Enriching Soil, Enhancing Life

AN ACTION PLAN FOR SOIL HEALTH

SOIL HEALTH
INSTITUTE

UNIFY ■ RESTORE ■ PROTECT

MESSAGE FROM THE SOIL HEALTH INSTITUTE

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Dear Friends:

Imagine a time when farmers and ranchers are given the tools they need to *not only* grow our food, *but also* enhance water quality, build resilience to drought and pests, increase carbon sequestration, reduce greenhouse gas emissions, and expand pollinator and other wildlife habitat, all while using economically viable practices that sustain our rural landscapes. Such is the promise of soil health.

Consequently, it is with excitement over the continued momentum for improving soil health, recognition of the responsibility we all have to current and future generations to do just that, and gratitude to the many stakeholders who have contributed their ideas and expertise, that the Soil Health Institute offers this Action Plan for enhancing the health of our soils, ecosystems, and indeed, our lives.

Through the actionable steps described in this Plan, we can increase productivity and resilience. We can achieve greater environmental and human health benefits. We can develop widely accepted soil health measures for national deployment, establish the current state of soil health in the United States, and identify areas where investments will have greatest impact. We can improve agricultural profitability, reduce economic risk, establish the economic value of healthy soil to producers and the public, spread partnerships to achieve wide-scale adoption, increase public awareness, and ensure that policies are well-informed to support all of these advances.

Reflective of the soil itself, this Action Plan is a living document that will evolve as our knowledge, experience, insight, and needs also change. I invite all who have an interest in participating in this journey to join and help make soil health the cornerstone for managing our natural resources throughout the nation and around the world. We, and all future generations, have a critical stake in the outcome.

Sincerely yours,

C. Wayne Honeycutt

C. Wayne Honeycutt, Ph.D.
President and CEO

OUR MISSION: SAFEGUARD AND ENHANCE THE VITALITY AND PRODUCTIVITY OF SOIL THROUGH SCIENTIFIC RESEARCH AND ADVANCEMENT

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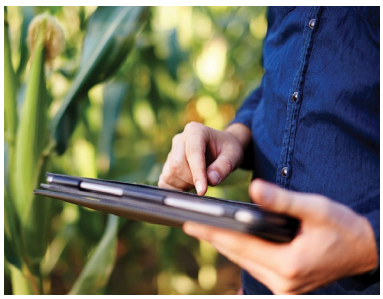


OVERVIEW

In 2013, the Samuel Roberts Noble Foundation and the Farm Foundation, NFP, convened leaders from agricultural industry, farms, ranches, government agencies, and non-governmental organizations to examine the current state of our world's soil health and its roles in a vibrant, profitable, and sustainable ecosystem. As the group identified diverse and complex issues regarding soil health, it became clear that a collaborative organization was needed to spearhead accurate, science-based information, create a sense of urgency, and coordinate leadership. Thus, the Noble Foundation and the Farm Foundation created the Soil Health Institute, whose mission is to ***"Safeguard and enhance the vitality and productivity of soil through scientific research and advancement."***

As an independent, nonprofit organization charged with coordinating and supporting soil stewardship and advancing soil health, the Soil Health Institute (SHI) is focused on fundamental and applied research and ensuring its adoption. We recognize that soil health must emerge as the cornerstone of land use management decisions throughout the world during the 21st century because healthy soil is the foundation of life and society. Enhancing soil health allows us to improve water quality, increase drought resilience, reduce greenhouse gas emissions, improve farm economies, provide pollinator habitat, and better position us to feed the 9.7 billion people expected in the world by 2050.

The SHI program is designed to move scientific knowledge and technology from the research laboratory to the farm field by bringing together traditional and non-traditional agricultural industry partners, farmers, ranchers, government agencies, scientists, and consumers to focus on one common, clear goal: protecting and enriching our soils. The Soil Health Institute is committed to working with all partners to enhance and disseminate knowledge and technologies directed at key soil processes to increase productivity, resilience, and environmental quality; identify research and adoption gaps; coordinate national partnerships to address those gaps; and help drive the transformational changes needed for the betterment of soil health and ultimately society.

Knowledge generation is the foundation to improving soil health and the leading priority of the Soil Health Institute (Fig. 1). This Action Plan details our commitment to it in several sections. Our commitment includes basic, translational, and applied **research** in the natural sciences to elucidate biological, chemical, and physical soil functions and how they link management practices to desired outcomes in agriculture and the environment. The SHI works with industry leaders, government, independent research organizations, and academic institutions to identify and prioritize gaps in soil health research and to develop strategies for funding the research needed to resolve the most pressing soil health issues.

Producers are important partners in this effort, as they tell us their needs for information, and they work alongside experts to test and implement soil health management practices in real-world situations. The SHI then ensures that knowledge and information generated from scientific research is available for prompt, widespread dissemination to all stakeholders. Numerous, yet focused, partnerships are developed to facilitate adoption of the new knowledge and technologies.

Knowledge generation for measurements and standards is targeted specifically at developing reliable and economically feasible methods for measuring soil properties and processes considered vital to soil health. Knowledge generation in the socioeconomic sciences seeks to develop analytical approaches and principles for supporting producers, processors, and policymakers so they can make sound decisions consistent with economic realities and the many management decisions that must be made to produce food, feed, fiber, and biofuels.

In addition to knowledge generation, our work with many public and private partners on **measurement and standards** reflects one of the Institute's key objectives: establish, coordinate, and oversee a National Soil Health

Figure 1.
The Soil Health Institute achieves its mission through application of improved measurements and standards, economic analyses, communications and education initiatives, and support for policy development to move new knowledge and technologies through to adoption and effective implementation on the land.

Assessment based on measurement standards that reflect regional soil characteristics. The SHI recognizes the importance and promotes the use of standardized soil testing measurements validated through soil testing and research as well as by working with agricultural communities to benefit producers and promote soil and water conservation. Working with partners, the SHI envisions that a National Soil Health Assessment will provide a baseline for quantifying the current state of soil health, inform decisions for most effective soil health practice implementation, and serve as a marker for measuring future progress.

The SHI will strive to increase awareness of the costs and benefits associated with using practices that maintain or enhance soil health. By including **economic analysis** as an integral part of our soil health research programs, the Institute will provide farmers and ranchers information they need to adopt positive soil health practices, increase agricultural productivity and conserve natural resources with confidence.

The Soil Health Institute is also committed to serving as a central hub for **communications and education** regarding soil health research and soil-related information. Informing policymakers, the scientific community, producers, industry leaders, and consumers underscores and emphasizes each of the Institute's primary activities and is critical to cultivating healthy soils for a healthy future.

Finally, recognizing that American agriculture is the backbone for food security, strong economies, and innovation worldwide, the SHI will work closely with experts on public **policy** to enhance an agricultural system where freedom, opportunity, prosperity and civil society flourish. The Institute will promote soil health as a cornerstone of well-informed policy.

The success of the Institute's programs depends on strategic partnerships with individuals and organizations that conduct or sponsor research, outreach, education, and implementation of soil health knowledge and technologies in ways that complement our own. In turn, these partnerships allow the SHI to lead, sponsor, and implement programs well beyond our individual capacity. Just a few examples of our partners include faculty at universities across the country, scientists in the USDA

Agricultural Research Service and Natural Resources Conservation Service, experts in other federal and state government agencies, non-governmental field-oriented organizations such as the Soil Health Partnership and The Nature Conservancy, professional societies such as the Soil Science Society of America and the Soil and Water Conservation Society, organizations with regional and local knowledge such as the National Association of Conservation Districts, private laboratories using current methods of soil analysis, and communications professionals with a track record of communicating information about agriculture and the environment. This list is not comprehensive, and we actively seek new partners who share our vision for soil health and assert expertise and action that balance the Institute's focus on creation and use of new knowledge.

The success of the Institute's programs also depends on partnerships with organizations who offer funding support. Such organizations include traditional sources of funding for research and technology development in the natural and socioeconomic sciences, such as governmental agencies having missions for funding public and/or private-sector research. Non-governmental organizations are vital partners as well. As our understanding of soil health improves, many realize that enhancing soil health is a viable mechanism to accomplish goals of a variety of organizations having interest in agricultural productivity, environmental quality, or sustainability. When those organizations see value in a capacity to consider soil health in the context of their own programs in ways they have not previously realized, the Soil Health Institute stands as a willing collaborator, coordinator, and portal to a national community of soil health experts who, with commensurate resources, can help other entities achieve their vision and mission.

Because of these dual capabilities for science and partnerships, the SHI's efforts described in this Action Plan are nimble and scalable. They can be expanded in scope and focus in response to ever-changing resource availabilities, the state of the science, the insights of our community of experts, and the complementary missions of our partner institutions who work with us through interest and investments in soil health. As resource and scientific capacities increase, the work described herein can be expanded and enhanced in scope and deepened in relevance and impact.

Based on Institute goals and extensive multi-partner organizational efforts to date, this Action Plan is organized into five sections reflecting the Institute's general priorities:

- Research
- Measurement, Standards and Assessment
- Economics
- Communications and Education
- Policy

This Action Plan presents the Soil Health Institute's priorities and direction beginning in 2017. The Action Plan has no specific end date, but instead is a living document subject to refinement as our partners and stakeholders advise, objectives are achieved, and understanding of soil health evolves.

We invite you to join our journey to make soil health the cornerstone for managing natural resources throughout the nation and around the world.

RESEARCH

INTRODUCTION

The overall goal for the Soil Health Institute's research program is to address strategic, high priority needs of the scientific and stakeholder communities for advancing soil health. Collaborative public-private research developed under this plan will contribute collectively to enhancing productivity, resilience and environmental quality through soil health. Results will increase the scientific knowledge base that will allow soil health management practices and systems to be designed and implemented across a wide range of soils, climates, and cropping systems to increase a given soil's capacity to provide water and withstand drought, suppress diseases, and provide nutrients. It will expand the role of soils for producing nutritious food and feed, improving water quality, increasing carbon sequestration, reducing greenhouse gas emissions, and improving human and animal health. Soil health-promoting practices that show promise individually will be evaluated in multiple combinations that may benefit soil health in different and reinforcing ways. We refer to these as "soil health management systems" that engage several practices simultaneously to enhance soil health while sustaining or enhancing productivity and environmental quality in economically feasible ways that are consistent with other on-farm decisions.

