EMPLOYING STATISTICAL MODELS TO DETERMINE THE SOIL TESTS AND/OR SOIL CHARACTERISTICS THAT IMPROVED EONR PREDICTION IN CORN

Daniela Orjuela-Díaz[1], Carrie A.M Laboski[2], Francisco Arriaga[1]
[1]Soil Science Department, University of Wisconsin - Madison, WI, USA
[2]USDA- ARS, Pasture Systems & Watershed Management Research Unit, University Park, PA, USA
orjueladiaz@wisc.edu (765) 775-9150

ABSTRACT

In corn production, nitrogen (N) fertilization is crucial for increasing yield. However, in the last few years, there has been a push to use less N due to environmental concerns and production costs. There has been an interest in using soil health tests to predict N mineralization potential and further understand soil N availability to adjust N recommendation rates. Different statistical models like regression or decision tree analysis have been used to determine how the Economic Optimum N Rate (EONR) can be predicted using only soil test results and/or combining them with soil characteristics. The objective of this study was to evaluate statistical models to identify which soil test and/or soil characteristics predict the EONR for corn in Wisconsin. In total, 23 N response trials were conducted in 2019 and 2020. Samples from 0-15 cm depth were taken at planting from the no N treatments. A total of six soil tests were conducted: total organic carbon (TOC), total carbon (TC), active carbon, soil respiration, ammonium content (NH_4) at 0 and 7 days, and mineralizable N (PMN). EONR and yield were determined for each site. Regression and decision tree analyses were evaluated to predict EONR. The results identified NH_4 and active carbon as soil tests that can predict EONR in corn. Ammonium proved useful for detecting non or minimally responsive sites (mean 11.6 lb. N $acre^{-1}$), while active carbon was valuable for predicting EONR at responsive sites. The segmented, the decision tree, and multiple stepwise regression models performed similarly when evaluating actual vs. predicted EONR, with an average R^2= 0.7242. These diverse statistical analyses highlight the potential to assess optimal sidedress N rates for corn production, including identifying minimally or non-responsive sites.

INTRODUCTION

In corn production, for farmers, it is important to decrease nitrogen (N) use to maintain economic profit and avoid leaching and environment contamination. Better prediction of the potential N mineralization in the soil is key to understanding soil N availability. Recently, there has been an increase in interest in using soil health tests to potentially predict N mineralization. Further the use of different statistical models can be used as tools to predict EONR. These different statistical models allow to predict EONR based on single test results, combination of tests, and include soil characteristics in the models.

The objective of this study was to evaluate statistical models to identify which soil test and/or soil characteristics predict EONR for corn in Wisconsin.

METHODS

In 2019 and 2020, 23 small-plot field trials were conducted in 16 counties on private and university farms. Soil texture and drainage class, previous crop, use of cover crop, and manure history varied by site (Table 1). Corn grain yield response to sidedress N (0 to 200 lb. N $acre^{-1}$ in 40 lb. N $acre^{-1}$ increments at ~ V6; 4 replications) was evaluated. At each site, the EONR was calculated using an N: corn price ratio of 0.1 (e.g. 0.5 $ per lb. N:5 $ per lb. grain) after fitting a model to the yield response data (quadratic plateau, linear plateau, or linear; best-fit model chosen based on R^2).

Soil samples (0-15 cm) were collected in the no N control plot within 3 days of planting. Samples were dried (90 °F) and ground (2mm) and analyzed for six bio/chemical soil tests: total organic carbon (TOC), total carbon (TC), and total N (TN) all analyzed on a LECO CN928 combustion analyzer; active carbon (permanganate oxidizable carbon, modified from Weil et al., 2003); soil respiration (CO_2 measured after 4 day incubation with sample rewet, CASH manual); Ammonium content (NH_4) and Potential Mineralizable N, (PMN) measured as NH_4 content after 7 days of anaerobic incubation at 40 °C, both PMN and NH_4 were extracted with 2M KCL and read with a spectrophotometer. The soil characteristics included as predictors were Soil drainage class, Texture class, and Available water capacity.

The relationship between EONR and soil tests was evaluated using correlation. Regression, stepwise regression, and decision tree analysis were used to predict EONR based on soil test results and soil characteristics. All analyses were performed in R studio.

RESULTS

Using correlation analysis, the tests that best correlate to EONR were NH_4 (r= -0.75), Respiration (r= -0.72), and Active carbon (r= -0.56) (Figure 1). Visual inspection showed that a segmented model may best fit the relationship between NH_4 and EONR. The result was a linear plateau model with R^2=0.71, p value <0.001, and a critical point of 9.98 ppm (Figure 2). In the stepwise regression analysis, the best single predictor was NH_4 with Adj R^2=0.64 (Table 1). In addition, when using more than a single test, the overall best predictor of EONR was the model that includes NH_4 and active carbon Adj R^2=0.68 (Table 1). The model formula was EONR= 300.27 – 0.150*Active carbon – 20.36*NH_4.

