BUILDING A SOIL HEALTH DATABASE FOR FLORIDA RANCHLANDS

Soil, Water, and Ecosystem Sciences – University of Florida

Funded by the Florida Cattle Enhancement Board

This project established a statewide soil health database to characterize soil properties across Florida ranchlands and evaluate how management and site factors influence soil health.

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Final Report: Building A Soil Health Database for Ranchlands in Florida
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Soil health testing offers valuable data to promote environmentally friendly and climate-smart practices among cattle farmers. Several commercial and academic laboratories have developed methods to assess soil health; however, these methods cannot be readily applied to Florida ranchlands. Our unique soils and climate conditions call for a local soil health database to better serve the needs of the Florida beef cattle industry. To date, a comprehensive database of soil health in Florida ranchlands does not exist. Building a representative dataset is the essential first step towards developing a soil health assessment method for Florida ranchlands.

The main objectives of this project are to 1) develop an open and living soil health database for Florida ranchlands (The Database, in short); and 2) identify the influences of state factors and common management practices on soil health conditions. This proposal addresses the FCA Research & Education Priorities #4 Ranching Activities: Interactions with the Environment.

SAMPLING STRATEGIES

The collection of the soil samples was done in collaboration with UF|IFAS extension agents and ranchers. Soil cores (5-10) were collected in each field to form a composite sample from either grazed pasture or hayfields at the 0-15 cm depth. In addition to that, GPS coordinates were recorded for each sample which will help in generating the climate data (precipitation and temperature) from the database *Worldclim*. Data regarding soil order and suborder, soil series, and drainage class were extracted from the NRCS Web Soil Survey. A total of 129 soil samples were collected in 35 counties in Florida (Figure 1).

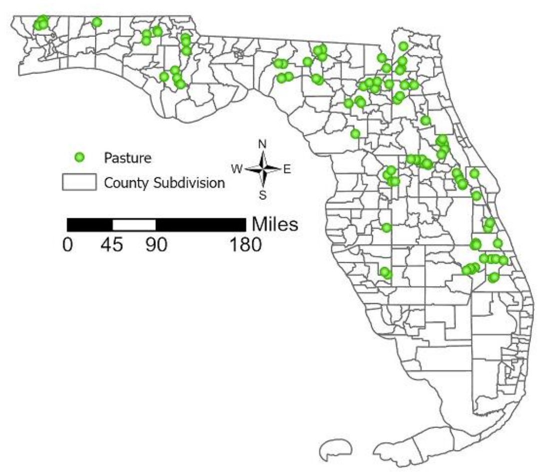


Figure 1. Sample location across the state of Florida.