This section of the Institute's Action Plan does not stand alone. Research and analyses on economic costs and benefits, as well as social and cultural aspects of on-farm decision making, are an essential complement to the physical-chemical-biological research described in this section. The Economics section of this Action Plan addresses such research. Similarly, research focused specifically on measurements, standards, and approaches to soil health assessment is highly relevant and supports the research described in this section, however, it is described in detail in the Measurement, Standards, and Assessment section of the Action Plan. In its entirety, the Institute's research portfolio is intended to yield analytical methods and standards, production and soil resource management methods, support for decision making, and recommendations that are actionable, beneficial, economically feasible, and acceptable by agricultural producers.

GOAL: Enhance Productivity and Resilience through Improved Soil Health

Desired Outcomes

Enhanced soil productivity and resilience to extreme weather by increasing available water holding capacity, increasing water infiltration, suppressing soil-borne plant pathogens, and increasing nutrient availability.

Information Gaps and Management Needs

In some soils and environments, improving soil health can enhance available water holding capacity (AWHC), infiltration, and nutrient availability. However, specific relationships between soil organic carbon (SOC) and AWHC, along with the relationships between SOC and water infiltration, differ among soils. Research is needed to quantify, understand and predict these differences to make field-level management recommendations and decisions. The mechanisms and processes underlying soil-borne disease suppression are largely unknown, and a wide array of biological, chemical, and physical variables and processes make nutrient availability an elusive and dynamic property to measure. For these and other reasons, choosing soil health practices/systems to achieve quantitatively predictable, targeted benefits to AWHC, nutrient availability, and plant disease management remains extremely challenging. Consequently, fundamental knowledge of these processes and relationships is required to enhance productivity and resilience through soil health.

PRIORITY: Optimize Available Water Holding Capacity in Important Agricultural Soils

Specific Needs to Address Information Gaps

Research is needed to quantify the relationships between SOC and AWHC. Because these relationships vary among soils, research is also needed to identify the variables influencing those relationships and to determine the limits within which accurate predictions can be made. Information is also needed on the current state of AWHC for major agricultural soils and the levels that may be reached. This information must be an integral part of analyses that provide the basis of a Decision Support System that will allow farmers to make sound decisions to enhance AWHC for their specific soils.

Anticipated Product(s)

Decision Support System for farmers that allows them to make well-informed decisions on using soil health management systems for achieving a targeted AWHC and associated productivity in their soils.

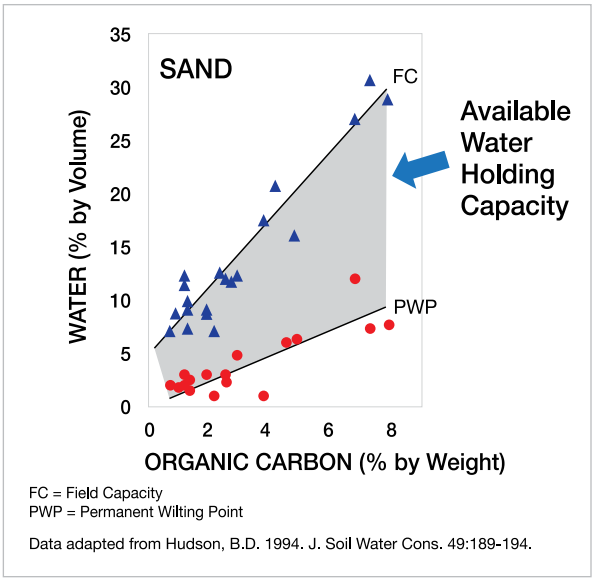
Intended Impact

Farmers and ranchers will be given the science-based tools they need to employ soil health-promoting principles and practices to achieve a targeted level of resilience to drought by enhancing their soils' available water holding capacity. This will allow soil health to serve as an effective risk management tool by farmers/ranchers, which will significantly increase adoption of soil health-promoting practices and systems.

Actionable Steps

a. Quantify current levels of AWHC for important agricultural soils.
   1. Develop equations for describing the quantitative relationships of variables influencing AWHC. Primary variables to be evaluated should include soil particle size and SOC, but others should also be evaluated if needed (e.g., soil mineralogy).
   2. Establish the limits of each quantitative relationship. Evaluate the utility of the "similar soils index" developed by NRCS for establishing these limits.

b. Quantify attainable levels of AWHC for important agricultural soils.
   1. Based on the above, develop the equations predicting changes in AWHC (e.g., as a function of texture, mineralogy, SOC, etc.).
   2. Calculate the current levels of AWHC for selected soils by combining the above equations for predicting AWHC as a function of texture and SOC with soil C analyses from NRCS' Rapid Carbon Analysis project.
   3. Determine each selected soil's capacity to store SOC, based on published typifying pedon analyses and/or published models (e.g., Century Model).
   4. From the above, calculate the desirable AWHC for each soil selected.



c. Develop a Decision Support System specifically for farmer use that provides soil health management system options for achieving a targeted level of resilience to drought and heavy precipitation.
   1. Combine relationships among SOC, texture, and AWHC (established above) with existing models of plant-soil C dynamics (e.g., Century & DNDC models) to accommodate wide ranges of temperature, water, chemical composition of organic inputs, and management practices (e.g., cover crops, manure inputs, no-tillage) to develop a producer-oriented Decision Support System.
   2. Conduct field evaluations to validate/calibrate the Decision Support System across the range of variables influencing the above relationships.

PRIORITY: Optimize Water Infiltration in Important Agricultural Soils

Specific Research Needs to Address Information Gaps

Research is needed to quantify effects of numerous variables (e.g., soil particle size, aggregate stability, porosity, bulk density, mineralogy, antecedent water content, known traffic patterns, and others) on water infiltration rates and the ability to alter infiltration rate through targeted soil management practices in a predictable and accurate manner.

Anticipated Products

Decision Support System for farmers that incorporates research-based information on inherent soil properties and alternative soil health management practices for increasing water infiltration into their soils.

Intended Impact

Farmers and ranchers will be given science-based tools they need to employ soil health-promoting principles and practices to achieve a targeted level of resilience to drought and floods by increasing water infiltration into their specific soils. This will significantly increase productivity, decrease runoff and soil losses, increase return on investment, and thus encourage further adoption of soil health-promoting practices/systems.

Actionable Steps

a. Conduct a meta-analysis of research literature to analyze, summarize, and generalize the drivers influencing water infiltration rates and the ability to change those rates through management practices.
b. From the above meta-analysis, develop the equations for predicting changes in infiltration rate for a wide range of soils (particle size, mineralogy, SOC, C inputs, etc.) and management practices (no-tillage, cover crops, etc.).
c. Conduct field validation studies in partnership with private land owners to validate/calibrate the above predictions across a wide range of agricultural soils and soil health management systems. Determine the ability of recommended management practices to affect water infiltration rates through changes to the major drivers.
d. Develop a Decision Support System for farmers that incorporates inherent soil properties and alternative soil health management practices for increasing water infiltration into their specific soils.

PRIORITY: Optimize Suppression of Soil-borne Diseases through Soil Health Management Systems

Specific Research Needs to Address Information Gaps

Disease suppression can result from changes in soil microbial community composition and distribution through chemical applications, crop rotations, weed management, and other mechanisms. In addition, soil health management practices that influence soil water dynamics, microbial activity, and overall biodiversity of soils can impact soil-borne disease suppression. Such complexities arising from multiple components and interactions within the phytobiome must be better understood at a basic level to design soil health management strategies and practices to enhance disease suppression, increase crop productivity, and improve producer return on investment.

Anticipated Products

Foundational knowledge of the mechanisms and drivers for suppressing soil-borne diseases and management strategies that can be used to manage the microbial community will result in improved soil health management. This new and enhanced knowledge of better practices and improved systems will be transferred to producers and other interested parties through decision support tools and other information sources.

Intended Impact

The scientific knowledge base on the mechanisms and drivers for attaining disease suppressive soils is expanded to such an extent that soil health management systems can be designed and employed to help control soil-borne diseases.

Actionable Steps

a. Analyze the current state of process-level knowledge of the mechanisms, pathways, drivers, and other variables imparting disease suppression and the various soil health management systems/practices shown to be successful for suppressing diseases.
b. Conduct research to contribute fundamental knowledge of the roles and processes by which different soil microbial communities influence disease suppression.
c. Conduct research to determine how different management practices can be used to promote and maintain favorable physical, chemical, and biological (e.g., soil microbial communities) properties and processes to suppress soil-borne diseases.
d. Determine the effectiveness and persistence of soil health management practices and systems in affecting pathogen populations and microbial communities that determine the incidence and severity of soil-borne diseases.
e. Determine the current state of adoption and success of practices and systems imparting disease suppression.
f. Develop predictions on the potential levels of disease suppression that may be attained through soil health management.
g. Transfer the information/technology developed to producers through Cooperative Extension, SARE, NRCS, ag retailers, and others.

PRIORITY: Optimize Plant Nutrient Availability in Important Agricultural Soils

Specific Research Needs to Address Information Gaps

New mixes of multiple plant species are increasingly used as a cover crop by farmers, with little known about the plant-to-plant interactions, their impact on soil microbial communities, and the significance of that impact on microbial-mediated processes influencing nutrient availability. With increased interest in enhancing soil health also comes increased need for understanding the processes and drivers influencing nutrient

availability from manure and other organic sources so that such amendments can be managed for achieving multiple production and ecosystem benefits. Much of this information is only known for limited experimental conditions. In general, many of the field-based studies upon which Land Grant Universities have relied for providing farmers with nutrient recommendations were largely conducted using management practices (e.g., moldboard plow tillage) and cultivars either no longer in existence, or not consistent with a soil health management systems approach for production.

