

## Standard To Validate Innovations in Agricultural Testing

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### Abstract

As global agriculture faces escalating challenges, improved nutrient management procedures are essential for sustainability. Establishing standardized processes to validate and legitimize emerging soil testing technologies is critical for gaining acceptance from users and regulatory bodies. Standardized methods for evaluating soil fertility needs are essential to meet agricultural demands while mitigating environmental impacts, such as nutrient runoff. This initiative highlights and outlines the importance of refining nutrient management protocols and developing new effective, and accurate soil testing methods.

The emergence of new soil testing technologies creates challenges for local and national agencies regarding their incorporation into existing soil nutrient assessment procedures. To address this, the proposed standards project will develop a comprehensive protocol and policy for validating innovative methodologies. Using an open forum and the consensus-based standards development process—sponsored by the Geoscience and Remote Sensing Society and overseen by IEEE—the priority is on collaboration, transparency, and adherence to regulatory requirements.

A standardized method to benchmark accuracy creates a method for widespread acceptance by users, regulatory bodies, and the global community. Harmonized definitions and standardized methodologies must be created with a focus on precision in proximal and remote sensing measurements. Guidelines are necessary to integrate Monitoring, Reporting and Verification (MRV) systems, compare sensing data with soil measurements, and analyse yield responses using new test methods. A regulatory standard will ensure the best-suited sensing technologies are offered to users, enabling sustainable agricultural practices and environmental stewardship.

### 1. INTRODUCTION

The proposal aims to develop an inclusive protocol that establishes a standardized and globally accepted process for the validation and legitimization of emerging soil testing technologies. This standard would create a structured mechanism for innovative methods to gain acceptance among users, practitioners, and regulatory bodies. The need for such a standardized framework and the challenges associated with validating new innovations in agricultural testing are well-documented in numerous studies and reports. However, the existing standards are deeply rooted in outdated methodologies, leaving little to no room for innovation or the adoption of cutting-edge technologies. As one study notes, “The findings suggest the necessity for greater application of formal methods and the need for standardized, domain-specific methods to support this assessment” [3].

A need exists to understand and define the complexities involved in developing such a standard, offering a dual approach to validation: first by comparing novel soil testing technologies against well-established benchmarks, and second, by formulating standardized recommendation thresholds tailored specifically for emerging methods. The proposed is a detailed and comprehensive framework, the development of this protocol seeks to overcome the traditional limitations associated with wet chemical lab analysis, which can often be limited in remote areas, slow, and costly. The standardized framework encourages the adoption of alternative approaches that are not only more cost-

effective but also quicker and perhaps even more precise, making them better suited to modern agricultural needs.

The proposed standard will utilize the process established by IEEE recommended standard creation guidelines to create a standard for validating innovative agricultural tests as they relate to nutrient management. The proposed standard will empower farmers and producers to a future where innovative soil testing technologies are not just validated for their scientific accuracy but are also widely embraced as global industry standards. This forward-thinking approach would enable a shift away from the constraints of outdated practices to a more progressive model where innovation drives sustainable agriculture.

Examples of emerging innovations that highlight the need for a validation methodology include visible-near-infrared (VNIR) spectroscopy, satellite-based near-infrared (NIR) methods, and other modern techniques and technologies as they emerge. These technologies showcase the potential for groundbreaking advancements in nutrient management and the necessity of establishing a framework for their formal evaluation and acceptance. This protocol could guide the agricultural community toward an era where precision, efficiency, and sustainability become the cornerstones of nutrient management practices. This standard offers a transformative outlook on the future of agriculture, fostering a global ecosystem where innovative soil testing methodologies improve productivity while preserving environmental resources for generations to come.

