



CONFERENCE REPORT

CONFERENCE on CONNECTIONS BETWEEN SOIL HEALTH and HUMAN HEALTH

October 16-17, 2018
Silver Spring, Maryland USA



COORDINATED BY



SOIL HEALTH
INSTITUTE

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OVERVIEW

Conference Overview

Soil health is defined as “the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans.” Healthy soils contribute to a range of ecosystem functions in the environment, such as sustaining plant and animal productivity and biodiversity, maintaining or enhancing air and water quality, and supporting human health and habitation.

Many in the community of agriculture and food sciences, as well as some in the human and veterinary medicine communities, see benefits from an improved understanding of connections between soil health (and the farming practices that can promote it) and human/animal health. Such connections may occur through the impact of land management, crop and livestock production, commodity processing, and other aspects of food production on the nutritional quality of foods, food safety, environmental quality, the human microbiome, and other factors.

Historically, however, when we have considered how soil health supports human health, it has often been in the context of feeding our growing world population, certainly a noble goal by itself. More recently, we have studied how healthy soils contribute to ecosystem functions, sustaining plant and

animal productivity and biodiversity, filtering contaminants and thus maintaining or enhancing air and water quality and ultimately supporting human health. This topic was addressed in brief among many others at a recent conference, “Soils: The Foundation of Life” hosted by the National Academies of Sciences, Engineering, and Medicine in Washington, DC, December 2016 (see <https://www.nap.edu/read/24866/chapter/1>; accessed January 10, 2019). However,

- Make relevant connections between soil and human health sciences;
- Identify promising research opportunities;
- Explore funding mechanisms that will lead to scientific findings that benefit the health of agricultural systems, the environment, and the public;
- Provide a forum to initiate interdisciplinary teams to address research needs; and
- Create a roadmap for future collaborations and progress.



Goals for this “Kickstarter Conference”

there had been no major transdisciplinary conference focusing specifically on the topic, especially as techniques for studying soil and human microbiomes have advanced both areas of science. Mostly, we have stayed within our disciplines, addressing soil health’s possible impact on human health, various soil-borne pathogenic organisms, parasitic infections, bacterial suppression, immunity, and other topics discussed during broad conferences, symposia, and concurrent sessions within larger meetings.

We recognize that great environmental and social challenges exist, but these challenges offer opportunities for experts in human health and soil health fields to interact and make significant progress for achieving greater global sustainability. Few conduct research that bridges these fields. Differences in language, funding sources, research priorities, and even locations on university campuses and government buildings are impediments to exploring this most fundamental relationship between soil and human health.



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Thus, a multi-disciplinary conference was designed to bring our communities together, establish the current state of our collective knowledge, identify gaps and associated priorities, and scope the path forward. This national conference on soil health-human health connections was held October 16-17, 2018, in Silver Spring, Maryland. The conference provided an opportunity to:

- hear from scientific leaders who could address the known and potential connections among relevant agricultural, biological, social, earth, and human health sciences;
- provide a forum for interdisciplinary discussions;
- identify areas of high-priority research that could and should be conducted;
- create networking opportunities that could lead to interdisciplinary teams to address those research needs; and
- propose funding mechanisms for science investigations that could ultimately benefit the health of agricultural systems, the environment, and the public.



To organize a conference that could achieve those goals, an interdisciplinary team of agricultural, biological, earth, and human health scientists developed the agenda around key topics and a series of presentations and panels featuring outstanding experts in a range of human health, soil health, agricultural, urban, and environmental fields (<https://soilhealthinstitute.org/wp-content/uploads/2018/10/Soil-Health-Human-Health-Conference-Program-digital4.pdf>; accessed January 10, 2019). The conference

was designed as a workshop to develop a roadmap for collaborative, interdisciplinary exploration into the connections within and among microbiome ecosystems, soil health, food production, nutrition, and human health.

The conference offered the following:

- keynote addresses from experts in the soil health and human health communities to provide broad perspectives;
- technical sessions on specific aspects connecting soil health and human health, featuring overview speakers and panelists discussing current research and knowledge gaps;
- breakout sessions to identify high priorities for research and strategic connections among different disciplines;



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- a session on the connections and disconnections between food/agriculture policies and human health policies;
- a panel discussion among representatives of public- and private-sector organizations that could consider funding new research on human health-soil health connections; and
- development of a consensus on next steps to further promote and implement research on soil health-human health connections.