Anticipated Products

Basic and applied knowledge of nutrient availability dynamics for contemporary practices used in soil health management systems will be developed and transferred to farmers.

Intended Impact

Farmers will be provided with nutrient recommendations that are relevant to and calibrated for contemporary soil health management systems.

Actionable Steps

a. Conduct a meta-analysis to establish the current state of knowledge on the impacts of soil health management systems on macro- and micronutrient content and plant availability. This includes analysis of, among others, rotations, cover crops, different cover crop mixes, and animal manures with different characteristics, as well as the impacts of climatic drivers and chemical composition of inputs on process rates (e.g., mineralization, uptake, leaching) and how these components influence the activity of soil microbial communities that drive many of these processes.

b. From the above analysis, determine and document any generalizations that can be established regarding the impact of soil health management systems on the total amounts and temporal/spatial dynamics of nutrient availability.

c. From the above meta-analysis, identify and document research gaps, including the effect of soil health management systems on the interaction between microbial communities and plant genotypes that promote root growth, nutrient uptake, and drought tolerance, as well as the availability of macro- and micronutrients influencing human health.

d. Calibrate long-standing and/or widely used nutrient recommendations for production systems employing soil health management systems/practices. The calibration should make optimal use of the measurements and standards identified by the Soil Health Institute's partner-led work on measurements and standards, ensuring that those particular indicators and methods are included as part of the calibration field studies.

GOAL: Quantify and Enhance Environmental and Human Health Benefits that Result from Improved Soil Health

Desired Outcomes

This research will result in improved water quality through increased nutrient use efficiency and reduced nutrient losses, increased climate change mitigation through reduced greenhouse gas emissions and increased carbon sequestration, and increased knowledge of the relationships between soil health and human health.

Information Gaps and Management Needs

Numerous research studies have addressed management impacts on nutrient use efficiency, C sequestration, and greenhouse gas emissions. However, those individual studies need to be evaluated in a way that allows prediction of soil health practice impacts across multiple scales, climates, and management systems. In addition, while it is recognized that soils are important for human health, a paucity of research exists on these relationships, especially when considered in light of the potential benefits likely to be realized.

PRIORITY: Improve Water Quality by Increasing Nutrient Use Efficiency and Reducing Nutrient Losses

Specific Research Needs to Address Information Gaps

Evaluations at scales ranging from process-level to watershed are needed to determine the increase in nutrient use efficiency, reduction in nutrient loss, and overall improvement in crop productivity and environmental quality that can be attained. At the process level, meta-analyses are needed to evaluate the research literature with a focus on effects of soil health-promoting practices and systems on desired environmental goods and services. Meta-analyses are also needed at the watershed level, as many of the individual research projects measuring conservation practice impacts on edge-of-field nutrient losses have been independently conducted and require synthesis. Integrating this information across scales and developing farmer-friendly tools to aid in practice adoption will then substantively contribute to achieving the water quality improvement levels determined to be attainable.

Anticipated Products

Predictions of the levels of water quality improvement that can be attained from implementing soil health-promoting practices and systems will be provided to producers, natural resource professionals, and the public. A farmer-friendly Decision Support System based on validated and calibrated models of nutrient availability, uptake, and transport will be developed for implementation across a range of soils, cropping systems, and soil health management systems (including 4R nutrient management).

Intended Impact

Ground and surface water quality will be improved through increased adoption of soil health management systems.

Actionable Steps

a. Determine the attainable increases in nutrient use efficiency and attainable reductions in nutrient losses through improved soil health management systems.
   1. Process Level Evaluations:
      i. Conduct a meta-analysis of soil health management system effects on the dynamics of soil properties (e.g., bulk density, aggregation, porosity), drivers influencing their rates of change, and how those changes affect nutrient uptake by plants.
      ii. Conduct meta-analysis of research on nutrient uptake and nutrient use efficiency for different soil health management systems (e.g., cover crop mixes, rotations, manure and other biological amendments).
      iii. Conduct systematic analysis of research on soil health management system impacts on runoff and leaching.
      iv. Based on the above analyses, identify research gaps in our knowledge of key processes influencing nutrient use efficiency, nutrient uptake, and nutrient transport through runoff and leaching; and develop a corresponding strategic plan for addressing those gaps.
   2. Watershed Scale Evaluations:
      i. Conduct meta-analysis of "edge-of-field" studies evaluating soil health practices/systems for their impacts on soil and nutrient losses.
      ii. Incorporate information from the above process level meta-analyses into watershed scale models of nutrient uptake by plants and transport through runoff and leaching that account for changes in soil properties (e.g., root distribution, nutrient mineralization) resulting from soil health management systems (including 4R nutrient management) and which influence nutrient uptake, leaching and runoff.
      iii. Employ watershed scale models of nutrient uptake by plants and transport through runoff and leaching that account for changes in soil properties (e.g., root distribution, nutrient mineralization) resulting from soil health management systems (including 4R nutrient management) which influence nutrient uptake, leaching and runoff.
      iv. Determine current adoption levels of soil health management systems (i.e., through the National Soil Health Assessment, NASS, and NRCS-CEAP).
      v. Based on the above data and watershed scale models, calculate the attainable reductions in nutrient losses through soil health management systems and identify key watersheds/sub-watersheds where adoption would have its greatest impact. Integrate this information with outputs of economic analyses to assess practicality of adopting practices on a scale adequate to achieve soil health objectives.

b. Achieving the Attainable
   1. Develop a farmer-friendly Decision Support System based on validated and calibrated models of nutrient availability, uptake, and transport across a range of soils, cropping systems, and soil health management systems (including 4R nutrient management).

PRIORITY: **Increase C Sequestration and Reduce Greenhouse Gas Emissions**

Specific Research Needs to Address Information Gaps

Evaluations and applications are needed to interpret existing research information on how soil and crop management practices affect greenhouse gas emissions, with a specific focus on practices/systems that improve soil health. Research is also needed to establish achievable, targeted levels of SOC for important agricultural soils, quantify potential increases to be attained, and develop decision support tools for producers to help them achieve those SOC increases and associated benefits.

Anticipated Products

Producers, agribusiness, conservation organizations, and policymakers will be provided estimates on the ability of important agricultural soils to sequester C and reduce greenhouse gas emissions using soil health-promoting practices and systems.

Intended Impact

Estimates of C sequestration and greenhouse gas emissions that can be attained through soil health improvements will significantly enhance adoption of soil health-promoting practices, leading to enhanced productivity, drought resilience, climate change mitigation, water quality, wildlife habitat, and soil and water conservation.

Actionable Steps

a. Estimate the increases in C sequestration and reductions in greenhouse gas emissions attainable on U.S. cropland and pasture/grazing lands through adoption of soil health management systems.
    1. Conduct systematic analysis of GRACEnet and other research project results to establish field-measured decreases in greenhouse gas emissions for different production systems, soils, and climates employing soil health-promoting practices/systems.
    2. Evaluate "typifying pedon" SOC analyses published by NRCS for each important agricultural soil as an indicator of the SOC level that can be attained for each soil (i.e., to provide a targeted goal). Combine SOC analyses from the NRCS Rapid C Analysis project with "typifying pedon" data to calculate potential increases in SOC that can be attained.

b. Achieving the Attainable
    1. Determine plant biomass inputs and characteristics for different soil health management systems (e.g., from NASS, CEAP) to model C dynamics and SOC levels (e.g., from the CENTURY Model) to predict the impacts of

different soil health management systems on achieving those SOC increases and the time, resources, and management systems required to do so.

2. Widely distribute and employ the same Decision Support System developed for achieving a targeted level of available water holding capacity by increasing SOC. As part of this deployment, communicate the achievable increases in SOC and available water holding capacity for specific soils and soil health practices to enhance adoption.

PRIORITY: Establish and Expand the Current State of Knowledge on the Relationships between Soil Health and Human Health

Specific Research Needs to Address Information Gaps

Many soil health-promoting practices and systems influence soil microbial ecology and activity, root proliferation and distribution, soil-borne pathogen suppression, air-borne particulate matter, and water quality. Interdisciplinary research (ranging from soil scientists to physicians and dieticians) is needed on how soil health management systems influence sustainable nutrition by impacting plant (and thus animal) nutrient availability and uptake, and therefore the nutritional quality of food (including dairy products).

Anticipated Products

A comprehensive analysis describing the known and unknown relationships between soil health and human health will be developed that establishes the current state of knowledge and prioritizes key questions requiring additional research for enhancing human health through soil health.

Intended Impact

The role of soil health for improving human health will be authoritatively established, and the additional research needs for expanding human health benefits through soil health-promoting activities will be identified and prioritized. This will open new and significant resources for enhancing soil health.

Actionable Steps

a. Assemble and commission an interdisciplinary team of scientists covering the full breadth of soil health - human health interactions to conduct a comprehensive evaluation of the known and possible relationships between soil health and human health, including soil health impacts on nutritional quality of food for human and animal consumption.
b. From the above evaluation, prioritize key gaps in research.
c. Obtain resources to address those gaps, and widely distribute the results.

MEASUREMENT, STANDARDS, and ASSESSMENT

Introduction

The overall major goals for the Institute's work on measurements and standards are to 1) establish a suite of methods and standard operating procedures (SOPs) that will provide accurate, precise measurements of soil physical, chemical, and biological properties having known relationships to soil health; 2) develop a series of priorities and procedures for pilot studies to demonstrate proof of concept for a National Soil Health Assessment (NSHA); and 3) initiate an ongoing, long-term NSHA to track the status and trends of the health of the Nation's soils in a way that provides actionable information for land managers and decision makers at all levels who wish to improve soil health. The activities developed under this plan will evaluate, select, and improve measurements and SOPs to increase the number of reliable standards used routinely and widely for the NSHA. Activities will include evaluating and comparing accuracy and precision of measurements not currently considered adequate for this application. The specific measurements and SOPs will then be applied in a series of scaled pilot studies developed over time, as resources permit, leading to an ongoing NSHA.