When including the soil characteristics as predictors, the decision tree analysis identified NH_4 and active carbon as the most effective parameters for EONR prediction. Ammonium proved useful for detecting non or minimally responsive sites (mean 11 lb N $acre^{-1}$), while active carbon was valuable for predicting EONR at responsive sites (Figure 2). Because the models predicting EONR from active carbon were not significant, and model parameters were very similar regardless of high or low active carbon in the original decision tree, a Modified decision tree was created by combining the active carbon branches (Figure 3). The resulting prediction of EONR when NH4 < 6.8 ppm was EONR = -0.2236*Active carbon + 244.68 with an R^2= 0.48 and a p value= 0.001 (Figure 3). Incorporating soil drainage class, texture class, and available water into decision tree analysis did not yield any significant predictors for EONR. The model outputs were used to calculate a predicted EONR, which showed that all models could predict EONR based on test results (Figure 4). Overall, the modified decision tree was the best model with an R^2=0.82.

Table 1. Stepwise regression analysis using soil health tests to predict EONR

# Of Parameters	Test combination	R^2	Adj R^2	AIC	BIC	Cp	RMSE
1	NH_4	0.64	0.62	220.4	222.1	1.3	40.5
1	Respiration	0.45	0.42	229.3	231.1	11.0	50.1
2*	NH_4+ Active carbon	0.72	0.68	218.3	220.0	-0.67	36.8
2	NH_4 + Respiration	0.70	0.67	219.3	221.0	0.02	37.7
3	NH_4 + TC + ActiveC:TN	0.73	0.68	220.6	221.9	0.53	36.8
3	NH_4 + TOC + ActiveC:TN	0.72	0.68	221.1	222.3	0.82	37.2

*Indicates the best model

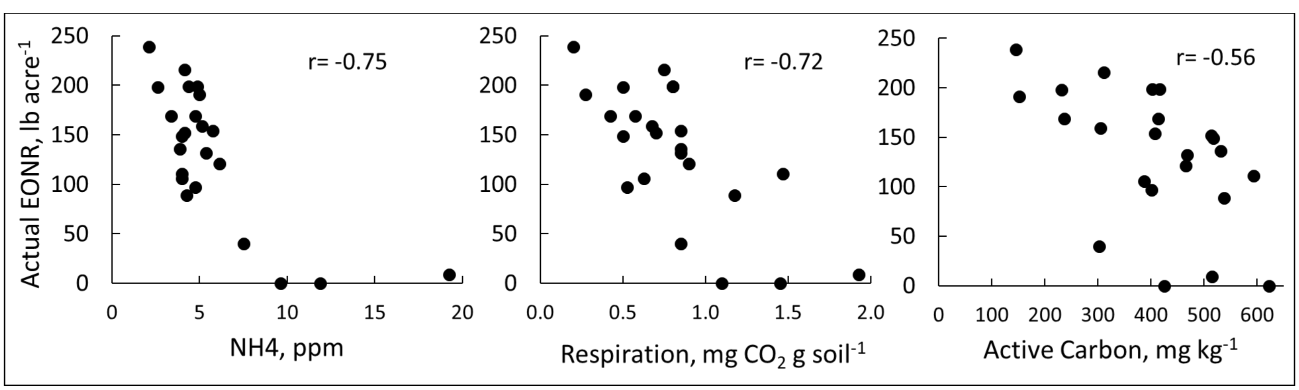

Figure 1. Correlation analysis between EONR and soil test results.