More than 180 attendees from more than 120 different organizations brought perspectives from the agricultural, biological, earth, human health, and veterinary sciences. A dozen attendees were graduate students, who were provided free admission through a competitive process. More than 40 attendees were speakers and panelists invited to achieve a balance between soil health and human health interests and expertise; the remainder participated following an open registration.

During the course of the conference, attendees identified promising research opportunities, considered requirements for interdisciplinary teams to address research priorities, and proposed funding mechanisms that would lead to scientific findings benefiting the health of agricultural systems, the environment, and the public.

The principal product of the conference was a Top 10 recommendation list for advancing science and policy connecting soil health and human health for the benefit of agriculture, the environment, and human health (see page 15). Additional valuable recommendations were documented.



This report contains:

- brief descriptions of the sessions and the assignments to the speakers and panelists;
- summaries of most of the presentations, along with links to YouTube videos of presentations and slides (when granted speaker permission);
- major recommendations developed by the attendees during breakout sessions;
- proposed next steps; and
- an appendix containing additional recommendations from the breakout participants.



PRESENTATIONS

Summary of Presentations in Plenary Sessions

Subject matter experts presented keynote addresses, overview talks, and panel briefs during the conference plenary sessions.

Keynote speakers were offered considerable latitude in their remarks on connections between soil health and human health. As there are very few real experts on these connections, keynote speakers had opportunity to be speculative or provocative. They were given the opportunity to build from their own work or work of others to identify information gaps and advocate for specific kinds of research. Several keynote speakers delivered remarks at the conclusions of plenary sessions and had the opportunity to respond and adapt to ideas heard during the meeting. Speakers were encouraged to challenge attendees' imaginations and lay the groundwork for forward-looking discussions, including discussions to be continued after the conference.

Overview speakers opened specific technical sessions and chaired topic-specific panels. Overview speakers offered 15-minute introductory presentations on a specified panel topic from a broad perspective. These speakers had the option of talking about their own experiences or accomplishments. They were encouraged to stress the unknowns and knowledge gaps and the importance of knowing more about the panel topic's link between soil health and human health. They were encouraged to advocate for more work on their particular area of expertise. After an overview presentation, they introduced panelists and moderated the panel discussion.

Panelists were allotted 10 minutes each for a focused assignment. Panelists confined their remarks to identifying a specific knowledge gap limiting advancement in the understanding of soil health-human health connections; the status of research and knowledge related to the issue; recommendations on research; the kind of team needed to undertake the research; resources needed; and potential impact of research outputs.



Following each overview and panel session, the panel chair moderated a question-and-answer session from the audience. Questions and comments were submitted

electronically and selected for discussion by the conference chair. All questions, including those *not* addressed in the discussions, received from attendees were retained for future reference.

Presentations are summarized briefly in the following pages and appear here according to agenda order. Presenter biographies can be found in the conference agenda (<https://soilhealthinstitute.org/wp-content/uploads/2018/10/Soil-Health-Human-Health-Conference-Program-digital4.pdf>; accessed January 10, 2019). Links to video-recorded presentations are noted.



PRESENTATIONS

Conference Goals and Overview – Dr. Steven Shafer, Interim Chief Scientific Officer of the Soil Health Institute, briefly reviewed the origin and development process for this conference on soil health and human health. Objectives included (i) identifying priorities, (ii) making relevant connections, (iii) creating opportunity for interdisciplinary teams, and (iv) creating a roadmap. (<https://youtu.be/k9meXCRGy5w?list=PLdFV/keklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)

Keynote Address 1 – Day 1 - Soil Health-Human Health Connections: Introduction from the Medical Community – Dr. Jerome Paulson, Emeritus Professor, George Washington University, School of Public Health, opened the conference with a keynote address about the conventional definitions – and segmentation – of human, soil, and global health and the newer concept of planetary health. Dr. Paulson speculated on potential avenues to bridge these health concepts for researchers, physicians, and practitioners. (https://youtu.be/igczuA_cX4w retrieved 2/11/2019)