GOAL: Determine the appropriate measurements to initiate a National Soil Health Assessment and to assess soils at specific locations, including a framework for comparing new and established measurements

Desired Outcomes

Widely accepted measurements for routine, national-scale use to quantify physical, chemical, and biological properties and processes in soils will have valid relationships to soil health. The suite of routine and widely used measurements will be open to new and improved measurements and methodologies.

Information Gaps and Management Needs

Members of the soil health scientific and practitioners' community are not uniform in their views of the usefulness and readiness of different indicators of soil health. Several approaches to developing a consistent method to assess soil health have been developed. Few have been used widely for large-scale assessments of soil health, largely because of shortcomings with data variability and interpretation (e.g., landresources.montana.edu/soilfertility/documents/PDF/reports/NutDigSu2015.pdf) or limitations of the procedures and interpretation beyond specific regions and soils. One approach that has been used in diverse locations around the world is the Soil Management Assessment Framework (SMAF), which was designed as a user-friendly spreadsheet for indicator selection, interpretation, and integration into a series of unitless indices based on pre-tested algorithms or scoring functions (Andrews et al., 2004. Soil Sci. Soc. Am. J. 68: 1945-1962). These individual physical, chemical, biological, and nutrient index scores can be further combined to produce an overall soil health index; however, the usefulness of a single-value index has not been accepted by everyone in the scientific and practitioner communities.

Perceived gaps in information required to use and interpret indicators and subsequently manage soils vary with indicators under consideration. The following is illustrative of different gaps and needs for indicators currently considered for development of readily available, reliable applications. Over time, other measurements/indicators will be evaluated for immediate use and possibly developmental status, as determined to be improvements to the ongoing assessment.

Measurements are indicators of soil health that can be categorized as follows.

Tier 1: An effective indicator of soil health, defined regionally and by soil groupings across the nation. Thresholds are known to indicate (at minimum) "Poor", "Adequate", and "Good" that are outcome based (yield, environmental goals, etc.), and specific management strategies can be suggested to improve soil functioning.

Tier 2: An effective indicator of soil health that is known to be related to improvements or degradation of soil. Potential ranges may be known in some regions but not nationally, but research is needed to establish thresholds to meet a relative standard of a healthy soil in various regions. There is some knowledge of management practices that can change measured values and the soil processes that affect observed measurement results. Further development of a Tier 2 indicator may bring it into Tier 1. A Tier 2 indicator may be tested alongside Tier 1 indicators in local, regional, or national assessments.

Tier 3: An indicator that has potential to add significant information about soil health in specific locations or on large scales, but specific relationships among measured values, soil processes, and effects of land management are not fully understood. Tier 3 indicators are promising enough to warrant research on these relationships, as well as development of SOPs for production laboratory implementation and interpretation, in support of eventually developing them to meet Tier 1 criteria.

Measurements and protocols will be chosen as the "current best available" indicators recognized by a consensus of experts in the scientific and service lab communities, based on the following criteria:

- sensitivity to changes in soil and crop management systems;
- representational of soil processes relevant to agricultural production and environmental outcomes;
- indicative of agriculturally significant changes within 5 years; and
- available for use in commercial production laboratories (reproducible and acceptable procedurally and economically; directionally interpretable for agricultural management decisions).

PRIORITY: **Specify Tier 1 measurements to be used in the NSHA**

A likely suite of measurements taken on samples to initiate the NSHA include the following. This selection needs to be validated by the scientific community.

Physical: Texture, water-stable aggregation (3 sieves, separating macro- and micro-aggregates), bulk density, penetration resistance, visual rating of erosion

Chemical: Routine chemical analysis (N, P, K, micros, pH, CEC, %BS, EC), soil organic C

Biological: Short-term C mineralization (respiration during 3-4 day incubation), N mineralization, crop yield

PRIORITY: **Evaluate measurements currently considered Tier 2 and develop consensus for measurement procedures and interpretation**

Specific evaluation needs to address information gaps for Tier 2 measurements. There is high likelihood that some or all of the following measurements and laboratory protocols can be tested in the field along with Tier 1 measurements to determine adequacy for widespread application.

Measurement	Indicator of	Information Need	Actionable Steps and Desired Outcomes/Product(s)	Intended Impact
B-glucosidase activity	Potential to decompose plant residues and provide energy to the microbial population (General Biological Activity)	Reduce uncertainties related to how measurements are affected by sampling time, as well the range of values found, interpretation endpoints	Meta-analysis of literature to relate Bg activity to other soil properties such as SOC, especially soils under different management practices. Establish SOPs and costs	Acceptance of measurement, SOP, and interpretation
Macro-aggregate stability	Water partitioning	Ease of measurement and value of data for three methods, and relationships among methods; quantitative relationship between macro-aggregate stability and water partitioning; change in values obtained in different conditions; correlations with management, soil type, mineralogy, organic matter, infiltration, water storage	Review of literature (esp. soil erosion); SOP for methods; comparison of results	Selection and acceptance of one method and SOP
Permanganate oxidizable carbon	Carbon food source, active carbon	Determination of detection ranges; how to measure high-carbon samples; covariates that affect measurements; range in measurements in different environments; determination of the portion of the carbon pool being extracted; response relationships between carbon measured versus microbial community structure and activity	Meta-analysis of literature; SOPs for soils of widely different carbon concentration; estimates of how other soil properties affect analytical outcomes	Determination of SOP(s) required for different soils; data interpretation
Soil protein vs Illinois Soil Nitrogen Test/Solvita Labile Amino Nitrogen Test vs CO_2 flush	Bioavailable nitrogen	Ease of measurement and value of data for three methods; estimates of sampling error, variability among soils and regions	Data from samples analyzed by the different methods within and among analytical laboratories; meta-analysis of literature; relationship between management and values obtained	Selection and acceptance of one method and SOP; interpretation of data
Ester-linked fatty acid methyl ester; phospholipid fatty acid test	Microbial community structure and diversity	Sampling error, variability among soils, variability within soil profile, variability among analytical labs, data interpretation with respect to directionality as affected by management	Data obtained from comparisons among location, management practices, depth, time, collection method, conditions during shipping and storage	Selection and acceptance of one method and SOP; interpretation of data
Nematode population densities	Dominance of the nematode community by plant-parasitic vs saprobic nematodes	Interpretation of population thresholds and ratios that can affect plant health	Meta-analysis of the literature; data on value of community structure (e.g., ratios of pathogens to non-pathogens) and absolute numbers affecting crop productivity	Acceptance of measurement and data expression, interpretation relative to crop health and yield
Pathogenic fungi quantification, pathogen bioassays	Population load of plant pathogenic fungi having wide host ranges, or important in production of specific crops	Interpretation of population thresholds that can affect plant health	Meta-analysis of the literature; data on numbers affecting crop productivity; value and interpretation of bioassays instead of direct quantification	Acceptance of measurement and data expression, interpretation relative to crop health and yield

PRIORITY: **Evaluate measurements proposed by researchers for Tier 3 consideration and develop measurement procedures and interpretation**

Specific Research Needs to Address Information Gaps

Current research suggests measurements that, based on physical, chemical, or biological principles in soil science, may eventually be useful as soil health indicators. Fundamental research is needed to establish clear links among such measurements, processes in soil for which they are indicative, and desirable outcomes such as improved crop health and yield, water quality, etc.

Anticipated Products

Measurements, methods, and data that justify further testing as Tier 2 indicators.

Intended Impact

New Tier 2 indicators for field evaluation on a scale intended to help justify for eventual wide scale, consensus-driven use in Tier 1.

Actionable Steps

a. Evaluate under experimental conditions possible new indicators useful in soil health assessments. (For example, sequencing of DNA recovered from soil may be useful in microbial metagenomic analyses to indicate the presence of soil microbial communities that suppress soil-borne pathogens, thereby helping to sustain or enhance crop growth and yield.) Conduct research to establish clear links, preferably quantitative, among metagenomic data, pathogen suppression, and plant growth and yield.

b. For potential indicators identified in step a, conduct research to determine the processes and mechanisms in soil that explain how the indicator can be a reliable predictor of soil health.

c. When experimental links between indicator data and desired outcome(s) have been established, conduct field experiments to determine the extent to which management practices known to promote soil health (determined by currently accepted methods) affect potential new indicators, to establish full links among indicator data, processes and mechanisms, desired outcomes, and the influence of management practices.

PRIORITY: **Evaluate existing methods and frameworks for soil health assessment and assessment reporting**

Specific Research Needs to Address Information Gaps

Indicators and their associated methodologies, methods of summarizing data, and reporting frameworks that already exist have not been subject to side-by-side comparisons in a wide variety of environments to determine which, if any, offer the broadest applicability.

Anticipated Products

Data to support developing summary documentation as decision aids for choosing indicators, specific SOPs, and reporting methods in the NSHA.

Intended Impact

A framework for summarizing and reporting data from soil health assessments that takes advantage of methods that have already been developed and demonstrated in specific environments, with specific soils, etc. will increase use of soil health measurements.

Actionable Steps

a. Collect soil samples and analyze, summarize, and report assessment-style outputs according to protocols described for different assessment approaches that have been applied in different regions, on different soils (e.g., SMAF, CASH, Haney, others). To the extent feasible, include long-term sites that allow comparison and evaluation of soil health management systems. Also include additional Tier 1-3 indicators for consideration as measures to refine the comprehensive assessment.

b. Prepare a report making a side-by-side comparison of methods, laying out the pros and cons of each method and making a recommendation for a method expected to be applicable on the widest scale possible.

