# Final Technical Report

# FCEB Project #34

**Final Report: Rapid and cost-effective prediction of soil health indicators for Florida ranchlands**

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Soil health assessment considers not only soil fertility but also biological and physical limitations of soil processes, resulting in the need for numerous soil health indicators. Analysis of these indicators is expensive, time-consuming, and labor intensive, involving heavy use of chemical products and water. There is an urgent need for a rapid and cost-effective testing approach to promote soil health management in the Florida ranchlands.

Therefore, the use of a technique that will decrease the time and cost associated with soil health analysis is critical for soil health management. Several studies have successfully evaluated the performance of soil spectroscopy analysis coupled with statistical modeling to predict soil health indicators. We are using the Florida Ranchland Soil Health Database (the Database, in short) to advance our understanding on soil health management in ranchlands and improving the efficiency in soil health analysis.

The main objectives of this project are to 1) develop a rapid and cost-effective model using mid-DRIFTS technology to predict soil health indicators for Florida ranchlands; and 2) to verify the new model by expanding the Database. This proposal addresses the FCA Research & Education Priorities: Ecosystem services of grazing lands.

## SOIL HEALTH INDICATORS

In the Database, a wide range of biological, chemical, and physical indicators of soil health were measured following a standardized set of methods. We measured the bioavailability of phosphorus, potassium, and magnesium to determine the potential nutrient limitation using Mehlich-3 extraction solution at the Analytical Research Laboratory at UF|IFAS. Often considered as a master variable, pH was determined in a 1: 2 (soil: water) mixture using an electrode.

We analyzed a suite of biological soil health indicators. Soil organic matter has been determined via loss on ignition. We have completed the measurement of active carbon also known as potassium permanganate oxidizable carbon (POX-C), which is a measure of biologically labile pool of soil carbon that has been found to be responsive to changes in management practices such as organic amendments and cover (Weil et al., 2003). We also measured mineralizable carbon (Cmin), which is an index of the metabolic activities of soil microorganisms who are responsible for breaking down organic matter, recycling nutrients, and suppressing plant disease (Larkin, 2015; Nunes et al., 2020). The Cmin was determined by measuring $CO_2$ production over 24 hours from rewetted soil with an infrared gas analyzer (Bekku et al., 1997). Water-extractable organic carbon (WEOC) was determined by mobilizing the water-soluble organic carbon from soil and then quantified with a total carbon analyzer (Shimadzu - TOC).

The mid-DRIFTS spectra were obtained using an XY Autosampler (Pike Technologies) that increases the through-put of spectroscopic analyses. All measurements were conducted from

4000 to 400 $cm^{-1}$, 4 $cm^{-1}$ wavenumber resolution and with 24 co-added scans. Calibration models were developed on a representative portion of samples (70% of the dataset) and validated on the remaining samples (30% of the dataset).

## SAMPLING STRATEGIES

To expand the database, we collaborated with UF | IFAS extension agents and Florida ranchers by offering a complementary soil health test. Farmers who consented to participate in the project have received a pre-paid label and samples instructions to collect and send their samples to the University of Florida (Soil, Water, and Ecosystem Sciences). A soil health report was sent to each participant upon analyses of the samples. A total of 100 ranchers have agreed to participate in the study resulting in 64 samples (Table 1), categorized as most and least productive according to the farmers.

Table 1. Summary of the farmers who responded to the online form and the farmers who submitted their soil samples

| Participating Farmers | County Reached | Farmers Providing Samples | Total Samples |
|---|---|---|---|
| 100 | 32 | 23 | 64 |

## OUTCOMES

*Predicting soil health indicators*

Predicting soil health indicators with mid-DRIFTS has shown promising potential, especially for carbon-related indicators. The performance of mid-DRIFTS technique was evaluated through statistical modeling based on $R^2$ which informs on how well the measured values are performed compared to the one produced by the model. For instance, $R^2$ of 0.72 and 0.61 were obtained when predicting organic matter and POX-C with partial least square regressions, respectively. This method is less effective for Cmin and WEOC with $R^2$ of 0.48 and 0.25, respectively.