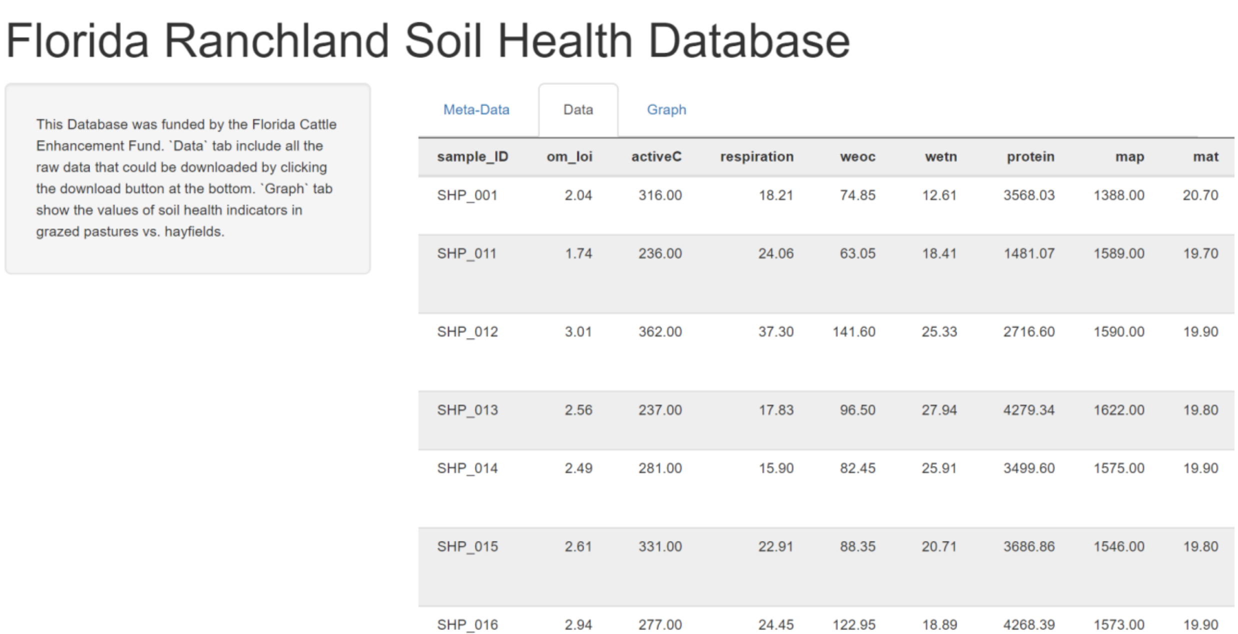
SOIL HEALTH INDICATORS

In The Database, a variety of biological and chemical indicators of soil health were measured following a standardized set of methods. We used Mehlich-3 extraction to determine the potential nutrient limitation (i.e., phosphorus, potassium, calcium, and magnesium) on forage productivity. Often considered as a master variable, pH was determined in a 1:2 soil slurry (soil:water) using an electrode. We have analyzed a suite of biological soil health indicators. Soil organic matter has been determined via loss on ignition (LOI, %). We have completed the measurement of active carbon, or potassium permanganate oxidizable carbon (POX-C, ppm), 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). Soil respiration, also known as mineralizable carbon (Cmin, ppm), measures 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). It was determined by measuring CO_2 production over 24 hours from rewetted soil with an infrared gas analyzer (Bekku et al., 1997). Soil protein index (ppm) has been shown as a potential indicator of plant available organic nitrogen (Hurisso et al., 2018), and was measured using a colorimetric assay applied on the citrate extract of autoclaved soil (Wright & Upadhyaya, 1996). The analysis of soil texture was significantly delayed due to a malfunction of instrument. We will update the texture data to the online database soon.

OUTCOMES

Online Database

The entire database has been made available to the public at https://ylin2.shinyapps.io/FL_Ranchland_Soil_Health/ (Figure 2). All the raw data could be downloaded directly from the website. The website also provides all the necessary meta-data to understand the measured indicators, as well as plots comparing values of indicators between grazed pastures vs. hayfields.



sample_ID	om_loi	activeC	respiration	weoc	wetn	protein	map	mat
SHP_001	2.04	316.00	18.21	74.85	12.61	3568.03	1388.00	20.70
SHP_011	1.74	236.00	24.06	63.05	18.41	1481.07	1589.00	19.70
SHP_012	3.01	362.00	37.30	141.60	25.33	2716.60	1590.00	19.90
SHP_013	2.56	237.00	17.83	96.50	27.94	4279.34	1622.00	19.80
SHP_014	2.49	281.00	15.90	82.45	25.91	3499.60	1575.00	19.90
SHP_015	2.61	331.00	22.91	88.35	20.71	3686.86	1546.00	19.80
SHP_016	2.94	277.00	24.45	122.95	18.89	4268.39	1573.00	19.90

Figure 2. Screenshot of the Florida Ranchland Soil Health Database.

Relationships among indicators

Chemical indicators of soil health are correlated with each other (Figure 3). There are strong positive correlations between Mehlich 3-extractable K, Mg, and Ca with correlation coefficients above 0.75. This finding is not surprising, as these indicators all correspond to cation availability. As an anion, Mehlich 3-extractable P is more strongly correlated with Ca than K or Mg. In contrast, soil pH is only weakly correlated with other chemical indicators.