GOAL: Design and conduct pilot studies to evaluate approaches to large scale assessments of soil health

Desired Outcomes

Data from measurements chosen for pilot assessments will be used to establish a national dataset that will eventually include national assessment data, and will represent management systems from a range of poor to excellent soil health status nationwide, such that they provide information on the functioning of essential biological, physical, and chemical soil properties and processes:

- General biological activity
- Microbial community structure and diversity
- Carbon food source
- Biological N supply
- Water partitioning
- Nutrient availability
- Carbon storage
- Compaction
- Pathogen pressure

Information Gaps and Management Needs

For field sampling and analyses of soil samples collected for soil health assessment, indicators developed as described in the previous section must be used to compare samples strategically collected from fields with different combinations of soil type and management to establish accuracy, precision, and uncertainty related to each indicator. As these become known for a given indicator on increasing geographic scales, sampling schemes and analytical SOPs can be established, leading to a plan for an ongoing NSHA.

Intended Impact

Measurements taken according to SOPs that meet criteria described in Goal A will demonstrate the proof of concept for soil health assessment and be used in a series of pilot studies at increasing geographic scales, eventually leading to an ongoing NSHA. Data obtained in pilot studies will begin to provide a background against which an assessment in a specific location can be interpreted. At all scales, a wide range of metadata will enable soil measurements to be interpreted in an environmental and management context. Sampling guidelines, statistical rigor (within and among sampling points for individual soil or management types and conditions), accuracy and precision of Tier 1 indicators, the potential usefulness of Tier 2 and Tier 3 indicators, and data for initial assessments will all be outcomes of these pilot studies.

Actionable Steps

Each pilot study will:

a. Involve qualified statisticians to ensure statistical validity;
b. Focus on lands in food production systems, including cropland and grazing lands (limits for inclusion to be defined) in commercial production or on experiment stations such as the USDA Long-Term Agro-ecosystem Research (LTAR) network;
c. Include sampling sites encompassing a range of perceived soil health from "bad" (degraded)

to "good" (productive);

d. Provide data that are publicly available for inspection and analyses by the scientific community, while ensuring confidentiality of the sources;
e. Enable definition of baselines (for the sites included in any particular pilot) and scoring functions (to be developed for purposes of comparisons among management practices, environments, etc.); and
f. Be based on a hierarchical, priority-based, stratified design to support interpretation across scales, such as (but not necessarily limited to):
    - Land use
    - Region or MLRA
    - Production system
    - Soil type
    - County
    - Management practices
    - Weather history (rainfall, temperature, others).

At each pilot study's scale, metadata will be documented to provide a context for interpreting soil health indicator data with respect to management practices, environmental conditions, and changes. Metadata will include:

Location metadata

- GPS coordinates
- Historical weather (3 yr. minimum)
- Typical number of Growing Degree Days (GDD)
- Farm Service Agency maps
- Google maps
- Soil survey maps
- SSURGO data
- Sampling time (to account for temporal variability)

General soil information

- Soil classification
- Texture
- Landscape position
- Aspect/slope
- Previous soil tests
- Surrounding watershed features

Management metadata

- Owned/leased
- Previous land uses (pasture, cropland, etc.; 10 yr. minimum)
- Stocking rate (if applicable)
- Cropping history and yields (3 yr. minimum)
- Fertilization history (10 yr.)

- Manure application history
- Irrigation type, rate
- Drainage
- Residue management (tillage, residue cover)
- Cropping history/rotation (3 yr. minimum)
- Record of cover crops
- Tillage history (as many years as is available) and timing (fall vs. spring)
- Tillage implements (chisel, disc, etc.)
- History of interaction with service providers

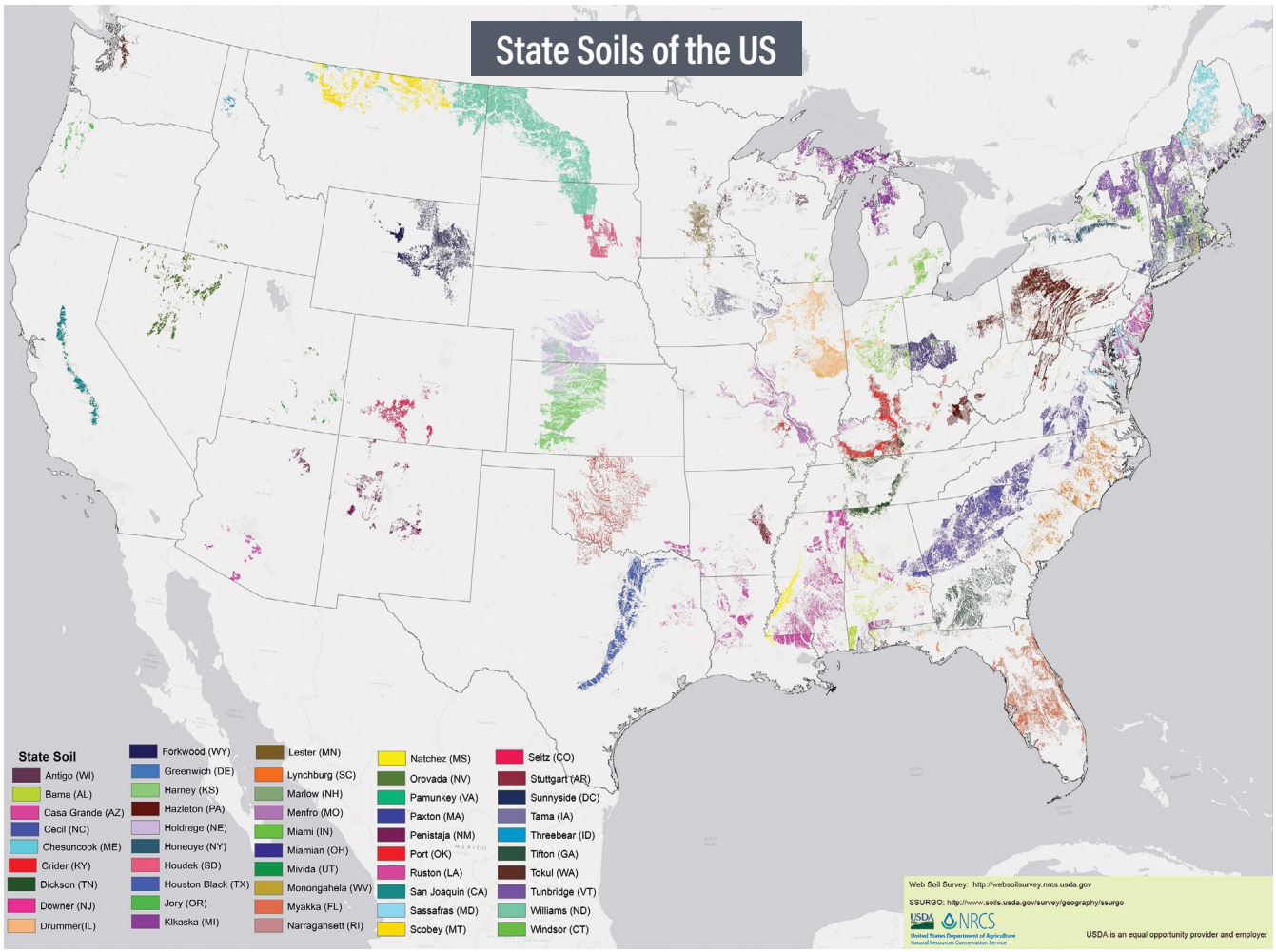
Visual metadata

- Visual rating of soil condition
- Visual rating of plant condition
- Weed cover

The initial pilot study will be based on sampling State Soils. A State Soil is identified on the Natural Resources Conservation Service website (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/edu/?cid=stelprdb1236841) as *"….a soil that has special significance to a particular state. Each state in the United States has selected a state soil, twenty of which have been legislatively established…. Areas with similar soils are grouped and labeled as soil series because their similar origins, chemical, and physical properties cause the soils to perform similarly for land use purposes….Each series consists of soils having major horizons that are similar in color, texture, structure, reaction, consistence, mineral and chemical composition, and arrangement in the soil profile."* State soils are geographically widespread (often the series having the largest land area among soils in that state) and often agriculturally important.

The initial pilot study will sample the state soils from all 50 states. Exact sampling points on these soils will be selected on the basis of available metadata (above) and an established geospatial sampling framework (or a framework modeled on one), e.g., the National Resources Inventory, NASS sampling framework, or other. Soil will be collected on at least three sites for each state soil. Sampling protocol, including soil depth and composite samples, will be defined by a blue-ribbon panel of experts convened by the Institute.

This initial pilot study may be augmented subsequently by additional sampling of state soils at sites where state soils occur on locations contained within locations of the USDA Long-Term Agro-ecosystem Research (LTAR) network or the NSF National Ecological Observatory (NEON) network. Locations within these networks, and on other sites such as long-term research plots (e.g., Morrow plots at the University of Illinois, USDA-ARS GRACEnet, university and USDA experimental watershed sites) or other research networks are data-rich and can add further interpretive value to the pilot study.



The initial pilot study will be expanded in scale as resources permit by increasing the number of sampling points on each state soil to include a wider variety of environmental conditions, production systems, and management systems. Increasing scale will permit analyses of within- and among-field variation; establish baseline values for indicators in different soils; begin to illustrate how land management practices can affect soil health; and provide data to strengthen the statistical design of soil health assessments at increasing scales.

Subsequent studies at increasing scales may involve increasing coverage of states (e.g., other soil series covering large areas within each state); increasing varieties of production and management systems within states; and alternative sampling frameworks to improve statistical inferences.

Progress and timelines for pilot studies and their specific designs will depend on resources available for measurement/SOP development, evaluation, selection, and subsequent deployment in the field.

GOAL: Conduct a full National Soil Health Assessment

Desired Outcomes

The full NSHA will:

- Establish **baselines** for soil health at regional to national scales;
- Identify **trends** in changes in soil health;
- Establish a context to **interpret** soil health information obtained for individual land managers and local decision makers;
- Support selection of land management **practices** that will lead to improvements in soil health and the resulting benefits to agricultural production and natural resources; and
- Provide information to **policymakers** responsible for public policies in agriculture and natural resources.

Information Gaps and Management Needs

Implementation of a full NSHA depends on fulfilling two needs that are intended outcomes from the pilot studies described above.

