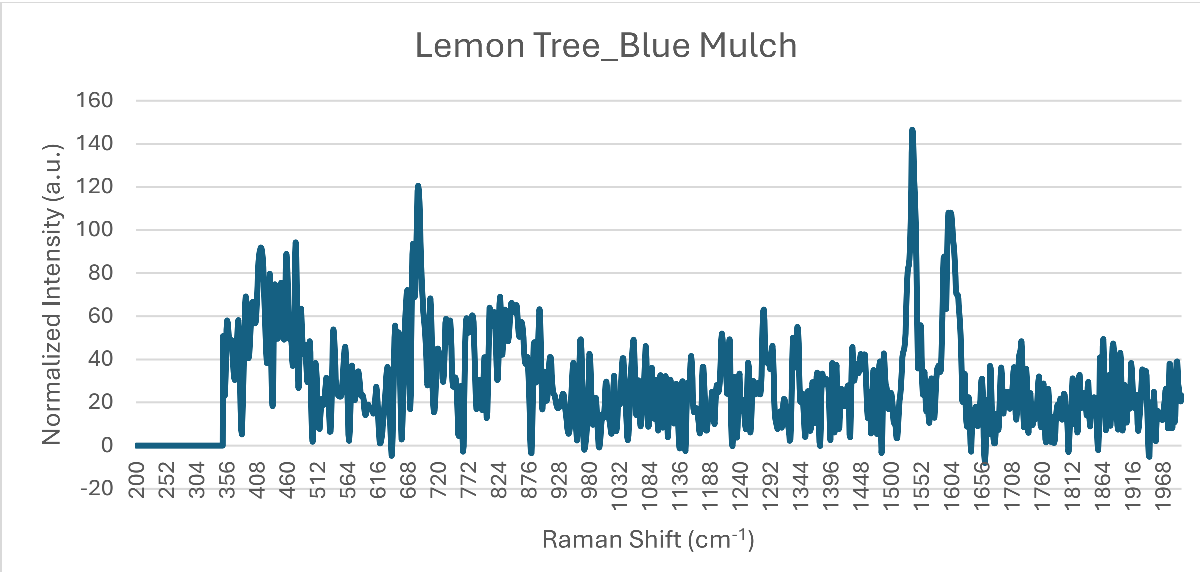

Indor Practice Field_Leaf
Normalized Intensity (a.u.)
Raman Shift (cm-1)


Veterans Park_Crumb Rubber
Normalized Intensity (a.u.)
60
50
40
30
20
10
0
-10
200 252 304 356 408 460 512 564 616 668 720 772 824 876 928 980 1032 1084 1136 1188 1240 1292 1344 1396 1448 1500 1552 1604 1656 1708 1760 1812 1864 1916 1968
Raman Shift (cm-1)


Veterans Park_Leaf
Normalized Intensity (a.u.)
1200
1000
800
600
400
200
0
-200
200 252 304 356 408 460 512 564 616 668 720 772 824 876 928 980 1032 1084 1136 1188 1240 1292 1344 1396 1448 1500 1552 1604 1656 1708 1760 1812 1864 1916 1968
Raman Shift (cm-1)


Lemon Tree_Red Mulch
Normalized Intensity (a.u.)
100
80
60
40
20
0
-20
200 252 304 356 408 460 512 564 616 668 720 772 824 876 928 980 1032 1084 1136 1188 1240 1292 1344 1396 1448 1500 1552 1604 1656 1708 1760 1812 1864 1916 1968
Raman Shift (cm-1)


Lemon Tree_Tan Mulch
Normalized Intensity (a.u.)
250
200
150
100
50
0
-50
200 252 304 356 408 460 512 564 616 668 720 772 824 876 928 980 1032 1084 1136 1188 1240 1292 1344 1396 1448 1500 1552 1604 1656 1708 1760 1812 1864 1916 1968
Raman Shift (cm-1)



Lemon Tree_Blue Mulch
Normalized Intensity (a.u.)
160
140
120
100
80
60
40
20
0
-20
200
252
304
356
408
460
512
564
616
668
720
772
824
876
928
980
1032
1084
1136
1188
1240
1292
1344
1396
1448
1500
1552
1604
1656
1708
1760
1812
1864
1916
1968
Raman Shift (cm-1)

Calibration of a Portable L-Band Radiometer (PoLRa) for Accurate Soil Moisture Mapping on Golf Course Fairways

Madan Sapkota, Chase Straw, Ph.D., Benjamin Wherley, Ph.D. and Elia Scudiero, Ph.D.

