

Prioritizing Soil Health Metrics for Predicting Edge-of-Field Water Quality Outcomes in the Great Lakes & Mississippi River Basins

Molly Meyers (University of Wisconsin-Green Bay), Francisco Arriaga (University of Wisconsin-Madison), Will Osterholz (USDA Agricultural Research Service), Andrew Margenot (University of Illinois), Anna Cates (University of Minnesota), Christine Sprunger (Michigan State University), Yichao Rui (Purdue University)

ABSTRACT

- In the pursuit of implementing effective conservation practices to enhance soil health and water quality, this study addresses the challenge of developing effective measurement strategies. The extensive variety of methods available for measuring soil health can make this task daunting and resource-intensive, complicating comprehensive application.
- Our presentation aims to simplify this complexity by highlighting soil metrics that are not only indicative of edge-of-field (EOF) water quality losses in the Great Lakes & Mississippi River Basins but are also practical and feasible for long-term monitoring.
- To ground our metric prioritization in empirical evidence, we conducted a structured ranking exercise involving six researchers who evaluated 28 soil parameters based on four criteria: correlation with EOF losses, ease of measurement, responsiveness to soil health practices, and resilience to seasonal changes.
- This analysis is complemented by insights from relevant scientific literature, offering a holistic view of how soil metrics correlate with EOF water quality outcomes and guiding the selection of the most impactful and manageable metrics for conservation efforts. Notably, Water Extractable Phosphorus (WEP), Penetration Resistance, and Basal Respiration were identified as the top chemical, physical, and biological parameters, respectively, due to their significant roles in soil health and water quality management.

INTRODUCTION

- Effective conservation practices require accurate measurement strategies to assess soil health and water quality. However, the extensive variety of methods available for measuring soil health can be daunting and resource-intensive, complicating comprehensive application for farms and conservation professionals.
- This study aims to identify practical and feasible soil metrics that correlate with EOF water quality losses in the Great Lakes & Mississippi River Basins. A structured ranking exercise was conducted involving six researchers from Wisconsin, Indiana, Illinois, Minnesota, Ohio, and Michigan.
- The goal is to provide actionable insights for farmers and conservation professionals, supporting more efficient and targeted measurement strategies in this region. Our recommendations highlight the top three chemical, physical, and biological parameters that serve as high-priority indicators of soil function and its impact on EOF losses.



METHODS

- Survey Structure & Data Collection:** To identify practical soil health metrics, we conducted a structured ranking exercise with six researchers (see Acknowledgments). They evaluated 28 soil health parameters based on four criteria:
 - Correlation with EOF losses: Assessing both theoretical relationships and observed data to prioritize parameters predictive of water quality outcomes.
 - Resilience to seasonal changes: Evaluating stability under diverse environmental conditions, including temperature and moisture fluctuations.
 - Responsiveness to soil health management system (SHMS) changes within five years.
 - Ease of measurement: Considering time, cost, and equipment needs.
- Each criterion was rated on a scale of 1 to 3, with 3 indicating high performance, 2 indicating medium performance, and 1 indicating low performance.
- Data Processing and Scoring:** Scores were averaged across criteria, with each criterion weighted equally at 25, making the maximum total score 100.