## 2. STAKEHOLDER ENGAGEMENT

The proposed validation process includes Methods A, B, and C (details below). The standard aims to create a path for soil testing innovation through a standardized validation method. These include 'double-blind' laboratory programs, field response studies, and the rigorous validation conducted in collaboration with university research initiatives. The proposed methodologies serve as examples of methods to validate innovations in accordance with a scientific method to validate the accuracy, reliability, and reproducibility of emerging soil testing technologies. The goal of the standard is to establish essential correlation guidelines, define tolerance levels, and promote the integration of academic collaboration, creating a foundation which future advancements can be built.

The implementation of this protocol takes a holistic and inclusive approach, as highlighted in the proposed validation methods. The importance of active collaboration amongst all stakeholders is paramount to the effort including agricultural agencies, academic research institutions, farmer/producers, and technology providers. This collaborative framework is not only essential to the protocol's success but is also instrumental in its evolution into an internationally recognized standard. Through the inclusion of all stakeholders in the creation, decision-making and refinement processes, the protocol aims to ensure widespread acceptance, relevance, and adaptability for the agricultural industry.

Transparency lies at the heart of this protocol, as it emphasizes clear communication of objectives, methodologies, and findings throughout the standardization and validation process. The collaborative refinement of the protocol guarantees that it remains open to emerging technological innovations and the evolving needs of the agricultural sector. Adhering to IEEE standards further enhances its credibility, positioning the protocol as a dynamic and forward-thinking framework that is well-equipped to accommodate the complexities of modern technological changes and agricultural practices.

As the agricultural industry continues to advance, the proposed protocol seeks to address the challenges of validating next-generation soil testing technologies while maintaining a commitment to precision, efficiency, and sustainability. The standard seeks to navigate uncharted territory by setting benchmarks for innovative methods. This framework aims to redefine soil testing standards globally. Its comprehensive approach not only facilitates the adoption of cutting-edge technologies but also ensures their integration into sustainable agricultural a growing population. This standard will provide a framework to encourage innovation, growth and progress to an area of testing that is often overlooked in relation to traditional methods. User adoption of agricultural testing innovation is paramount for nutrient management and contributes to global food security through responsible nutrient management.

## 3. POLICY FRAMEWORK

The growing need for effective soil nutrient management is driven by the increasing demand for sustainable agricultural practices, which is in dire need science-based breakthroughs to practices, paving the way for a future where science and innovation collaboratively shape the way we manage resources and feed incorporate cutting-edge testing methodologies. In

response to these challenges this standard will develop a comprehensive proposal that introduces a policy and protocol aimed at defining a standardized framework for the validation and legitimization of innovative agricultural testing methods. This proposal represents a crucial step in fostering both the acceptance of advanced technologies and the promotion of innovation within the field of nutrient management.

The proposed policy and protocol recognize the limitations of traditional soil testing methods, which often rely on time-consuming and outdated processes that may not meet the precision, efficiency, and scalability required in modern agriculture. By establishing a standard for validating emerging technologies, the framework seeks to address these shortcomings and create a structured pathway for their integration into mainstream agricultural practices. This initiative emphasizes the importance of rigorous scientific validation to ensure the credibility, reliability, and practicality of new methodologies, thereby building trust among stakeholders such as farmers, researchers, regulatory bodies, and technology developers.

The central theme of this proposal is the concept of fostering innovation in nutrient management. The framework highlights the transformative potential of cutting-edge approaches, such as visible-near-infrared (VNIR) spectroscopy, drone-based soil analysis, and satellite imaging, to revolutionize the way soil health is assessed and managed. By defining clear validation standards, the protocol aims to encourage the development and adoption of these innovative methods, enabling the agricultural sector to achieve greater precision, efficiency, and sustainability.

Moreover, the framework highlights the need for stakeholder engagement, collaboration and advocacy to ensure its successful implementation. Engagement with agricultural agencies, academic institutions, and technology providers is critical to establishing a unified approach to soil testing innovation. The proposed standard emphasizes the importance of transparency and iterative refinement in the protocol, ensuring that it remains adaptable to evolving technological landscapes and the dynamic needs of the agricultural industry.