Keynote Address 2 – Day 1 - Soil Health-Human Health Connections: Introduction from the Soil Health Community – Dr. David Montgomery, Professor of Geomorphology, University of Washington, continued the conference opening in a keynote address telling the history of the erosion of topsoil and organic matter due to human soil management and declining soil health. Dr. Montgomery described some soil best management practices that lower erosion rates and add organic matter back to the soil. (<https://youtu.be/6HwlqR1YnNk> retrieved 2/11/2019)

The Influence of Soil Health on Human Nutrition – Overview by Dr. Naomi Fukagawa, Director, Beltsville Human Nutrition Research Center, U.S. Department of Agriculture - Agricultural Research Service, provided a broad picture of areas where soil health and human nutrition could overlap and suggested benefits for natural resource management, disease prevention, and human health. Balanced diet was noted as key, although a knowledge gap exists between production aspects of food and human nutrition. (<https://youtu.be/z-Q7fIDoang> retrieved 2/11/2019)

Panel Presentation by Dr. Michael Grusak, Director, Edward T. Schafer Agricultural Research Center, Fargo, North Dakota, discussed the impact of climate change (elevated CO₂, higher temperatures, altered water availability) on soil nutrient availability for crop plants and how changes in plant physiology and metabolism/soil microorganisms influence soil chemistry and nutrient availability. The impact of breeding tools, mitigation strategies, and changing dietary patterns need to be understood to enable predictions of long-term ecosystem nutritional productivity and development of best practices for ensuring a nutritious food supply. (<https://youtu.be/0HwL2Ziy8TU> retrieved 2/11/2019)

Panel Presentation by Dr. Mulumbet “Millie” Worku, Professor of Animal Sciences at North Carolina A&T State University School of Agriculture and Environmental Sciences, focused on livestock and dairy food production and how those industries are tied to food safety and security through the soil. (<https://youtu.be/pyAlGowFXsA> retrieved 2/11/2019)



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Panel Presentation by Dr. Christian Peters, Associate Professor, Friedman School of Nutrition Science and Policy, Tufts University, outlined how shifting land management practices for soil health could influence the human diet. For example, increasing production of a variety of grains for human health could increase biological diversity in soil and affect soil health while certain crops grown for the human diet could require a more intensive cultivation, which in turn, could negatively impact long-term soil health. (<https://youtu.be/xapyaUnrJLs> retrieved 2/11/2019)

Panel Presentation by Dr. Jennifer Otten, Associate Professor, Department of Environmental and Occupational Health Sciences, School of Public Health, University of Washington, presented the connections between optimizing soils for food security and optimizing soils for soil health. Topics discussed were crop yield, management practices, global agriculture economics, and opportunities for further research. (<https://youtu.be/xO8-UVdSyos> retrieved 2/11/2019)

Panel Discussion

Panelists discussed the nutritional composition of crops under different soil management practices, drought and irrigation conditions, and mineral composition of soils. Concepts of bioavailability, food security, and food technology in relation to soil health were discussed, as well as potential opportunities for policy improvements and advocacy/education. (<https://youtu.be/xPf4zPjbqOs?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)

The Influence of Soil Health on Food Safety – Overview by Dr. Patricia Millner, Research Microbiologist, Environmental Microbial and Food Safety Laboratory, U.S. Department of Agriculture - Agricultural Research Service, described examples of the accumulation of microbes, nutrients, and other elements in our soils, as well as how foodborne illness outbreaks occur. (<https://youtu.be/hV6Qa2cMCI4?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)

Panel Presentation by Dr. Keeve Nachman, Director, Food Production and Public Health Program, Bloomberg School of Public Health, Johns Hopkins University, discussed how soil contaminants affect human health in urban environments where half of the global human population resides. (<https://youtu.be/p3swJrGwH4c?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)

Panel Presentation by Dr. David Ingram, Consumer Safety Officer, Center for Food Safety and Applied Nutrition, U.S. Food and Drug Administration, described how soil health could influence food-borne pathogens, as well as regulations and metagenomics analysis for product safety. (<https://youtu.be/-5BIMS1BvVk?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)



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Panel Presentation by Dr. Michele Jay-Russell, Program Manager, Western Institute for Food Safety and Security, University of California, Davis, focused her discussion on examples of research on food-borne illness outbreaks, especially pathogens found in wildlife and livestock and how soils relate to those outbreaks. (<https://youtu.be/oleCRfSad5A?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)