RESULTS & DISCUSSION

- The distribution of scores for biological, chemical, and physical soil parameters is illustrated in Figure 1, categorized by the four criteria. This helps to identify well-rounded soil metrics by revealing strengths and weaknesses within each category. Figure 2 presents the scores for each soil parameter by criterion, with high scores indicating better performance. The analysis reveals that no single parameter excels in all criteria, underscoring the need for a multi-parameter approach in soil health assessment.
- Our goal was to provide recommendations for the top three chemical, physical, and biological parameters to measure, as these are higher priority indicators of soil function and its ability to positively or negatively impact EOF losses. Parameters were prioritized based on their relative significance, determined by the ranking exercise, scientific literature, and expert judgment. The rationale for recommending each parameter is explained in Table 1, highlighting its importance to soil health practices and/or its relationship to EOF water quality outcomes.
- As shown in Table 1, for the chemical parameters, one phosphorus, one nitrogen, and one carbon parameter were included to provide a balanced representation of key nutrients. WEP was chosen for its strong correlations with EOF losses in the literature, Total Nitrogen for its higher ranking and resilience to seasonal changes, and Soil Organic Carbon for its broad recommendation as a key measure of carbon. For the biological parameters, Basal Respiration, Acid Phosphatase, and N-Acetylglucosaminidase (NAG) were selected. Basal Respiration is highly ranked and widely recommended, Acid Phosphatase showed strong correlations with EOF outcomes, and NAG reflects nitrogen cycling. For the physical parameters, Penetration Resistance, Soil Texture, and Aggregate Stability were chosen based on their rankings and correlations with EOF outcomes. While soil texture is not a soil health metric, it is critical for understanding inherent soil physical properties and their effects on water relations and nutrient availability.