The proposal addresses a pressing need within the agricultural sector by advocating for a standardized policy framework that validates and legitimizes innovative soil testing methods. This initiative not only paves the way for the acceptance of groundbreaking technologies but also promotes a culture of innovation that is essential for the future of nutrient management. By combining scientific rigor, stakeholder collaboration, and a commitment to sustainability, this policy and protocol have the potential to redefine agricultural testing standards and contribute to a more resilient and productive agricultural landscape worldwide.

### 3.1 Objective

The primary objective is to develop and implement a standardized policy framework designed to validate and legitimize emerging soil testing methodologies. This initiative seeks to ensure the credibility, reliability, and scientific rigor of

innovative approaches, while also fostering widespread acceptance and adoption within the agricultural industry. By creating a structured pathway for validation, this framework will actively promote technological innovation in the field of nutrient management, addressing the growing need for more efficient, precise, and sustainable agricultural testing practices.

The proposed framework emphasizes the integration of both aerial and proximal methods, reflecting a commitment to harnessing cutting-edge advancements in technology. Aerial methods, such as satellite imaging and drone-based sensors, enable rapid and large-scale assessments of soil health and nutrient levels across vast agricultural landscapes. These methods provide critical data that can inform decision-making processes, optimize resource allocation, and enhance overall productivity. Proximal methods, on the other hand, include ground-based techniques like visible-near-infrared (VNIR) spectroscopy and portable sensors, offering detailed, localized insights into soil composition and nutrient availability. Together, these complementary approaches represent a holistic and adaptive strategy for soil testing, capable of addressing diverse challenges and opportunities in modern agriculture.

A standardized framework for validating these methodologies, the initiative aims to overcome existing barriers to innovation, including outdated standards and a lack of formalized pathways for the recognition of innovative technologies. It seeks to build trust among stakeholders, including farmers, researchers, regulatory bodies, and technology providers, ensuring that novel soil testing methods meet rigorous scientific and practical benchmarks. Moreover, the framework aspires to facilitate the global harmonization of soil testing standards, encouraging international collaboration and knowledge exchange to advance the field of nutrient management.

This endeavour is particularly critical in the context of contemporary agricultural challenges, such as climate change, soil degradation, and the increasing demand for sustainable food production. The standard will support the development and validation of innovative soil testing methodologies. The standardized policy framework not only paves the way for more effective nutrient management practices but also contributes to the broader goals of environmental preservation and global food security. In doing so, it positions the agricultural sector to meet the demands of the future, blending precision, efficiency, and sustainability to create a resilient and thriving industry.

### 3.2 Guiding Principles

The validation process will encourage collaboration between technology providers, laboratories, and academic institutions for a collective validation process. The proposed a dual approach of validation against existing methods or standardizing new recommendation thresholds for novel technologies.

## 4. PROTOCOL DEVELOPMENT

Below is a list of proposed validation methods to be considered in the new standard to validate innovations in agricultural testing.

### 4.1 Validation Method A - Laboratory Correlation

Double Blind Program: Initiate a “double-blind” or ‘triple-blind’ program where laboratory participants receive standard reference soil samples (e.g., Agriculture Laboratory Proficiency Program, North American Proficiency Testing Program) without prior knowledge. Compare the mean value of a minimum of three laboratory results against the results obtained using the new innovative approach. Potential example in Table 1.