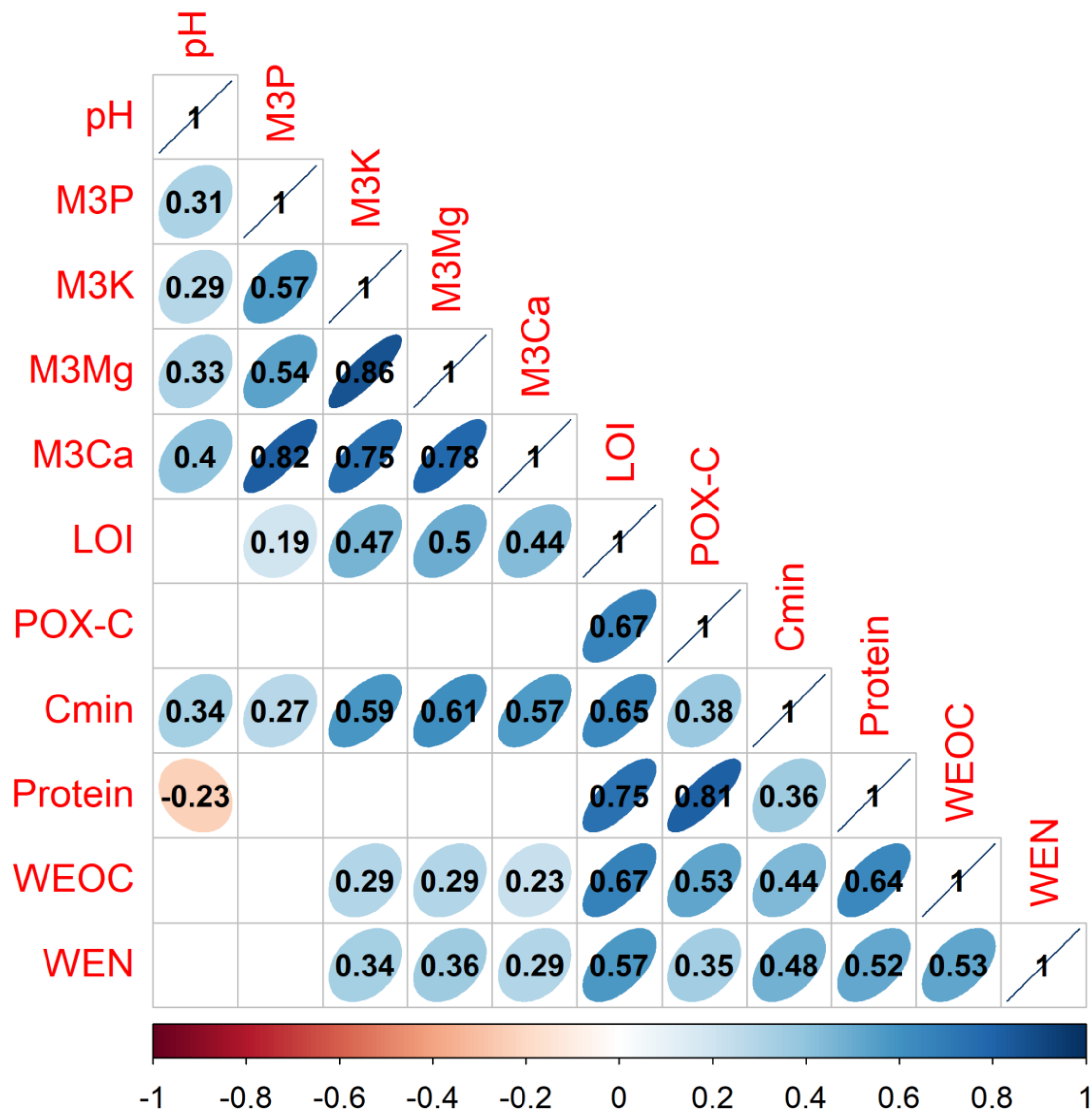


Figure 3. Correlation coefficients among soil health indicators. Values represent Pearson's correlation coefficient. Blue color indicates positive correlation, while red color indicates negative correlation. No value indicates that there is no significant correlation between the two indicators.

Biological indicators of soil health also correlate with each other (Figure 3). Most noticeably, soil organic matter (LOI) was positively correlated with all other soil health indicators. These correlations are also relatively strong, as their correlation coefficients are above 0.65, except for water extractable nitrogen. Given the simplicity and cost effectiveness of LOI measurements, these results suggest that LOI could be a useful indicator for future soil health research and assessment in Florida ranchlands. The active carbon and protein index is strongly correlated with each other. The two indicators also show similar responses to grazing systems (discussed later). These results suggest that active carbon and protein index might offer redundant information on soil health. It might be sufficient to include only one of them in future work.

Not all biological indicators of soil health are correlated with chemical indicators (Figure 3). Soil respiration, also known as mineralizable carbon (Cmin), is the only biological indicator that correlates with all chemical indicators. In particular, the correlations between Cmin and Mehlich 3-extractable cations are strong with correlation coefficients in the range of 0.57-0.61, suggesting that cations could explain 33-35% of variance of Cmin. As Cmin has been as an indicator of microbial activity (Liptzin et al., 2022), our results suggest that these cations not only serve as plant nutrients but only regulate microbial activity. In contrast, POX-C (active carbon) and protein index do not correlate with chemical indicators, while water-extractable organic carbon only show weak correlations. These indicators are likely presentative of a fraction of soil organic matter, rather than microbial activity.