As illustrated in Figure 1, SOM has been predicted more accurately than any other soil health properties, which is line with previous findings (e.g., (Gholizadeh et al., 2013)).There were significant and positive correlations between the measured and the predicted values. Mid-DRITFS shows great potential in predicting soil health indicators in Florida sandy soil, particularly POX-C, which is often thought of as the labile carbon pool in the soil. Thus, the mid-DRIFTS technique has great potential as a screening tool for estimating SOM and POX-C. The determination of SOM and POX-C takes at least a full day from sample preparation to the end results. In contrast, the spectra collection can be completed in less than an hour with high throughput instruments available at the UF IFAS. Additionally, the spectra collection does not require additional supplies or generate chemical waste. With the addition of more samples in the future, the performance of mid-DRIFTS model can be further improved.

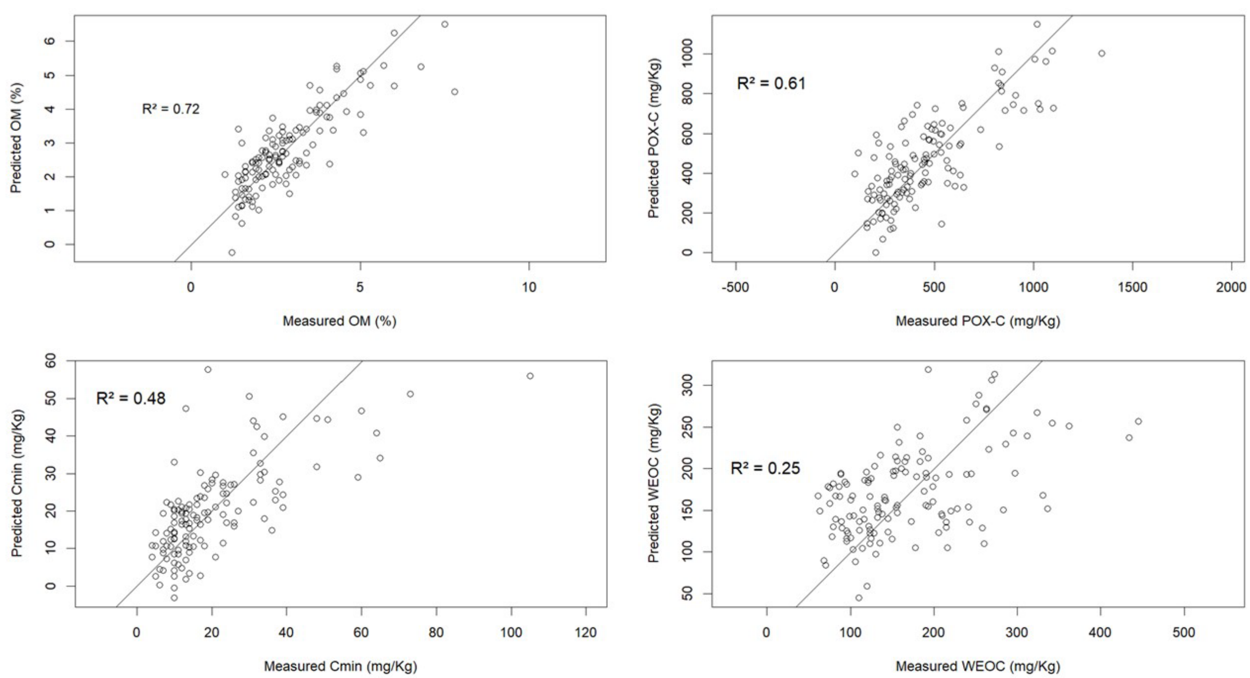


Figure 1. Scatter plot of measured versus predicted values from Florida ranchlands using linear partial least squares regression (PLSR). Straight lines indicate the 1:1 relationship. OM, organic matter; POX-C, permanganate oxidizable carbon; Cmin, mineralizable carbon; WEOC, water extractable organic carbon.