Table 1

Sample #1	pH	P1	K	OM	Ca	Mg	CEC	S	Na	Zn	Fe	Mn	Cu	B
Lab A	6.2	87.7	148.1	2.8	829	109.5	3.3	26.7	19.1	4.3	144.4	30.8	1	1.1
Lab B	6	93	138	2.7	797	102	3	21.5	20.8	3.9	133	28.1	0.9	0.8
Lab C	6.3	98	128	2.6	811	125	2.9	24.5	23.2	3.7	141	26.2	1.3	1
New Innovation	6.1	90	131	2.6	830	117	3.1	22.6	18.1	3.8	138	28.7	1.1	0.9
Mean of Traditional	6.167	92.9	138	2.7	812.3	112.2	3.067	24.2	21.03	4	139.5	28.4	1.07	0.97

- **Sampling Frequency:** Submit soil samples during the Spring and Fall seasons to participating labs or universities to assess overall performance. Make sure to address temperature variations and moisture. Run a comparative analysis to validate the efficacy of the test method
- **Correlation Guidelines:** Establish guidelines for accuracy by ensuring the correlation of determination ( $R^2$ ) value for correlation is not less than a predetermined value or falls within one standard deviation of the mean value reported by wet labs. This method will require input from many stakeholders. Currently chemical wet lab analysis has a large variation between different labs and methods. An in-depth analysis of this error should be considered when looking at the validation standard.

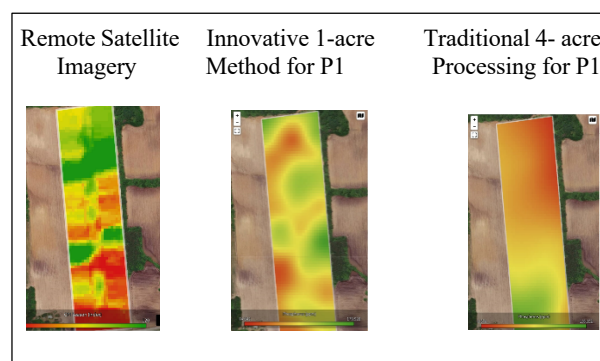


Figure 1

### 4.2 Validation Method B - Field Response Studies

- **Tolerance Levels:** If needed, submit recommended parameters based on field response studies, calibrating differing response levels to recommendations from innovative technology. Consider crop response, management practices, and nutrient recommendations derived from new methodologies. Compare proximal and remote data to demonstrate field response and validate efficacy of practice. (see comparative data in Table 1)
- **Performance Evaluation:** Compile results, evaluate performance, and conduct anonymous reviews by university scientists. This will require third party studies which demands additional costs and could present a barrier to entry for new scientific based innovations.
- The exact methods and procedures will need to be evaluated in the creation of the standard

### 4.3 Validation Method C - Research Validation

- Collaborate with university oversight to conduct comprehensive field studies, incorporating site-specific considerations. This should include field trials and supporting data with a minimum number of tests to validate.
- Publish the results to contribute valuable insights to the scientific community.

### 4.4 Additional Ideas

Additional ideas will be added as the proposed study group and working group help to define new methods to validate innovation in agricultural testing.

## IMPLEMENTATION

### 4.5 Collaboration and Advocacy

• To ensure the successful implementation and widespread adoption of the proposed protocol, it is essential to actively engage with key stakeholders across multiple sectors, including state agricultural agencies, research institutions, and technology providers. Building strong partnerships with state agricultural agencies is particularly vital, as these organizations play a central role in shaping agricultural policies, regulations, and outreach programs. By involving them early in the process, the protocol can align with existing state-level initiatives and address region-specific challenges, fostering a sense of collaboration and shared purpose. Engaging with research institutions offers an opportunity to leverage their expertise, resources, and credibility. Academic and scientific organizations can provide invaluable insights into the validation process, conduct rigorous peer-reviewed studies, and contribute to the iterative refinement of the protocol. These partnerships not only enhance the scientific rigor of the protocol but also encourage knowledge dissemination through academic publications, conferences, and workshops, helping to build broader awareness and acceptance.

Involving technology providers is equally critical, as they are at the forefront of developing innovative soil testing methodologies. Collaborating with these providers ensures that the protocol remains relevant, adaptable, and reflective of the latest technological advancements. Their participation also helps bridge the gap between research and practical application, facilitating the development of user-friendly tools and solutions that meet the needs of farmers and agricultural practitioners.