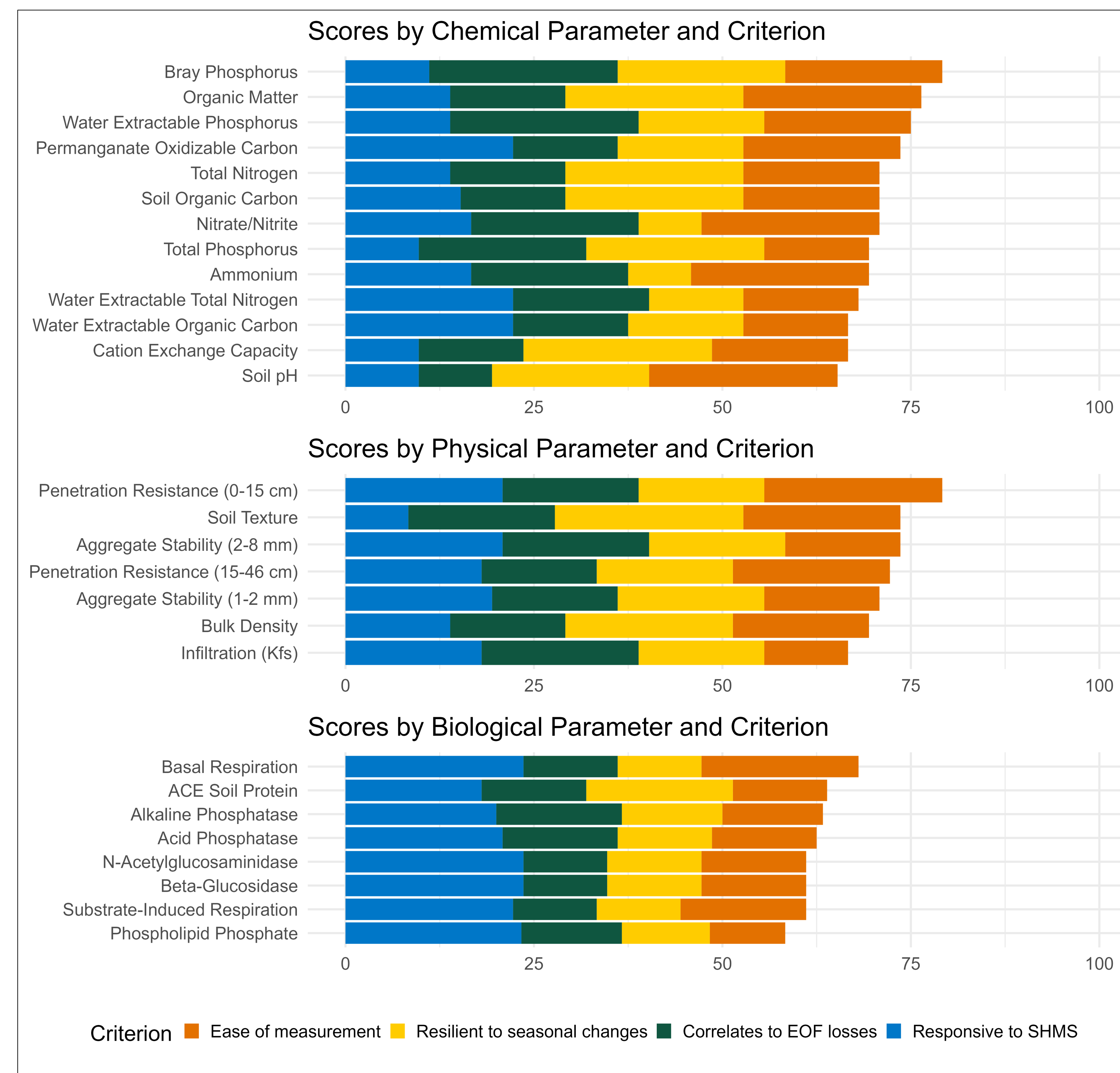


Figure 1. Scores by category and criterion for the 28 soil parameters considered. Note that the possible maximum score for each criterion was normalized to 25 points for a maximum total score of 100 for a specific soil parameter.