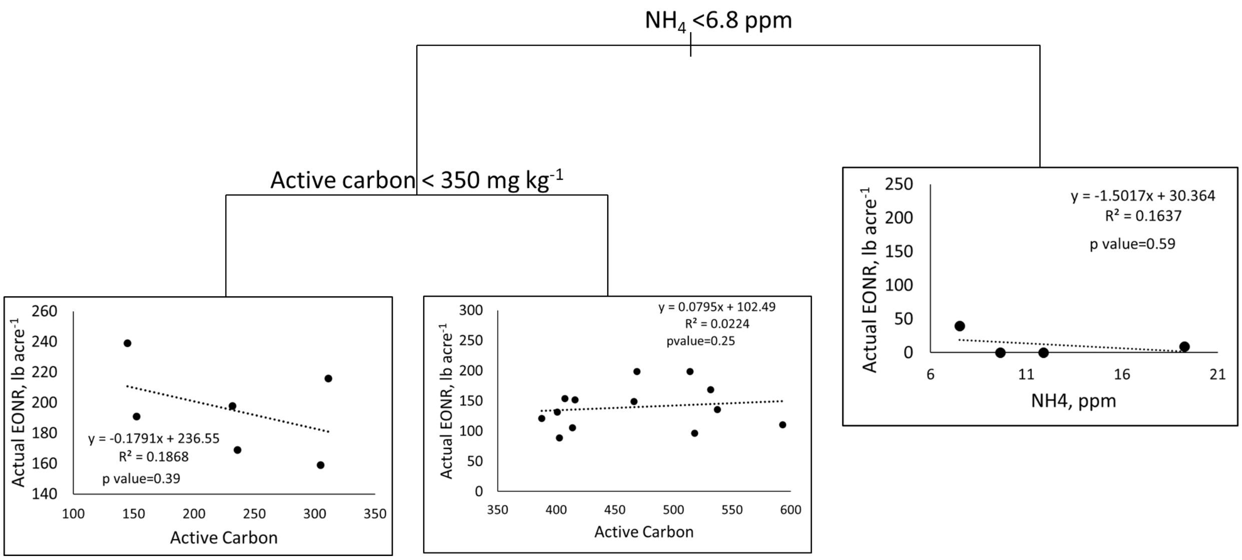

Figure 2. Decision tree analysis results using soil tests and soil characteristics to predict EONR.

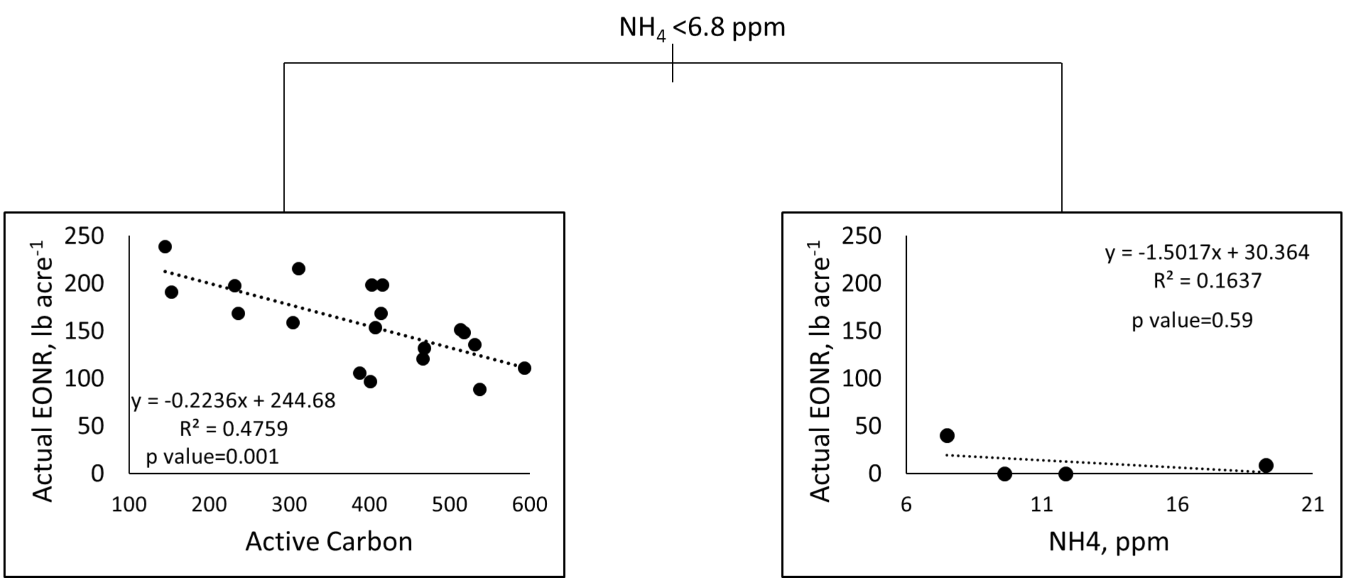

Figure 3. Modified Decision tree analysis results using soil tests and soil characteristics to predict EONR.