The recent introduction of the Portable L-band Radiometer (PoLRa), which operates based on microwave radiometry (Houtz et al., 2020), presents a promising opportunity for rapid, large-scale, high-resolution soil moisture mapping. In turfgrass systems, microwave radiometry is likely influenced by factors such as soil moisture, leaf water content, surface brightness, and temperature variations. Given these local influences, site-specific calibrations may be necessary (Scudiero et al., 2023).

This project aims to develop a robust calibration model for the PoLRa sensor to obtain accurate soil moisture measurements, enabling precise mapping to support efficient irrigation and reduce water usage on golf courses. Field testing will be conducted across various regions in Texas to validate the model in diverse environments and improve its broader applicability. The long-term goal is to make the calibration algorithm publicly available for easy implementation by industry professionals and researchers. The study objectives are to: 1) compare seasonal relationships in soil moisture between PoLRa and TDR sensors, and 2) develop a data-driven model to calibrate PoLRa measurements using minimal ground-truth data.

Research Progress Update

Data collection was completed at the two originally proposed locations (Jackrabbit Course and Fields Ranch East), and two additional sites, Austin Country Club in Austin Texas and Independence Golf Club in Midlothian Virginia, were included to strengthen model robustness. Across all four golf courses, 17 survey events were conducted between August 2023 and March 2025, generating 598 synchronized PoLRa–TDR paired measurements.

For each survey, PoLRa recorded vertical and horizontal brightness temperatures (TBV and TBH) and thermal infrared temperature (TIR). A polarization ratio (PR = (TBV − TBH) / (TBV + TBH)) was calculated to test whether polarization differences improved prediction. Soil organic matter (SOM) was sampled at two survey periods per location, and soil type information was included as an additional predictor. Ground-truth volumetric water content (VWC) at 1.5, 3.0, and 4.8 inches was measured using TDR.

All datasets were merged into a standardized database. PoLRa variables were treated as continuous predictors, and course and fairway as categorical factors. Linear mixed-effects models (LMMs) were used to evaluate relationships between PoLRa measurements and soil moisture at each depth, with TBV, TBH, PR, TIR, and SOM included as predictors and random intercepts for course and fairway. Model performance was assessed using R^2, RMSE, and MAE, with backward stepwise selection identifying the most influential predictors.

For calibration development, three approaches were evaluated: the factory (off-the-shelf) PoLRa calibration, a site-independent support vector regression (SVR) model trained on pooled multisite data, and two analysis of covariance (ANCOVA)-based approaches. The SVR model used TBV, TBH, and TIR as predictors and was evaluated using multiple cross-validation schemes to assess generalizability. The global ANCOVA model applied a shared slope across locations with course-specific intercepts, while the regional ANCOVA model developed separate calibrations for each course, incorporating a fairway-time factor to capture within-course spatial and temporal variation.

Model performance was compared using R^2, RMSE, and MAE. To identify the minimum number of ground-truth samples required for reliable calibration, subsets of two to nine TDR points per fairway were repeatedly selected and evaluated against established accuracy benchmarks (RMSE < 0.06 acceptable; RMSE < 0.02 very good).

Objective 1: Seasonal and Depth-Based Sensitivity

Key findings:

1. PoLRa showed the strongest moisture sensitivity at shallow depth (1.5 inches), with performance decreasing at 3.0 and 4.8 inches indicating the sensor is most sensitive to near-surface soil moisture.
2. The polarization variables TBV and TBH were consistently the most influential predictors across courses and depths. Removing either of them sharply reduced model performance.
3. Additional variables such as PR, TIR, SOM, and soil type contributed little to model performance and accuracy.

These results confirm that PoLRa primarily captures near-surface moisture, and brightness temperatures remain the core predictors in calibration.

Objective 2: Calibration Model Development

Key findings:

1. The factory calibration produced only moderate accuracy ($R^2 \approx 0.40$) with relatively high prediction errors, confirming the need for calibration.
2. A site-independent machine learning model (SVR) performed well when trained on pooled data but showed major accuracy declines when applied to new fairways, survey dates, or courses not included in training. This indicates that fully universal "one-size-fits-all" calibrations are unreliable in practice.
3. Both global and regional analysis of covariance (ANCOVA) approaches produced high and stable calibration accuracy across locations. The global ANCOVA model worked well because it used a shared radiometric–soil moisture slope while accounting for site-

level baseline differences, providing the best balance of accuracy, scalability, and ease of calibration.

4. The minimal ground-truth calibration analysis showed that only five to six sampling points per fairway were needed to achieve reliable calibration accuracy, reducing labor and improving operational practicality.