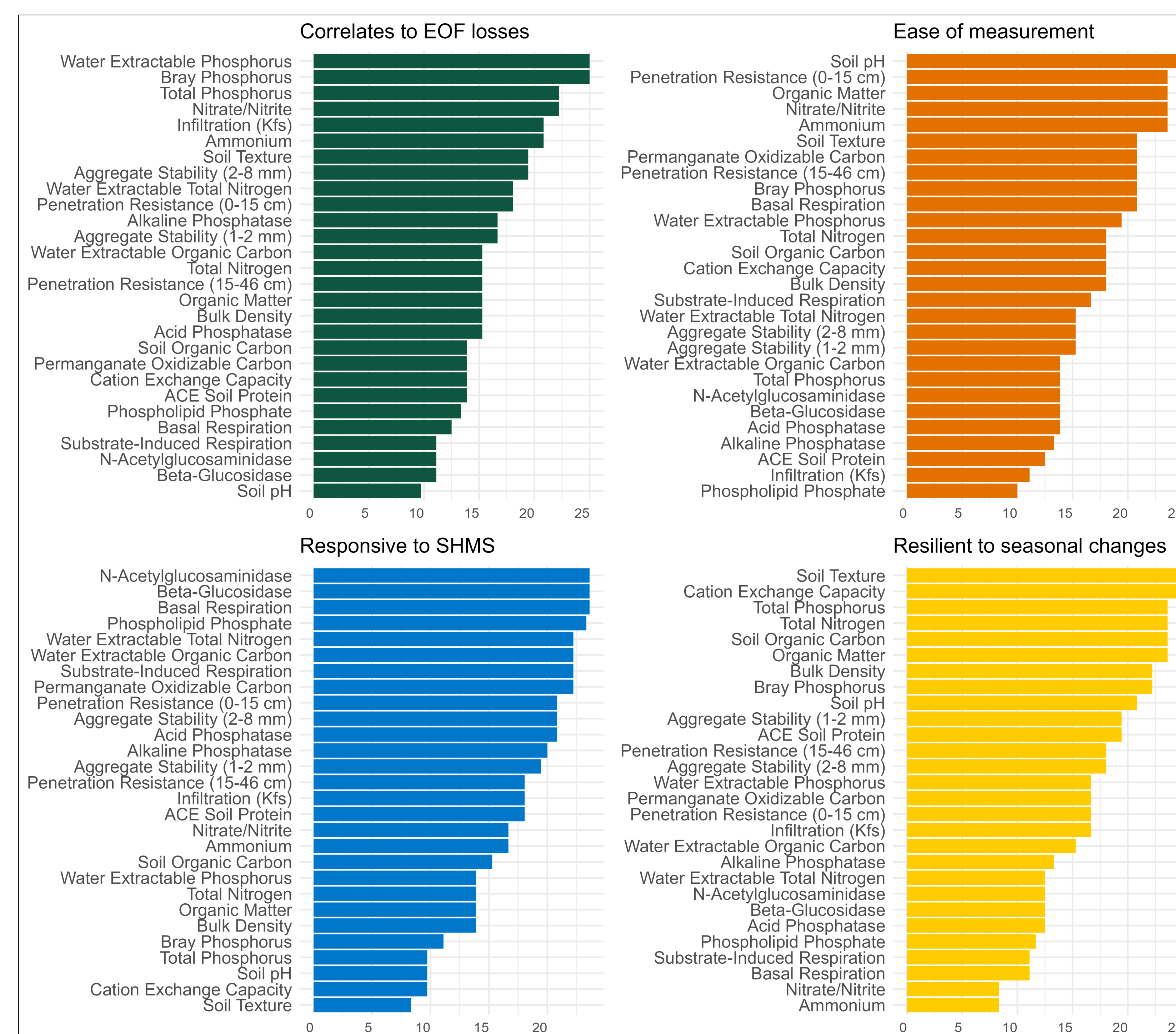


Figure 2. Scores by criterion for the 28 different soil parameters considered. The minimum and maximum scores for an individual soil parameter within a criterion are 8.33 to 25, respectively.

Table 1. Top three soil parameters and ranking recommended for predicting edge-of-field outcomes for each of the three soil property categories.

Category	Parameter Name	Ranking	Rationale & References
Chemical	1. Water Extractable Phosphorus (WEP)	Medium	Highly correlated with EOF losses, key for phosphorus runoff management. Osterholz et al., 2021: Correlated with DRP, TP losses.
	2. Soil Organic Carbon (SOC)	High	Enhances water retention and reduces runoff. Lewandowski & Cates, 2022: Linked to better water retention and reduced runoff.
	3. Total Nitrogen (TN)	Medium	Stable indicator for managing nitrogen inputs. Fermanich et al., 2022: Correlated with EOF nutrient export.
Physical	1. Penetration Resistance	High	Indicates soil compaction and root growth potential. Aryal et al., 2018: Affects water infiltration and root growth.
	2. Soil Texture	High	Affects water retention, infiltration, and nutrient dynamics. Fortuna et al., 2023: Influences water movement and nutrient leaching.
	3. Aggregate Stability	Medium	Reflects soil structure quality and resistance to erosion. Plach et al., 2019: Prevents soil erosion and maintains water quality.
Biological	1. Basal Respiration	High	Measures microbial activity and soil organic matter turnover. Martin-Lammerding et al., 2015: Improved under conservation practices.
	2. Acid Phosphatase (Acid P)	Medium	Involved in phosphorus cycling, correlated with EOF losses. Fermanich et al., 2022: Correlated with phosphorus availability.
	3. N-Acetylglucosaminidase (NAG)	Medium	Reflects soil enzyme activity and microbial community health. Sui et al., 2022: Improved with specific tillage and fertilization practices.



CONCLUSION

- Our research identifies key soil metrics that balance predictive effectiveness with practical feasibility, supporting more efficient monitoring efforts in the Great Lakes and Mississippi River Basins.
- We acknowledge the limitations of the current scoring system, such as potential biases in weight assignment or the subjective nature of scoring based on available data and expert judgment.
- These findings provide a framework for ongoing and future studies to enhance soil health and water quality monitoring.
- Future research should aim to validate these metrics in the Upper Midwest, Great Lakes Region, and other geographical contexts to enhance the generalizability and applicability of these recommendations across diverse farming systems.
- By fostering collaboration between scientific research and practical application, significant strides can be made toward improving water quality and ecosystem health through informed, data-driven soil health practices.

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