In contrast, the current model was not effective in predicting WEOC content. To improve model performance, we attempted to adopt new analytical methods, such as support vector machines and neural networks. Our results showed that these methods could improve the accuracy of predictions compared to the PLSR method (Table 2). A well-performing model is characterized by a high R-square, low root mean square error (RMSE), and a high residual prediction deviation (RPD). The predictive response of PLSR was better than SVM and NN for SOM, however the SVM outperformed PSLR for Cmin and WEOC. Our findings revealed that the accuracy of predicting soil indicators through mid-DRIFTS is contingent upon the chemometric modeling. When predicting soil organic matter, scientists found that SVM performed better than neural networks (Souza et al., 2012), while other demonstrated that SVM showed greater or similar performance compared to PLSR when predicting TOC (Jia et al., 2017).

Table 2. Summary of the different modeling approach (PLSR: partial least square regression, SVM: support vector machine, NN: neural network) used to evaluate the performance of mid-DRIFTS in predicting soil health indicators in ranchlands in Florida. SOM: Soil Organic Matter, Cmin: mineralizable carbon, WEOC: water-extractable carbon.

| | | $R^2$ | RMSE | RPD |
|---|---|---|---|---|
| **SOM** | PLSR | 0.80 | 0.52 | 2.23 |
| | SVM | 0.75 | 0.58 | 2.00 |
| | NN | 0.75 | 0.57 | 2.01 |
| **Cmin** | PLSR | 0.43 | 9.82 | 1.33 |
| | SVM | 0.54 | 8.84 | 1.47 |
| | NN | 0.50 | 9.22 | 1.41 |
| **WEOC** | PLSR | 0.24 | 58.65 | 1.15 |
| | SVM | 0.48 | 48.71 | 1.38 |
| | NN | 0.29 | 56.71 | 1.19 |

The use of mid-DRFITS in predicting various soil properties, specifically the proportions of clay, silt, and sand, demonstrates a remarkably high level of efficacy, which is effectively illustrated in Figure 2. At least 75% of variation in soil sandy or clay concentration could be explained by the PLSR model, highlighting the potential of mid-DRIFTS in assessing soil texture in highly sandy soils. However, it is important to note that the predictive accuracy concerning the extractable nutrients proved to be poor, as demonstrated by the coefficients of determination, $R^2$, which were recorded at 0.09 for phosphorus and a slightly improved 0.35 for potassium, as shown in Figure 3. This difference in predictive performance highlights the complexities involved in accurately modeling soils properties. Unlike organic matter and sand grain (quartz), these nutrients did not have corresponding reflectance features in the near infrared region. It is also worth noting that the spectral model was reasonable in estimating soil pH ($R^2 = 0.57$). Together these findings suggest that the mid-DRIFTS methods can be used to estimate pH, soil texture, SOM, and carbon-related soil health indicators. In contrast, these models show poor performance in predicting extractable nutrients.