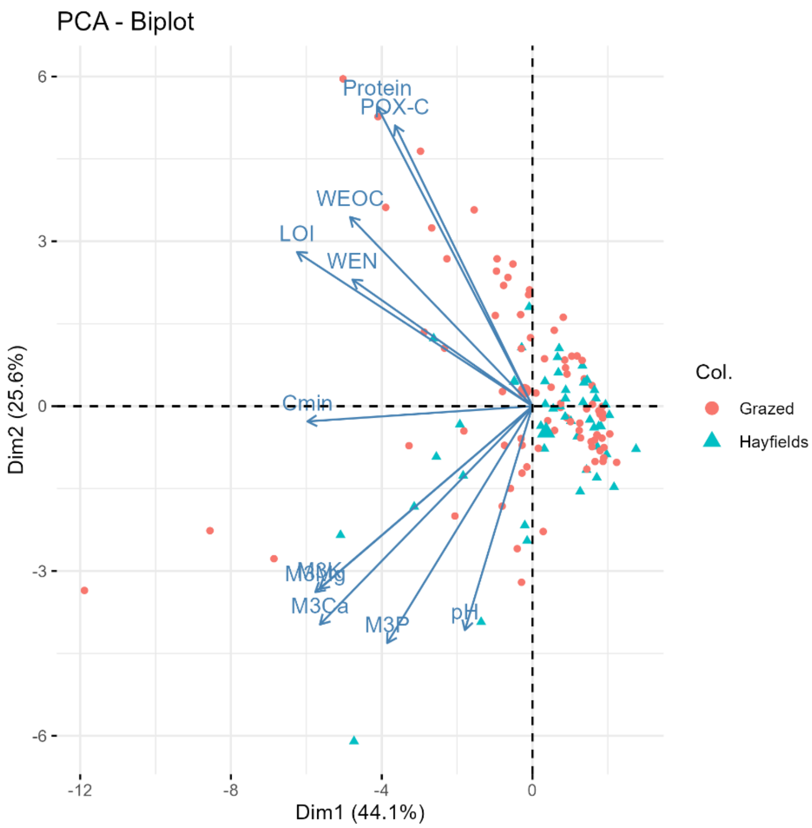


Figure 4. Principle component analysis (PCA) showcasing the relationships among soil health indicators. Dots indicate soil samples, while arrows represent the effects of soil health indicators. The first and second components together explain 69.7% of variance of the database.

Results of principle component analysis (PCA) further highlight the differences between chemical and biological indicators (Figure 4). The first and second components together explain 69.7% of variance of the database. The biological indicators are closely clustered together, except for Cmin, while the chemical indicators are together in a different cluster. The two cluster are roughly perpendicular to each other, suggesting that chemical and biological indicators are convening different information regarding soil health. The Cmin is relatively separated from both clusters, which is consistent with earlier results of correlation.