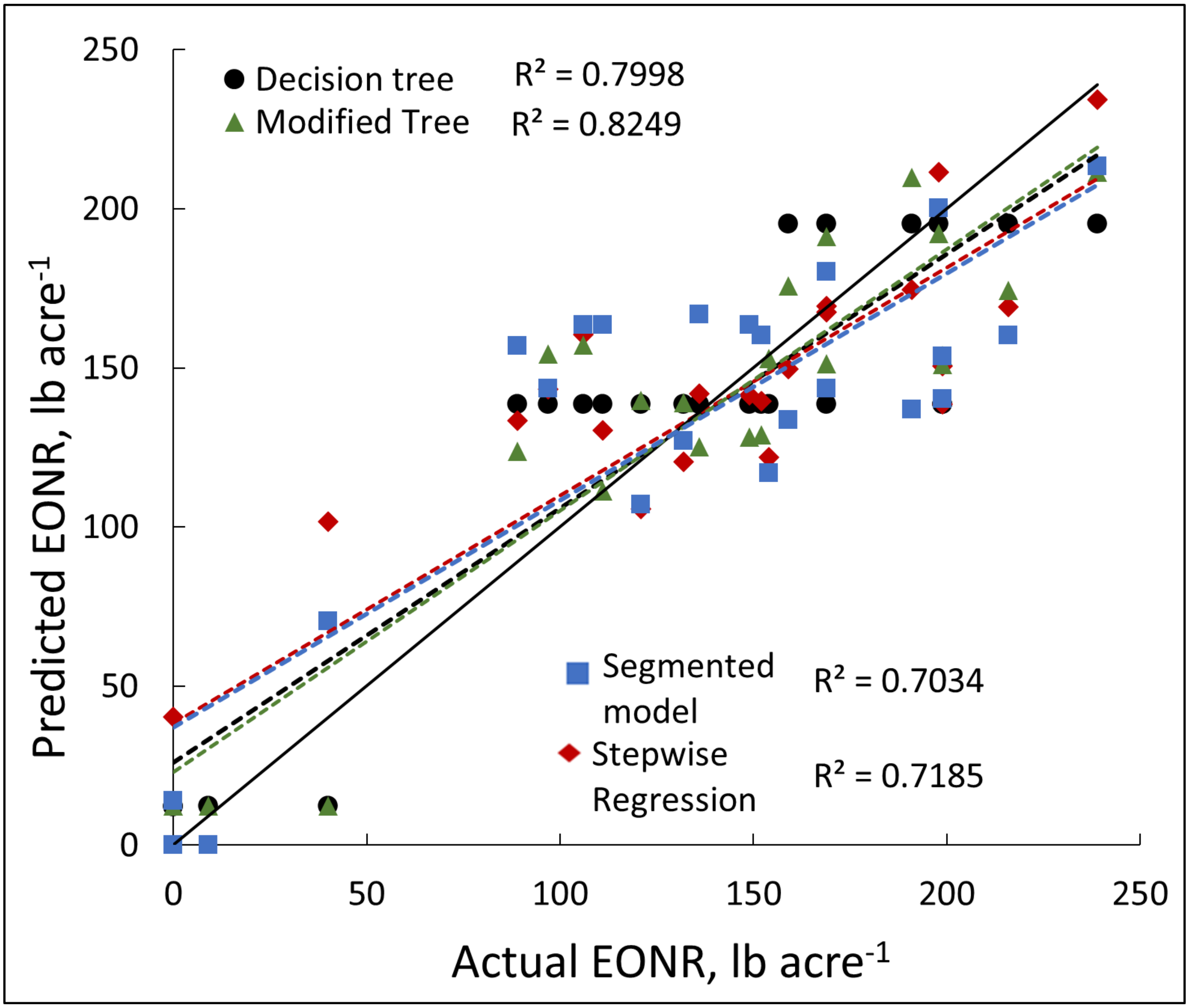

Figure 4. Actual EONR vs predicted EONR using outputs of the 4 different models.

CONCLUSION

The segmented model, decision tree, and multiple regression models performed similarly when evaluating actual vs predicted EONR, with an average R^2= 0.72 (Figure 4). The modified decision tree showed a marked increase in R^2 (R^2= 0.83) compared to the other models. While the modified decision tree has the highest R^2, it requires two soil tests. Thus, a segmented model, which is somewhat less predictive, may be more cost-effective since it requires only one soil test (Ammonium). In conclusion, these diverse statistical analyses highlight the potential to assess optimal side-dress N rates for corn production, including identifying minimally or non-responsive sites by analyzing 0-15 cm soil samples collected at planting for NH_4 and active carbon.

ACKNOWLEDGEMENTS

Thanks to Jerry Clark, Carl Duley, Bill Halfman, Phil Holman, Dan Marzu, Steve Okonek, Jamie Patton, Scott Reuss, Kevin Schoessow, Ken Schroeder, Dan Smith, and John Jones for their assistance in this research project. This work was funded by the Wisconsin Fertilizer Research Council and the Wisconsin Corn Promotion Board

REFERENCES

Weil, R.R., R.I. Kandikar, M.A. Stine, J.B. Gruver, and S.E. Samson-Liebig. 2003. Estimating active carbon for soil quality assessment: A simplified method for laboratory and field use. Am. J. Alternative Agric. 18(1):3–17.

Moebius-Clune, B.N., D.J. Moebius-Clune, B.K. Gugino, O.J. Idowu, R.R. Schindelbeck, A.J. Ristow, H.M. van Es, J.E. Thies, H.A. Shayler, M.B. McBride, K.S.M Kurtz, D.W. Wolfe, and G.S. Abawi, 2016. Comprehensive Assessment of Soil Health – The Cornell Framework, Edition 3.2, Cornell University, Geneva, NY.