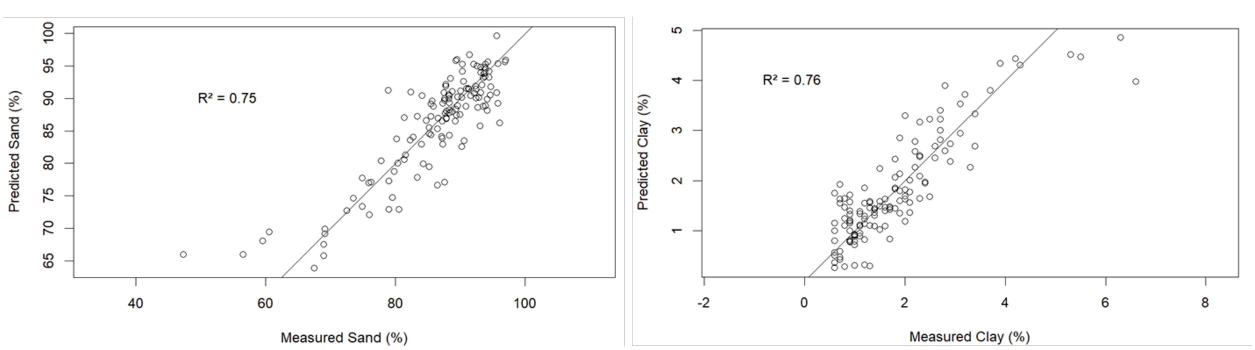

Figure 2. Scatter plot of measured versus predicted particle size distribution (clay and sand) from Florida ranchlands using linear partial least squares regression (PLSR). Straight lines indicate the 1:1 relationship.

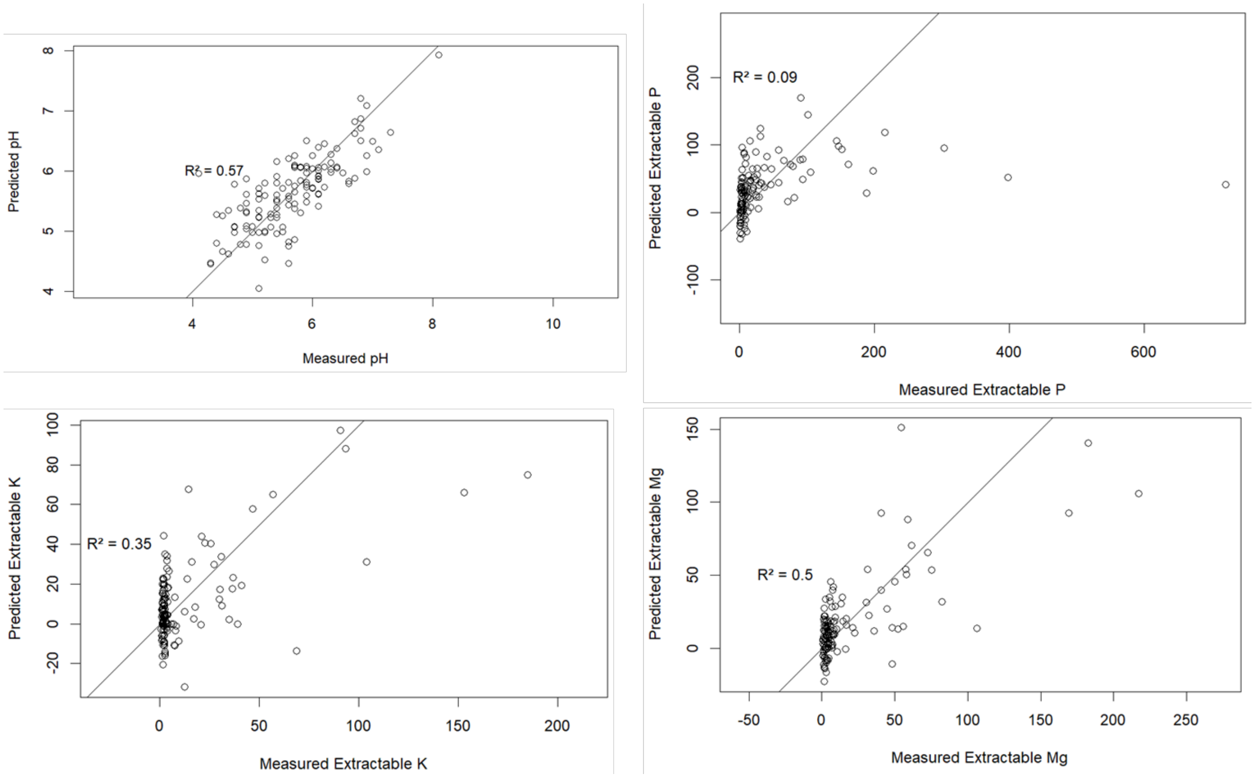


Figure 3. Scatter plot of measured versus predicted values from Florida ranchlands using linear partial least squares regression (PLSR). Straight lines indicate the 1:1 relationship. Extractable P (Phosphorus), K (Potassium), Mg (Magnesium) in mg $Kg^{-1}$.