Nutrient status

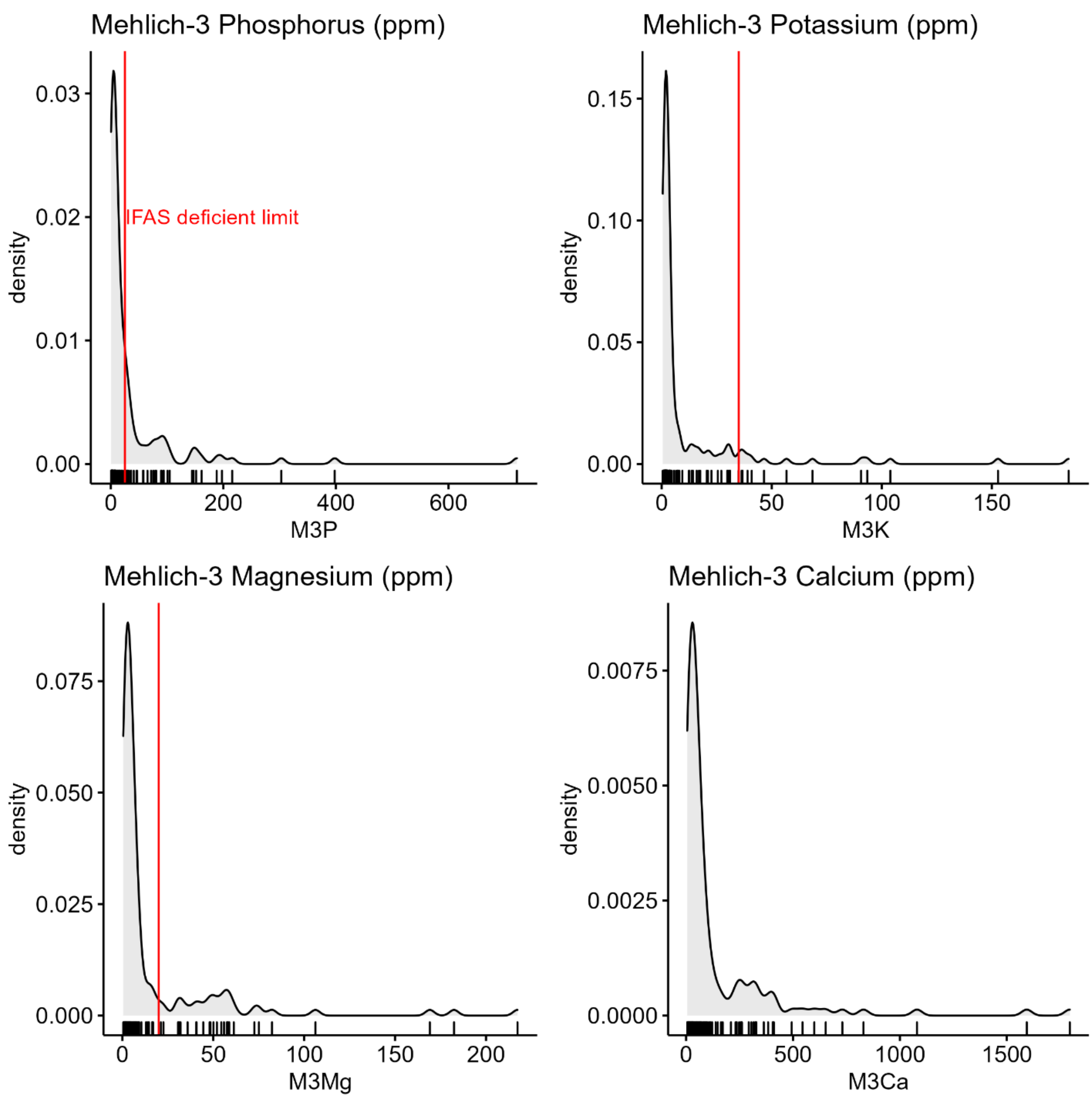


Figure 5. Density distribution of Mehlich 3 extractable nutrients relative to their deficiency limits (red vertical lines) recommended by UF IFAS.

We compare the measured Mehlich 3 nutrient values with their deficiency limits recommended by UF IFAS (Figure 5). All nutrients show a long tail on the right end of their distributions, indicative of high values. Most nutrient values are below their deficiency limits, while high nutrient values are rare. For instance, 70.9% of soils are below the phosphorus deficiency limit of 25 ppm. 79.5% and 90.6% of soils are below the deficiency thresholds of potassium and magnesium, respectively. Note that UF IFAS has not established a deficiency threshold for calcium yet. Even though our database includes many soils that are actively managed for hayfield, these nutrient values remain relatively low. These results highlight the challenges in managing nutrients in sandy Florida soils with low nutrient retention capacity (Shaddox & Sartain, 2017).