Parallel to stakeholder engagement, dedicated advocacy efforts must be undertaken to promote the protocol as an industry standard. This involves emphasizing the numerous benefits of standardized, innovative soil testing methodologies, such as improved accuracy, efficiency, and sustainability in nutrient management. Advocacy campaigns can target a wide audience, including policymakers, industry leaders, and the agricultural community, highlighting how the adoption of the protocol can address key challenges like soil degradation, resource inefficiency, and the growing demand for sustainable agricultural practices.

Such advocacy efforts should employ diverse strategies, including the publication of white papers, participation in

industry forums and summits, and the organization of stakeholder roundtables. Additionally, creating case studies and pilot projects that demonstrate the practical benefits of the protocol in real-world scenarios can serve as powerful tools to build trust and drive adoption. The emphasis on transparency, collaboration, and alignment with global standards such as those set by IEEE will further reinforce the protocol's credibility and position it as a transformative framework for agricultural innovation.

By fostering strong stakeholder collaboration and advocating effectively for its adoption this standard will revolutionize the manner with which we integrate technology into our food supply globally.

### 4.6 Transparency and Iterative Refinement

- Ensure transparency in the validation process, sharing results and insights with stakeholders.
- Facilitate an iterative refinement process, incorporating feedback from stakeholders and accommodating emerging technological advancements.

## CONCLUSION

The proposed creation of a standards development project dedicated to codifying a detailed protocol and policy framework for creating a validated and legitimate test methodology specifically designed to address the challenges and opportunities presented by innovative soil testing technologies. This initiative is intended to ensure the reliability, accuracy, and practical applicability of groundbreaking approaches in nutrient management, while simultaneously fostering their broader acceptance and integration into agricultural practices globally. By focusing on the formalization of validation processes and regulatory alignment, the proposed framework is positioned to set a new benchmark for the development, assessment, and adoption of innovative methodologies in soil testing.

This proposal advocates for science-based policies and procedures of the IEEE Standards Association, an organization renowned for promoting collaborative engagement and maintaining high standards of transparency and accountability. By leveraging these well-established guidelines, the proposed framework ensures that the development process is inclusive, participatory, and aligned with global best practices. The emphasis on collaboration encourages the active involvement of diverse stakeholders, including state agricultural agencies, academic researchers, technology developers, and industry practitioners. This collective effort aims to build trust and consensus around the validity and legitimacy of emerging soil testing methodologies, thereby strengthening their credibility and acceptance.

The proposed framework also emphasizes the importance of adaptability and iterative refinement, ensuring that it remains responsive to advances in technology, emerging scientific insights, and the dynamic needs of the agricultural sector. By incorporating mechanisms for continuous feedback and improvement, the initiative aims to create a living standard that evolves alongside innovations in soil testing and nutrient management. This forward-looking approach not only validates current methodologies but also establishes pathways for the introduction and acceptance of future technologies, fostering a culture of ongoing innovation.

In addition, the standards development project recognizes the critical role of stakeholder advocacy and engagement in driving adoption at both the regional and international levels. It emphasizes the need to communicate the benefits of standardized, innovative soil testing approaches, such as increased efficiency, cost-effectiveness, and sustainability in nutrient management practices. Advocacy efforts will highlight the framework's potential to address pressing challenges like soil degradation, climate change, and resource inefficiency, demonstrating its alignment with the broader goals of sustainable agriculture and environmental preservation.

Ultimately, this proposal seeks to redefine soil testing standards by creating a comprehensive protocol and policy framework that paves the way for the widespread acceptance and integration of cutting-edge nutrient management technologies. Through rigorous validation, stakeholder collaboration, and adherence to IEEE standards, the initiative aspires to build a foundation for the future of agricultural testing—a future characterized by precision, innovation, and sustainability. In doing so, it contributes not only to the advancement of soil testing practices but also to the resilience and productivity of the agricultural sector.

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