We also identified the spectral regions that are most important in predicting soil health indicators. These spectral regions correspond to the key functional groups of organic matter and the reflectance features of major soil minerals. Our results show that both SOM and POX-C are positively correlated with a specific organic matter group, known as aliphatic, representing the labile pool of carbon in the soil. In contrast, both indicators are negatively correlated with the reflectance feature of Si-O bonds as found in quartz. These results suggest that as the sand content increases, the presence of these organic groups decreases (Figure 4). We also noted that the POX-C showed a stronger correlation with the aliphatic function group than SOM, while SOM showed a stronger correlation with Si-O bonds. These results are consistent with the interpretation that POX-C represents labile soil carbon. They also imply that organic matter exists as coatings of sand grains, which mask the reflectance of quartz in SOM-rich soils.

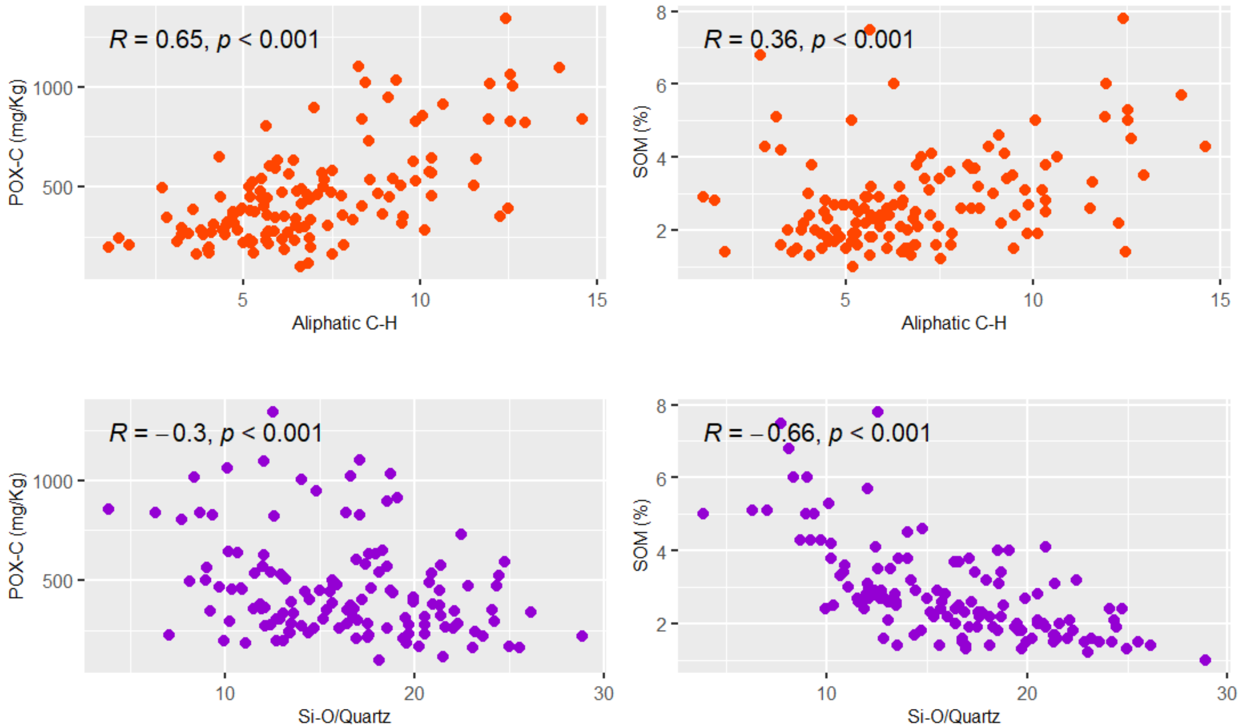


Figure 4. Correlation between POX-C, SOM and aliphatic functional groups and mineral component (Si-O/Quartz).