Impacts of pasture systems

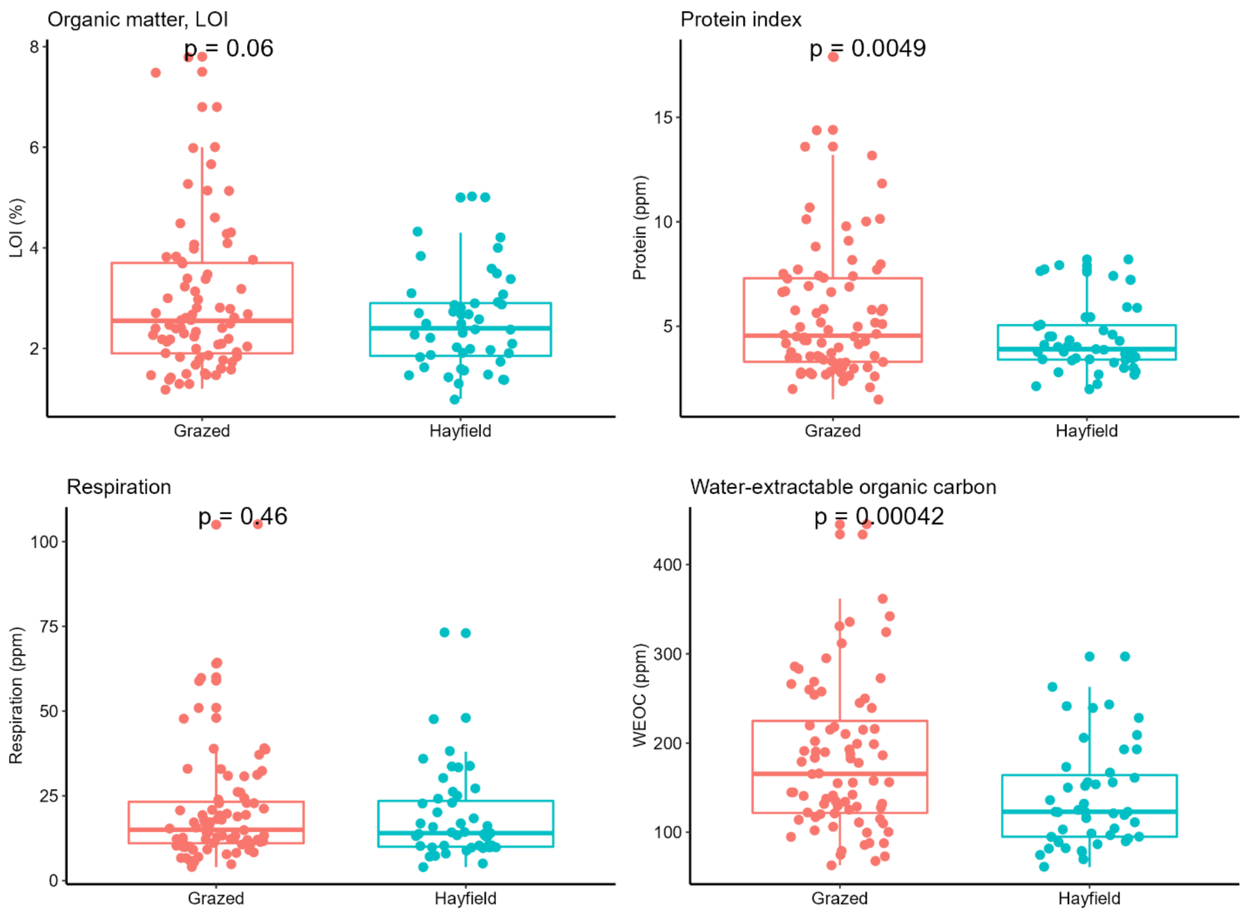


Figure 6. Impacts of pasture systems on soil health indicators. P values indicate statistical significance.

Our results show that pasture systems (i.e., grazed pastures vs. hayfields) have a strong impact on the values of soil health indicators (Figure 6). Soil organic matter is marginally higher in grazed pastures than in hayfields ($p = 0.06$). Protein index is significantly higher in grazed pastures than in hayfields ($p < 0.01$), while POX-C and WEOC also show similar patterns. These findings reflect important differences in management practices between grazed pastures and hayfields. The hayfields are subject to a greater management intensity as opposed to the grazed pasture. Use of heavy machinery, tillage, fertilization, and pest control are commonly used in hayfields, while these practices accelerate organic matter decomposition by disrupting soil structure and relieving nutrient limitation (Nunes et al., 2020; Sanderman et al., 2017). In addition, the accumulation of livestock waste likely contributes to higher soil organic matter in grazed pastures than in hayfields (Russelle et al., 2007). Interestingly, Cmin value is not affected by pasture systems. Our results suggest that Cmin is likely representative of microbial activity, while other indicators including protein, POX-C, and WEOC are more indicators of organic matter availability.

In terms of chemical indicators, only Mehlich 3 phosphorus was marginally higher in hayfields than in grazed pastures (p = 0.08), while other chemical indicators are not affected by pasture systems. More frequent fertilization in hayfields is likely to explain the differences in phosphorus. Overall, our results indicate that management intensity has a strong impact on the soil health of Florida pastures, and most biological indicators, with the exception of Cmin, are able to reflect this difference.