- *Use of **specific measurements** of soil physical, chemical, and biological properties having known relationships to land management practices and soil health.* Scientific consensus is required to select the suite of measurements that can be conducted to give the necessary accuracy, precision, and information value in an economically feasible way on a national

scale. Tier 1 and possibly some Tier 2 measurements (as described above) will be used.

- *Creation of **sampling design and protocols** that can be deployed in a statistically rigorous way that will enable valid conclusions to be drawn from the data.* This is required to conduct field proof-of-concept for the NSHA, followed by increasing the scope and scale of these studies over several years to reach the full NSHA.

Actionable Steps

a. Conduct the NSHA across a diverse array of soil series, environments, agricultural production systems, and management strategies, reflecting the stratified design described above. There are 3,144 counties and county equivalents in the United States. The NSHA will include all 50 states, however, not all counties will be sampled because not all contain land that meets metadata and design stratification criteria described above, e.g., a county may not include lands involved in food production, or the food production areas are arid rangelands used for livestock grazing but may not be conducive or economically justifiable to determining or improving soil health.

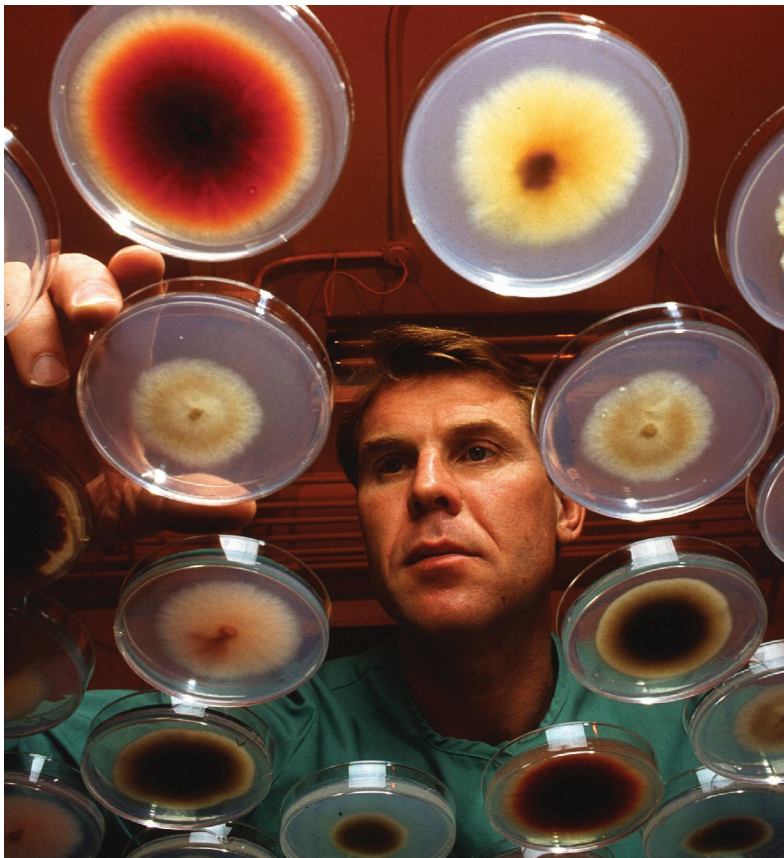
The exact sampling design, indicators, and analytical SOPs will be determined from the activities described above, in consultation with expert panels convened by the Institute. The NSHA is expected to be an ongoing activity based on a rotational sampling framework. There will be a set of samples collected yearly from a standardized set of locations (e.g., from state or benchmark soils) to provide a common dataset across years. Collections will be made from most sampling sites in not all years but revisited on a schedule, e.g., 5 years, to permit the entire national sampling frame to be repeated on that schedule. The exact rotational duration will be determined by the resources available and the statistical power desired, i.e., more resources permitting more analyses can enable the rotation to be shortened in lieu of collecting more samples in a given

year if sample number is considered statistically adequate for the inferences desired. Thus, data will reflect temporal variability and provide some indication of the "direction" of soil health trends regionally and nationally. Individual land managers who are interested in the health of soil on their land, and how management practices affect it, will be able to compare results from their soils to the national database and draw contrasts for similar soils, similar crop or livestock production systems, similar management practices (e.g., tillage, irrigation), etc.

The design, scale, and rate of implementation of the NSHA will depend on the resources available to the Institute's scientific partners.

b. Create a database that is publicly accessible from the Institute's website. Analytical data and accompanying metadata will be available on this site. The Institute will consult with the USDA National Agricultural Statistics Service (NASS) to establish procedures that will permit access, aggregation, and analyses but protect the confidentiality of the source of specific data and metadata, in the same way that NASS collects and analyzes national data without compromising data security and sampling location anonymity. Researchers and laboratories who receive funding support from the Institute to develop analytical methods, SOPs, and statistical designs must also deposit their data on the Institute website. It is anticipated that data collected for methods development, pilot studies, and the NSHA will also be posted on the website within 6 months of collection.

c. Transfer new information about soil health to the public. Data, metadata, methods descriptions, and SOPs will be available publicly through the Institute's website. The Institute's Action Plan includes strategies to communicate the availability of data, etc., to the agricultural, research, education, and policy communities. The Institute will assess no fees for access to data, etc., available on the Institute website. Publications and other communications that make use of these data, should cite the Institute website as the source. Whenever possible, such publications and other communications will be deposited in the Institute's Soil Health Research Landscape tool, also available on the Institute website.



ECONOMICS

Introduction

Farmers and ranchers are business owners and managers. Consequently, economics is a primary driver influencing adoption of all land management practices, including soil health-promoting practices and systems. Accordingly, to realize the environmental benefits of soil health management systems, the economics of such practices must be assessed, demonstrated, and communicated to increase adoption. Potential affordability of practices that can be implemented, profitability over different time horizons, investment risk, and barriers to adoption are key measures for assessing the economics of soil health management systems. The following objectives and approaches are proposed to address these issues. For initial analyses under this section of the Action Plan, deep, targeted case studies in priority climates/soil types/production systems may provide strong illustrative examples and test approaches to guide subsequent, broader analyses.

GOAL: Quantify Economic Risk of Soil Health Management Systems

Desired Outcomes

The resilience-promoting aspects of soil health management systems will result in increased yield stability (i.e., less variation in yield among years and/or locations) and reduced economic risk, thereby providing a key incentive for farmers and ranchers to adopt soil health management systems.

Information Gaps and Management Needs

Although the benefits of soil health practices to water quality, carbon sequestration, and others are well documented, very little research is available on the impact of these practices on economic risk to producers. Not only must this information be obtained, but it must then be communicated to producers so it becomes a factor (positive or negative) in their management decision process.

PRIORITY: Quantify and communicate soil health management system impacts on economic risk in agricultural production

Specific Needs to Address Information Gaps

Evaluations are needed to quantify the relationships among soil health-promoting practices and economic risk for a wide range of production systems, management practices, climates, and soils. Variables influencing those relationships must also be identified, and the information must be transferred to producers to assist in their management decisions.

Anticipated Products

Fact sheets, videos, blogs, etc. describing the role of soil health on economic risk will be developed for a farmer audience and distributed by SHI and partnering government agencies, crop commodity organizations, agri-businesses, cooperative extension, conservation groups, and others. A scientific paper describing the approach, analysis, and findings will be published in a peer-reviewed scientific journal to document the scientific merit of the approach used and conclusions drawn.

Intended Impact

Adoption of soil health management systems determined to reduce economic risk will increase because producers will be provided technically authoritative evidence that soil health practices reduce yield variability and investment risk.

Actionable Steps

a. Conduct a systematic review of the scientific literature that evaluates the impact of soil health-promoting practices on economic risk, yield, and/or yield variability.

b. Summarize the information analyzed in a comprehensive assessment that not only includes available measures of economic risk (i.e., from actual measured economics data or yield variability), but that also documents and evaluates the influence of all pertinent parameters/practices on the results obtained. Analyze all data to determine conclusions and generalizations that can be drawn on such co-variates as cropping system, climatic zone, soil properties, etc. Evaluate short-term and long-term economics, their associated interchangeable sacrifices, and potential policy connections.

c. Develop information and educational resources (e.g., 1-2 page fact sheets) for farmer audiences that summarize impacts of soil health management systems on economic risk. Field-test draft fact sheets with a subset of farmers across a range of cropping systems and climatic zones and revise final fact sheets accordingly to optimize message effectiveness. Distribute fact sheets to partners who work directly with farmers, including USDA-NRCS, The Nature Conservancy, Soil and Water Conservation Districts, Ag. Retailers, and Land Grant Cooperative Extension. Develop and distribute press releases to assist with message distribution and adoption.

d. Enter all literature summarized for assessing economic risk into the existing Soil Health Research Landscape information system so all users can search and find information on specific research projects pertinent to soil health practice impacts on resilience, yield variability, and economic risk.

GOAL: Determine profitability of soil health management practices and systems

Desired Outcomes

Educational materials developed for and distributed to farmers will inform decision making related to the impacts of soil health management systems on potential profitability. This is expected to increase adoption of soil health-promoting practices.

Information Gaps and Management Needs

Producers need more information on the potential profitability of soil health-promoting practices relevant to their particular production systems. Such information is generally not available for the wide range of cropping systems, climates, soils, and management practices required. The best specific sources of information for evaluating potential profitability must also be identified and used.

PRIORITY: Develop and distribute partial budgets for producers that allow them to determine potential profitability of soil health practices in crops and geographies relevant to their particular production system

Specific Needs to Address Information Gaps

Development of partial budgets requires community consensus around the format desired and most useful to producers, data needs, and production systems of interest for analysis.

Anticipated Products

Fact sheets will be developed that include example partial budgets comparing with and without soil health-promoting practices for major production systems and geographic regions.

Intended Impact

Soil health management systems and practices determined to be profitable will be identified and communicated, thereby resulting in significantly greater adoption of soil health practices.