*Expanding the database*

The database was expanded with 64 more samples received from ranchers across counties in Florida (Table 1). To promote the sampling campaign, we designed a poster (Figure 5) and reached to county and regional extension agents, IFAS forage researchers, and the Florida Cattleman Association. We also advertised it during the 2024 UF Beef Short Course. We asked ranchers to submit at least one sample from their least productive (LP) field and another from their most productive (MP) field.


Figure 5. On the left: poster addressed to the ranchers, extension agents, and faculty. It was also made available publicly to all ranchers in Florida. On the right: the instructions on how to collect and ship the soil samples to the Soil Health lab at UF.

We compared SOM and Cmin between the two groups, but we didn't find any statistical differences (Figure 6). Noticeably, extractable potassium (K) was higher in MP fields than in LP fields with ($p < 0.01$). Soils from MP fields also tended to have higher pH than those from LP fields ($p = 0.11$). These results suggest that soil fertility and K limitation could be a factor driving forage production in Florida ranchlands. We plan to follow up with these findings by conducting greenhouse bahiagrass growth trials and assessing the importance of fertility in driving forage productivity and nutritive values. These new data will also be added to The Database to improve the ability of the model to predict the soil health indicators in Florida's ranchlands.

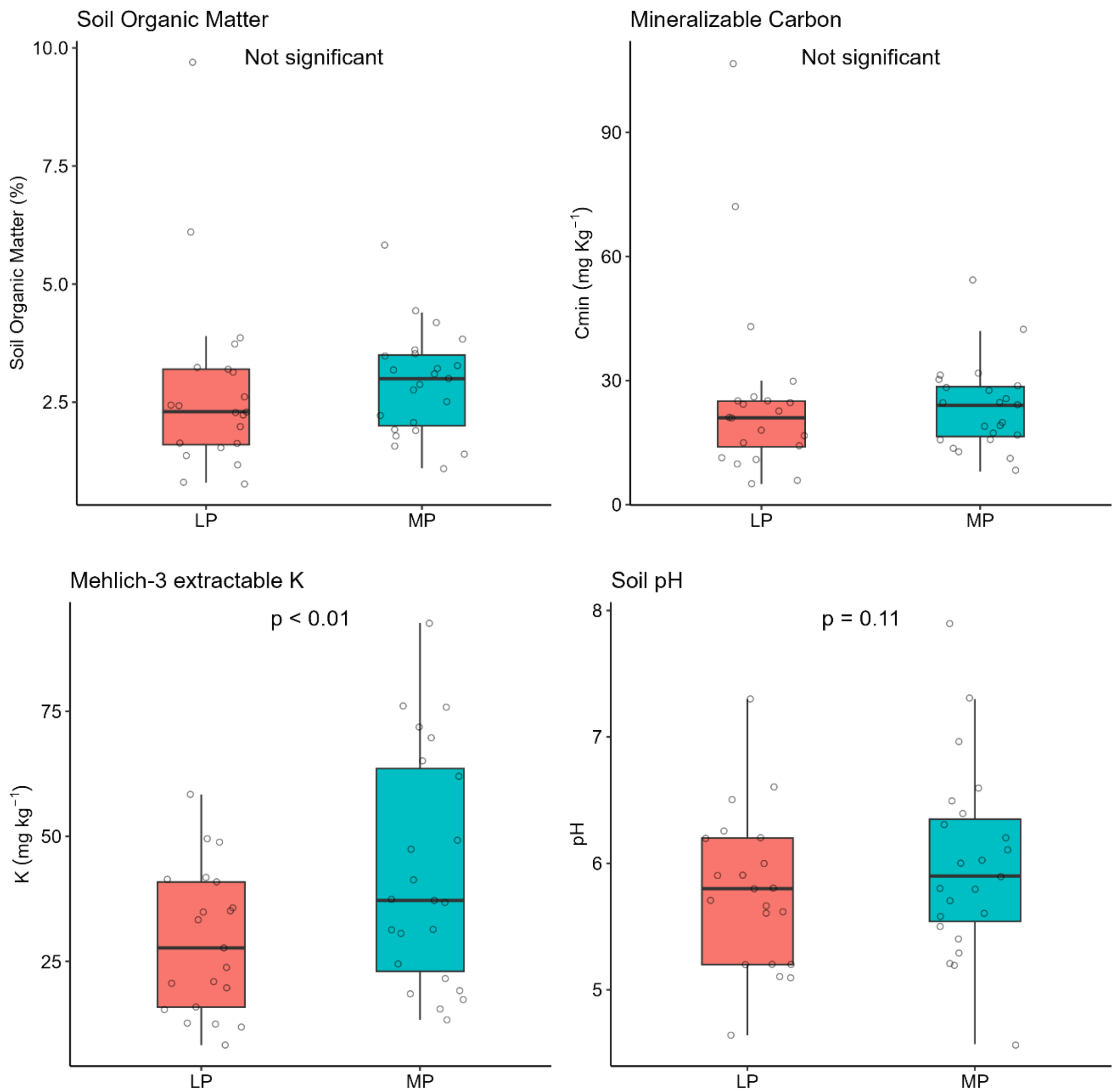


Figure 6. Boxplot of selected indicators among the two groups. P values indicate statistical significance. LP=least productive, MP= most productive.

## OUTCREACH

Co-PI Celestin predicted a poster on the ability of mid-DRIFTS to predict soil properties in the 2024 Summer Conference of the Soil Science Society of America (SSSA) in San Juan, PR from June 10$^{th}$-13$^{th}$ (Figure 7). This opportunity allowed him to exchange with scientists on the performance of mid-DRIFTS and the influence of organic components on soil health indicators. Since The database will remain open, we will continue to reach out to ranchers, extension agents, and faculty to increase our database and improve our model for better results. We are also preparing a manuscript for peer review in which we will summarize the findings of this study.