Impacts of drainage class

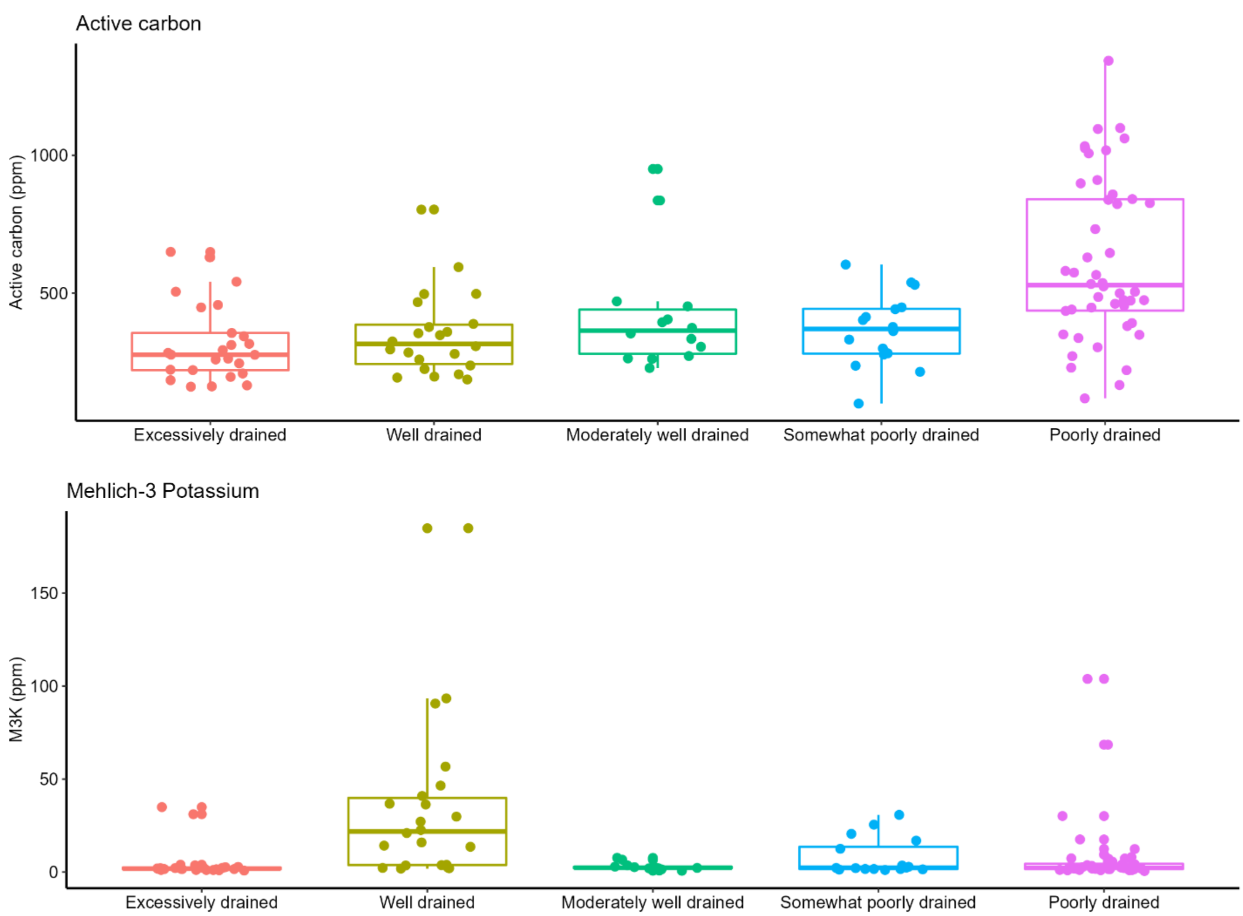


Figure 7. Impacts of soil drainage class on selected soil health indicators. Drainage becomes more constrained from left to right.

Soil drainage class is another important environmental driver that influences the values of soil health indicators (Figure 7). Except for Mehlich 3-extractable phosphorus, all soil health indicators vary significantly across different soil drainage classes. POX-C values are higher in poorly drained soils than in other classes with better drainage. Other biological indicators also show a similar pattern. Poor drainage is typically associated with high water table and more frequent of soil saturation and anaerobic periods, which all favor the accumulation of organic matter. Our results thus indicate that soil hydrological conditions are an important driver of organic matter accumulation in Florida ranchlands.

Soil drainage class also influences chemical indicators; however, its effects are different from those on biological indicators (Figure 7). For example, Mehlich 3-extractable potassium values are higher in both well drained and poorly drained than in other drainage classes. It is unclear why chemical indicators exhibit such a bimodal pattern across the drainage gradient. We notice that both well drained and poorly drained consist of more data points than other classes. Thus, it is more likely to obtain samples with high nutrient values in these classes, as high nutrient samples are rare. Further research is needed to better understand the impacts of soil drainage on chemical indicators.