Actionable Steps

a. Identify and assemble a balanced mix of soil health scientists, farmers, and economists to determine the type, availability, and sources of tools and data that are needed and currently available for developing partial budgets for producers with and without soil health management systems; and to determine the key production systems/geographies on which to focus. Include aspects of both short-term and long-term economics, their associated sacrifices, and potential policy connections.
b. Develop and populate a template for the agreed upon partial budget format that can be used across a range of production systems and inputs (e.g., manured and non-manured).
c. Engage a subset of farmers to ground-truth the partial budgets developed for their respective production system/region.
d. Construct and distribute educational materials for farmers on the impacts of soil health management systems on potential profitability based on alternative soil health management practices (cover crops, no-tillage, different rotations, options for utilization of cover crops/rotations, etc.).

GOAL: Establish Approaches for Monetization of Soil Health

Desired Outcomes

The economic values of soil health will be established from both producer and public perspectives.

Information Gaps and Management Needs

Little is known about the economic value of healthy soil to the producer, and even less is known about the economic value of healthy soil to the public. Establishing economic values from each perspective would by necessity be contextual. For example, from the producer perspective, the context may include type of crops grown, their market value, and potential yield increases possible through soil health practices. From the public perspective, the context may include nutrient runoff potential to surface water (depends on such factors as soil drainage/infiltration properties, landscape characteristics, climatic zone, and distance to water body).

PRIORITY: Estimate the economic value of soil health from producer and public perspectives

Specific Needs to Address Information Gaps

Information is needed on the current state of soil health for predominant soils, the attainable levels that are possible, and the potential increases in productivity and ecosystem services that may be expected if soil health is increased from the current state to that higher, attainable state.

Anticipated Products

White papers and/or models of current and potential economic values of soils will be developed for major agricultural soils in the U.S., with considerations given to producer and public (ecosystem service) benefits.

Intended Impact

Adoption of soil health management systems will significantly increase as a result of the realization that such investments have yield and ecosystem service benefits.

Actionable Steps

a. Convene working groups of producers, soil scientists, agronomists, economists, and ecologists/modelers to design the detailed path forward. Consider concepts of land valuation and application needs of environmental markets (e.g., carbon and water quality markets).
b. Coordinate assessments of the current state of soil health and estimates of attainable levels with working groups leading the Measurement, Standards, and Assessment activities.
c. Calculate potential productivity increases and ecosystem services (e.g., reduced nutrient losses through leaching and runoff) from published data or estimates from models.
d. Apply monetary values to those productivity increases and ecosystem service enhancements within a place-based, system-based context.
e. Write and distribute white papers documenting the approaches used and findings made.

COMMUNICATIONS and EDUCATION

Introduction

The overall goal of the Institute's Communications and Education effort is to increase adoption of soil health-promoting practices through effective communications and education by serving as a central hub for soil health information. The activities developed under this plan will broaden the depth of knowledge regarding the critical nature of soil health. Focused messages will be delivered through the Institute's active network of contributors and researchers using a variety of communication media. The Institute's primary activities in research, measurements and standards, economics, and public policy will be emphasized. In addition, the Institute will strengthen and support the communication and education efforts of partners' soil health initiatives, facilitate a common language about soil health, and systematically address gaps in outreach. Results of these activities will engage the public, farmers and ranchers, scientists, policymakers and industry in a conversation about soil health's impact on water quality, food security, resilience to climate change, climate change mitigation, human health, air quality, and pollinator and wildlife habitat. Through this open communication, the Institute will seek to increase the adoption of soil health management systems.

GOAL: Establish and Strengthen the Institute's Online Presence

Desired Outcomes

The Institute's diverse audience, consisting of funders, scientists, farmers and ranchers, policymakers, educators, landowners and managers, industry, and the public at large, will have ready access to useful soil health information. This audience will have heightened awareness and interest in soil health and will understand the opportunities for environmental and socioeconomic benefits arising from soil health. Demonstration sites, workshops, and conferences will be announced and new and existing soil health programs will be promoted.

Information Gaps and Management Needs

Significant information gaps exist among the Institute's audiences regarding the connection between soil health and its impact on water, climate, environment, productivity, and food security. There is a lack of a comprehensive organization communicating the efforts and successes of organizations and individuals working in soil health. There is also a lack of a comprehensive online repository of updated soil health research literature.

PRIORITY: Develop Materials and Processes for Active Outreach Online

Specific Needs to Address Information Gaps

Software automation will facilitate outreach by the Institute. Customer Relationship Management (CRM) tools are needed to target communications at specific audiences. Subjects for news kits need to be prioritized. A calendar of events needs to be designed and established on the Institute's website as a service to the broad soil health science and applications community. Social science (marketing) tools could be used to ensure the communication(s) resonate with targeted demographics.

Anticipated Products

A range of communication, education, and outreach products will be developed, including:

- Drip email to Institute partners and others who have expressed interest in the Institute;
- Trigger email to those who click-through or respond to a specific topic or article;
- News releases, exclusive articles, and media relations;
- Event-based news kits and support for specific topics (e.g., hypoxia);
- Collaboration with others (i.e., partner features);
- A calendar of regional and national conferences, speaking opportunities and partnership opportunities; and
- Website links to government agencies, foundations, nonprofits, and corporate partners, e.g., Land Grant Universities, USDA agencies, selected research facilities, environmental organizations and other organizations with interests in soil health, water quality, agricultural sustainability, and science-based climate information. The Institute's website will also feature a prominent link to the Soil Health Research Landscape tool.

Intended Impact

SHI audiences and partners will find the soil health information they seek through the Institute's website. Institute audiences and partners receive the information relevant to their interest(s) and/or mission(s) via email and news media. Institute audiences' depth of knowledge is broadened regarding the critical nature of soil health. Institute audiences are aware of the Institute's activities and those of its partners.

Actionable Steps

a. Re-design and continually improve the Institute's website to communicate soil health related information to a range of audiences. Measure online visibility via website actionable inquiries, organic search, media exposure, awareness growth, and standard social media metrics.
b. Develop event based news for important topics related to soil health (e.g., water quality, drought).
c. Develop and post a calendar of soil health related events, conferences, and opportunities.

GOAL: Facilitate Collaboration Among the Institute's Action Teams and Partners

Desired Outcomes

Outcomes include an internal communication platform that facilitates conversations and helps to increase synergies and awareness among the Institute's Action Teams and partners. An overall "systems approach" to soil health will incorporate ideas from research, measurements and standards, economics, and public policy to enhance the Institute's mission. The Institute's partners and the public will understand the rationale behind essential, tiered soil health indicators and measurement practices because the Institute's leaders in communications and education will collaborate with scientists leading the measurements and standards efforts.

Information Gaps and Management Needs

The Institute's Action Teams and major work are comprised of volunteers who may not be fully aware of important and connected activities in other parts of the Institute. Awareness, engagement, and idea-sharing need to be enhanced among the Institute's Action Teams and volunteers.

PRIORITY: Enhance Institute effectiveness by increasing communication and collaboration among volunteers working within the operational structure

Specific Needs to Address Information Gaps

Full establishment of Action Teams is needed to ensure consistent communication among Institute partners. Institute staff need to facilitate regular communications with co-chairs to establish goals and functions of the Institute's Action Teams.

Anticipated Products

Products include a quarterly summary of each Action Team's activity and progress, prepared by the co-chairs. A platform will be provided for Teams to interact and engage in conversation.

Intended Impact

Clear and regular communication will establish direction forward and consensus among individual Action Teams working collaboratively to fulfill the Institute's mission.

Actionable Steps

a. Institute staff will select Action Team co-chairs.
b. Each co-chair will prepare a slate of 5-10 potential team members and submit it to the Institute for review, discussion, modification, and approval.
c. The Institute will convene regular conference calls of the Action Team co-chairs.
d. Co-chairs will convene regular conference calls of the team members.
e. Co-chairs will submit quarterly reports to the Institute, and other reports on specific projects as needed.
f. Each Action Team will have at least one co-chair attend all Institute annual meetings.

GOAL: Increase Education of Potential Partners and Audiences About Soil Health's Key Areas of Impact

Desired Outcomes

The Institute's impact will be bolstered by strategic government, foundation, nonprofit, and corporate partnerships. Messages developed with partners will show unity and clarity as to how soil health benefits water, climate, environment, productivity and food security. As a result, soil health will be elevated to a national and international priority.

Information Gaps and Management Needs

Currently, no organization is responsible for coordinating public and private efforts focused on enhancing soil health. Communication can always be improved among public and private organizations focused on enhancing soil health. Increased unity, synergy and elimination of redundancies are needed among soil health related organizations.

PRIORITY: Establish Partnerships with Key National and International Organizations

Specific Needs to Address Information Gaps

There are many organizations interested in communicating about agriculture and the environment, but the connection with soil health is not always apparent. Organizations need to be aware that the Institute is a source of information that is valuable for developing messages about the benefits of soil health to the environment, agriculture, and society.

Anticipated Products

Educational materials and lists of experts appropriate for developing important messages about soil health will be developed.

Intended Impact

The visibility and importance of soil health will be elevated and strengthened by providing organizations with ready access to information and expertise about soil health. Such organizations may include agribusinesses; international scientific organizations; international conservation organizations; international government agencies; key countries that have similar organizations; and international manufacturers, academia, foundations, and media outlets.

Actionable Steps

a. Ensure that the Institute's website has information and links available for organizations pertinent to their needs and opportunities.
b. Create a list of experts at academic institutions, government agencies, private industry, and non-

governmental organizations who are interested in serving as sources of technical information.

c. Support organizations in their messaging and outreach by working with them to develop materials to communicate about soil health.
d. Develop joint opinion-editorials regarding the Institute's key areas of impact.
e. Enhance collaborations to increase adoption of soil health promoting practices.
f. Collaborate with partners such as the Farm Foundation to host educational forums on soil health.

PRIORITY: Educate the broader public about the principal benefits of soil health

Specific Needs to Address Information Gaps

Educators in most settings are not aware of soil health, let alone knowledgeable about it. Readily available information is lacking as a foundation for lesson development in schools. Educators who may be interested in the topic may not know where to go for reliable information about the subject.