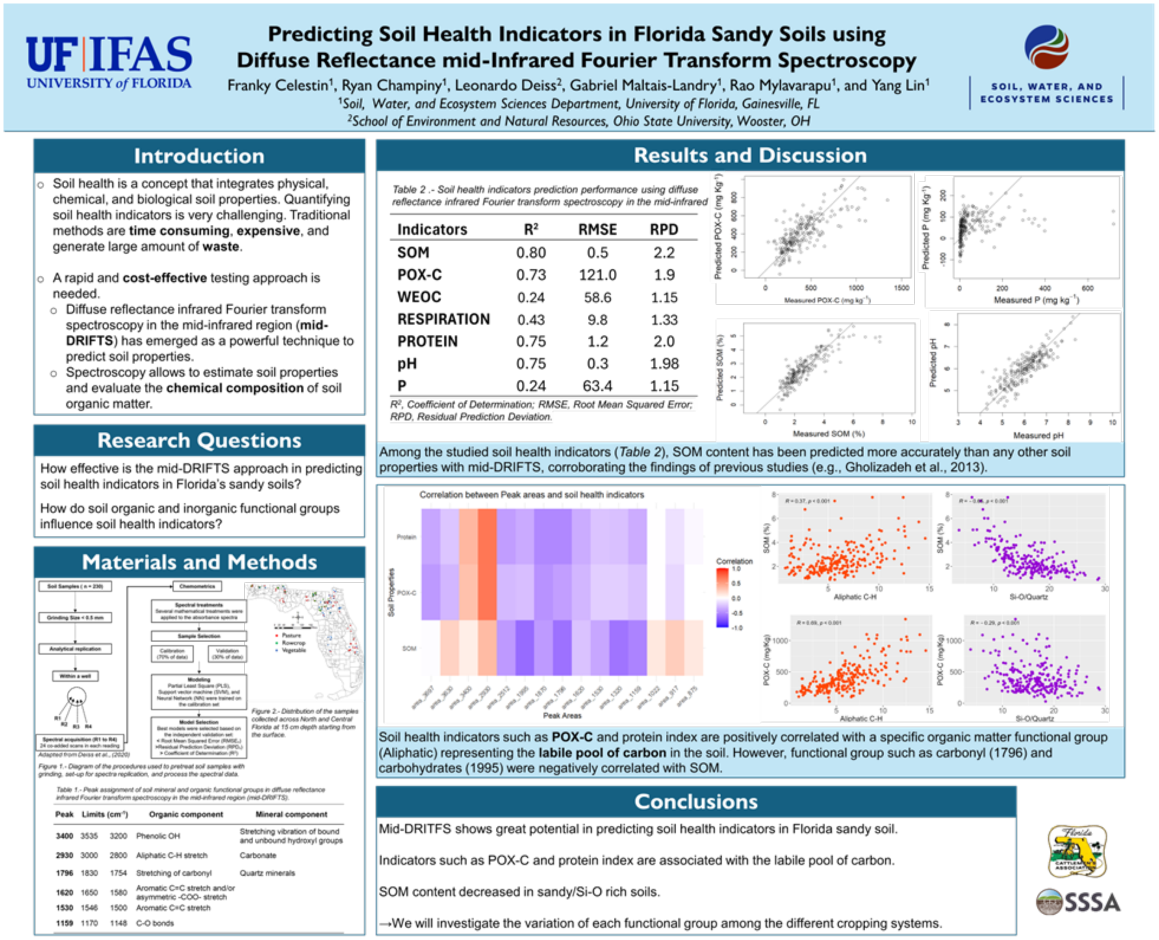


Figure 77. Poster presented at the Soil Science Society conference from June 10$^{th}$-13$^{th}$, 2024 in San Juan, PR highlighting the main findings of our research.

## Conclusion

Our findings revealed great potential of Mid-DRIFTS in predicting soil health indicators in Florida ranchlands. The expansion of The Database will contribute to improving the models for better accuracy in the predictions. The key findings from our results revealed that:

- The mid-DRIFTS models are effective in predicting SOM and POX-C .
- Chemometric modeling can significantly influence the performance of the predictions. In certain instances, SVM outperformed PLSR, but in other cases, the opposite occurred.
- The labile pool of organic carbon representing by the aliphatic group were positively and strongly correlated with POX-C which is a measure of the biologically available carbon in the soil.
- Soil physical properties, particularly, percent clay, silt, and sand were strongly predicted with coefficient of determination equal or greater than 0.75 for all

particle size between the measured and predicted values. This results, again, further highlights the ability of mid-DRIFTS to predict soil properties.