Relative importance of environmental drivers

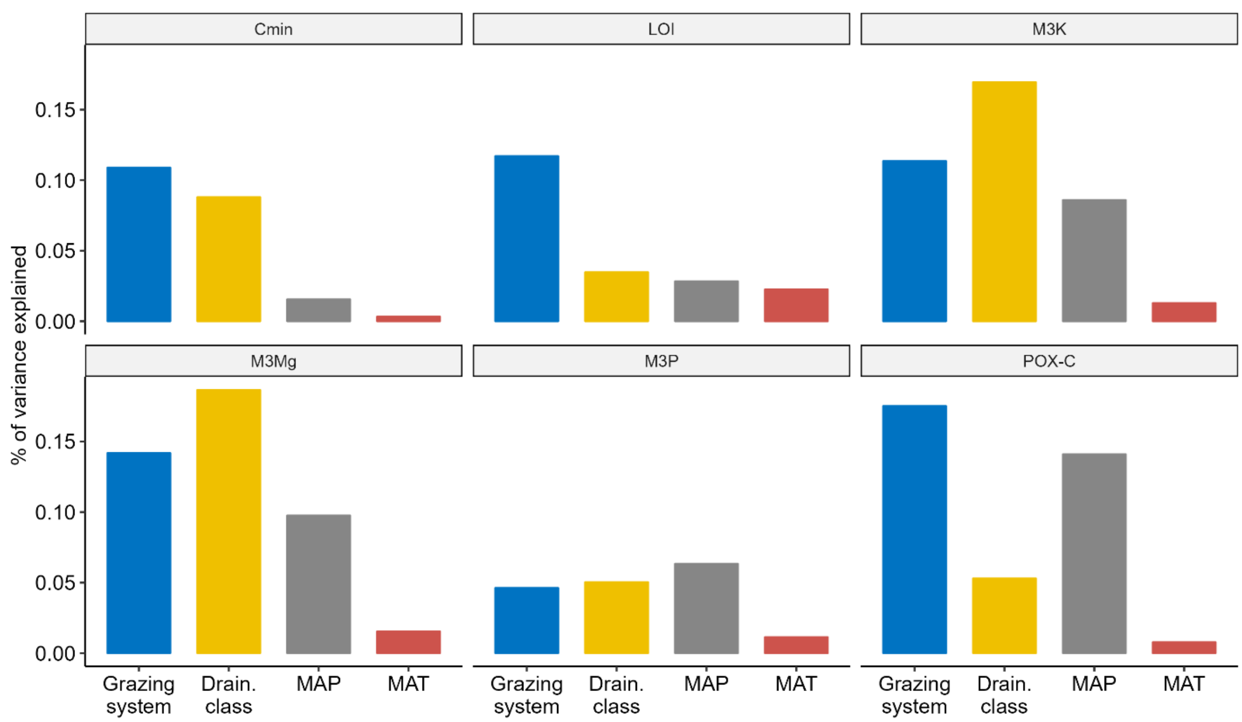


Figure 8. Percent variance explained by different environmental drivers for selected soil health indicators. Drain. Class, drainage class. MAP, mean annual precipitation. MAT, mean annual temperature.

Pasture system emerges as a key driver of soil health for most indicators (Figure 8). Pasture system consistently explains 10-20% of variance in each soil health indicator, highlighting the importance of management intensity on soil health. Drainage class also influences many indicators. For example, drainage class explains more variance than pasture systems for both Mehlich 3-extractable potassium and magnesium. However, as described in the last section, the effects of drainage class do not follow the gradient of soil hydrological conditions. Further research is still required to better understand the impact of soil drainage class on soil health.

Climate including mean annual precipitation and temperature do not cast a consistent effect on soil health indicators. Certain indicators, including POX-C and Mehlich 3-extractable cations, are affected by climate. For instance, POX-C values are generally higher in pastures with lower mean annual precipitation, while Mehlich 3-extractable potassium levels are lower. Interestingly, both POX-C and protein index show similar trends along the climate gradient, again suggesting that both indicators offer similar information regarding soil health. Although more research could help to better understand these patterns, the lack of consistent climate impact suggests that future soil health assessment might not need to consider climate variability in Florida pasture systems.

OUTREACH

Through this study we were able to communicate with farmers and extension agents directly on the importance of establishing a soil health database for Florida and its role in promoting a sustainable environment. From February 27th to 28th, 2023, we shared an update of our project with extension agents, UF faculty, and students at the UF|IFAS Annual Forage Workers Tour and Workshop in Marianna, FL. On March 17th, we addressed a group of producers and extension agents at the Spring Ranchers Forum proceeding hosted by the Central Florida Livestock Agents Group. We presented the soil health database project and discussed soil health management with producers. This has led to opportunities to visit and to sample soil from the ranches of several producers. We will explore other opportunities to engage with different stakeholders to promote the soil health database and increase the sampling collection.

CONCLUSION

The establishment and public accessibility of the Database is a significant step in advancing our understanding of soil health conditions in Florida ranchlands. Our analyses highlighted several key takeaways:

- There exists a clear distinction between chemical and biological indicators. While many chemical indicators correlate with each other, soil pH remained an outlier. Likewise, the biological indicators showed strong correlations, particularly the strong association of soil organic matter with other health metrics.
- Management practices exert a significant influence on soil health. Our data showed that hayfields, with their intensive management strategies, influence soil health differently than grazed pastures. This is evident in the organic matter content and other biological indicators.
- Soil drainage class emerges as a prominent factor affecting both biological and chemical soil health indicators. Notably, the patterns of chemical indicators across the drainage gradient are not intuitive and require further exploration.

- Contrary to expectations, climatic factors, such as mean annual precipitation and temperature, didn't exhibit a uniform impact on all soil health metrics. This suggests that in the context of Florida's pasture systems, climate variability may not be as pivotal a factor as previously believed.

The current study has opened up avenues for a nuanced understanding of soil health indicators in Florida's pastures. The database's potential as a tool for sustainable agricultural practices and the broader implications for environmental stewardship are evident. The findings urge for more focused research on a deeper delve into the intricate balance between various management practices and their implications on soil health.

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