Anticipated Products

Qualified expert partners willing to work with teachers will be identified from scientific societies, extension, government agencies, private sector, agricultural centers, vocational schools, and community colleges. Existing soil-related curricula and programs will be identified and made available for use in both formal and informal educational settings for youth. An inventory of existing community education programs will be developed for home and community lawn and gardens. Key messages and partnerships will be developed with organizations identified through an inventory of programs to encourage incorporation of soil health principles into existing curricula and programs. Coordinated efforts with national awareness campaigns will target outreach to youth and community educators to promote the soil health movement in education. A clearinghouse of available soil health resources, identified through an inventory and compilation, will be developed and promoted with educators in the field.

Intended Impact

Educators have ready access to information and experts to enable development of lesson plans and demonstrations on soil health and its benefits to the environment, agriculture, and people everywhere. Students have an increased appreciation and understanding of these topics and can explain, engage in, and advocate for soil health issues.

Actionable Steps

a. Ensure that the Institute website has information and links useful to teachers.
b. Create a list of experts at academic institutions, government agencies, and elsewhere who are interested in working with teachers.

c. Support teachers and soil health experts in developing materials and lesson plans to teach about soil health.

PRIORITY: Engage the Media and Develop Communications Material

Specific Needs to Address Information Gaps

Journalists depend on subject matter experts and expert-developed information to help craft public messages but may not know who those experts are in the area of soil health.

Anticipated Products

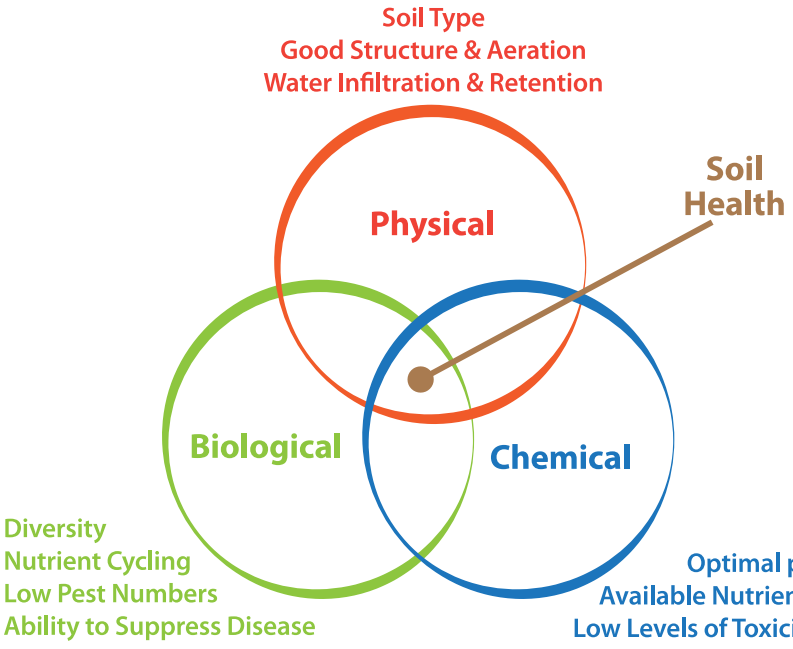
Media kits to address information and outreach needs will be specifically developed for media use. Possible topics may include societal benefits and case studies that appeal to wide audiences and can generate interest and support; and the relationship of soil health to important topics such as food security, the environment, climate, agricultural productivity, plant and animal health, agricultural markets and retail, and human health.

Intended Impact

Through well-planned and factual media stories, key audiences are engaged in a conversation about the priorities, benefits, and opportunities to have an impact through soil health. The adoption of soil health-promoting practices will be increased.

Actionable Steps

a. The Institute will identify and work with broadcast, print, and social media developers and reporters to stimulate interest in communications about soil health.
b. Create and distribute media kits and useful information to support widespread communications.



POLICY

Introduction

The Soil Health Institute advocates the use of information from peer-reviewed scientific and socio-economic analyses as a foundation for land management and natural resources decision making, especially that involving the long-term condition of the soil. Accordingly, the Institute seeks to provide to decision makers a firm foundation of soil health related scientific and socio-economic information and analyses that enable policy driven actions that will:

- Increase soil health through voluntary, non-regulatory, business-oriented mechanisms;
- Increase awareness and understanding of the benefits attributed to soil health, along with the corresponding public value of incentives for adopting soil health practices; and
- Increase public investment of resources in soil health to achieve widely available public benefits to food production and natural resource management that can be achieved by implementing soil health related science and technology.

Policymakers are supported by the Institute's scientific, technical, and economic work and its communication, education, and outreach initiatives that can relate reliable measurements of soil properties to specific land management practices, environmental conditions, and socio-economic incentives and obstacles to implementing soil health-enhancing practices. Results of the Institute's work on policy will help decision makers allocate public resources to sustain and enhance soil health as a primary mechanism to achieve desired environmental and socioeconomic goals related to land management and natural resources.

GOAL: Make Soil Health the Cornerstone of Natural Resources Management Policies Throughout the Nation

Desired Outcomes

Natural resources policies support research, education, and adoption of soil health management systems. Public policies related to agriculture and natural resources management routinely consider impacts on soil health when evaluating intended and unintended consequences.

Information Gaps and Management Needs

The positive and negative impacts of existing policies on soil health have not been thoroughly assessed. Planned or inadvertent impacts of policies, including the next Farm Bill, rarely take soil health into consideration, even though managing soil health has broad benefits to natural resources, agricultural systems, and food security.

PRIORITY: Assess Current Policies for Positive and Negative Influences on Soil Health

Specific Needs to Address Information Gaps

Analyses are needed to examine a wide range of national, state and local policies for their intended and unintended consequences on soil health and subsequent broader impacts on the environment and agriculture.

Anticipated Products

White papers will be developed for policymakers describing the actual impacts of existing policies, to be used as case studies as new or updated policies are developed. Papers may be suitable for publication in appropriate policy-oriented journals.

Intended Impact

The Institute is considered widely as a primary source of reliable information about soil health for policymakers and is valued as an unbiased source because it does not engage directly in policy development. Policymakers know that they have readily available, neutral, and factual bases for decision making via the Institute's programs, including analyses of economic costs and benefits of soil health-improving practices. The Institute website, including the Soil Health Research Landscape tool and information about Institute-funded projects, is readily available to policymakers and their staffs as a key resource for new findings,

analyses, experts, practitioners, laboratories, and stakeholders in the soil health community. Public policies related to agriculture and natural resources management routinely make soil health a primary consideration in evaluating intended and unintended consequences.

Actionable Steps

a. Develop case studies evaluating the positive and negative effects of policies on soil health. For example, the Conservation Stewardship Program (CSP) is an example of a positive policy that has the potential to be even more effective in promoting soil health. Oregon has had success with CSP contracts having specific soil health-promoting practices. Programs such as this will be easier to support relative to soil health if metrics or indices to help justify adoption of beneficial practices based on measurable outcomes can be developed as a part of the Institute's research and measurement activities. Big data, or data collected via the NSHA, could be utilized to create the index, which could also serve as a risk profile for land by the acre. The index could be especially useful in contracts between landowners and renters. In contrast, certain land lease agreements are detrimental to the longevity required of certain soil health management practices. Policies that integrate land owner incentives into lease agreements could promote better management. Negative impacts may be offset by incentives directed at the producer, who may not see the short-term costs of planting cover crops, for example, as a worthwhile investment on rented land.
b. Identify existing policies and policy making opportunities that can enhance the application of soil health concepts in policies. Examples include soil health research grants, soil health improvement in natural resources conservation programs, and soil health as a consideration in innovation grants programs.
c. Create a database and document archive to serve as a clearing house for information regarding successful adoption of soil health management strategies employed by states and other countries.

CREDITS

ABOUT THE COVER

Southwestern Wisconsin's 91,000-acre Coon Creek watershed is the birthplace of modern soil conservation. In 1933, the Soil Erosion Service selected Coon Creek as its pilot watershed demonstration. Farmers agreed to experiment with strip cropping, increase crop rotations and convert steep slopes to pasture or woodland. According to the USDA-NRCS, by June 1935, 418 of the valley's 800 farmers were participating in the project. Researchers have since calculated that the conservation practices have reduced erosion by at least 75 percent. Photo by Jim Richardson.

PHOTOS BY JIM RICHARDSON

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STOCK PHOTOGRAPHY

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The remaining photographs in this Action Plan were taken by USDA-ARS, USDA-NRCS, land grant university, or Soil Health Institute employees and are in the public domain. Please contact the Soil Health Institute if you would like further information about these images.

ABOUT THE SOIL HEALTH INSTITUTE

In 2013, The Samuel Roberts Noble Foundation and Farm Foundation, NFP, convened agricultural industry thought leaders, farmers, ranchers, government agency leaders, and non-governmental organizations to examine the current state of soil health and its role in a vibrant, profitable, and sustainable natural ecosystem. As the group identified diverse and complex issues regarding soil health, it became clear that a collaborative-oriented organization was needed to spearhead accurate, science-based information, create a sense of urgency and coordinate change leadership.

The Soil Health Institute is that organization. As the independent, nonprofit organization charged with coordinating and supporting soil stewardship and advancing soil health, the Soil Health Institute is focused on fundamental and applied research. We recognize that soil health must emerge as the cornerstone of land use management decisions during the 21st Century because healthy soil is the foundation of life and society, our world's remaining arable soil is degrading at a rapid rate and the global population is expected to exceed nine billion by 2050, increasing demand on agricultural production and natural resources.

The Soil Health Institute is designed to move from the research laboratory to the farm field – bringing industry, farmers, ranchers, government agencies, agronomists, and consumers toward the common goal of protecting and enriching our home.

The Soil Health Institute is a 501(c)(3) nonprofit organization. Your donation is tax deductible to the fullest extent of the law. Please consult your tax advisor for information.

To become informed and involved, contact:

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