The Database will remain open, as increasing our soil sample size is detrimental in our quest to improve soil health management in Florida ranchlands. Additionally, we will also take into consideration different management practices operated in the pasture systems to explore other factors that may influence the indicators. Furthermore, the insight we gathered so far represents a crucial step in enhancing our understanding of predicting soil health indicators.

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| Principal Investigator: | Lin,Yang |
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| Award Amount: | $24,907.00 |

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| **Invoice #** | I000130474 |
| **UF Award #** | AWD15835 |
| **Primary Project #** | P0325275 |
| **Primary Department:** | 60210000 |
| **Current Invoice Amount:** | $23,009.54 |

| Description | Current | Cumulative |
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| Personnel - Salary | $4,619.18 | $5,726.92 |
| Personnel - Fringe Benefits | $354.43 | $485.11 |
| Materials and Supplies | $10,115.88 | $10,115.88 |
| Contractual Services | $2,312.02 | $2,312.02 |
| Publication Costs | $11.00 | $11.00 |
| Other Expenses | $133.49 | $133.49 |
| Domestic Travel | $2,760.66 | $2,782.66 |
| Foreign Travel | $237.62 | $237.62 |
| Direct Cost | $20,544.28 | $21,804.70 |
| Facilities and Administrative Costs | $2,465.26 | $2,616.50 |
| **Total** | $23,009.54 | $24,421.20 |

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