Panel Presentation by Dr. Kalmia Kniel, Professor of Animal and Food Sciences, University of Delaware, discussed how soils contribute to the emergence and reemergence of protozoan pathogens and infections in humans. Formulation and execution of multi-disciplinary studies to research the complicated questions surrounding soils and human health was presented. (https://youtu.be/K1bGypTE6_Q?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP retrieved 2/11/2019)

Panel Discussion

Panelists discussed how pathogens found in soil could transfer via foods consumed by humans. Transmission of *E. coli* strains from soil to plants and animals through the use of manure in organic and hydroponic cultivation, how treated biosolids are analyzed for human safety, and the increase of antibiotic-resistant pathogens were specific examples. (<https://youtu.be/ZYy71UzP0TM?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)

Chemistry, Bioavailability, Fate, and Transport of Contaminants in Soil – Overview by Dr. Eric Brevik, Professor of Geology and Soils, Dickinson State University, described how heavy metals, excess nutrients, organic chemicals, and nano-particles in soils could affect human health. Lack of education of public about soils was noted. (<https://youtu.be/IVGcZ-wtSBo?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)

Panel Presentation by Dr. Nicholas Basta, Professor of Soil and Environmental Chemistry, The Ohio State University, highlighted bioavailability, form of heavy metals transported from soil to plants and animals, and entry into the human bloodstream. Different types of soils and plants can change the bioavailability of different metals. Criteria to decrease the risk of heavy metal exposure needs development. (<https://youtu.be/Hwjicbhukco?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)

Panel Presentation by Dr. Gregory Evanylo, Professor of Crop and Environmental Sciences, Virginia Tech, focused on reactive nitrogen as a pollutant, specifically in terms of bioavailable nitrogen, photocatalytic nitrogen, and radioactive nitrogen. Nitrogen in air, water, and soil interact continuously through ecological feedbacks, and exposures can impact human health in different ways. (<https://youtu.be/pf2GsOsNqCc?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)



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Panel Presentation by Dr. Linda Lee, Professor of Agronomy, Purdue University, discussed the implications of organic chemicals on soil and human health, as well as land application, composition, and toxicology of waste-derived fertilizers. (<https://youtu.be/5Nbmw6lds6c?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)

Panel Presentation by Dr. Jason Unrine, Associate Professor of Plant and Soil Sciences, University of Kentucky, focused on bioavailability of nanomaterials from man-made products, pesticides, and fertilizers in water and soil and the potential health risks of exposure. (<https://youtu.be/GPUB2ZddR1s?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)

Panel Discussion

Panelists discussed best practices to reduce the negative health impact of substances such as bioavailable heavy metals, how to reduce metal uptake by plants, and links to human nutrition. (<https://youtu.be/wHzUoka6W3o?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)

Interconnections of the Soil-Food-Human Microbiome – Overview by Dr. Lily Pereg, Associate Professor of Molecular and Cellular Biology, University of New England, Australia, discussed the lack of specific, quantifiable data on the continuum of microbial communities spanning the soil, crop plants, livestock, and humans, providing links between soil and human health and potential avenues to find such links. (<https://youtu.be/8FJHzJ53yrY?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)

Panel Presentation by Dr. Daniel Manter, Plant Physiologist, U.S. Department of Agriculture - Agricultural Research Service, discussed how to apply soil health concepts to develop soil and crop management strategies and targeting specific microbial functions to support those strategies. (<https://youtu.be/8NvSTDc9K6Q?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)

Panel Presentation by Dr. Joshua Steffan, Assistant Professor of Agriculture and Biology, Dickinson State University, addressed technology used to sequence genomes of various microbial species present in the microbiomes of soils, plants, animals, and humans. Variations in methods, unknown species and genomes, and ways to handle unknown or unrecognizable data in research were presented. (https://youtu.be/_K1MfzQkVhg?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP retrieved 2/11/2019)

Panel Presentation by Dr. Karl Wepking, Executive Director of the Global Soil Biodiversity Initiative, addressed how antibiotics given to livestock can be found in soil, plant, and human microbiomes and how antibiotic-resistant pathogens have developed over time. Special consideration to the effects of antibiotics on multiple aspects of soil microbial activity were also discussed. (<https://youtu.be/vpm-DKTIZu0?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)



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Panel Discussion

Panelists discussed the promotion of specific crops for soil health management to alleviate human health issues with a special consideration on managing beneficial and detrimental microorganisms in soil, around plants, and in/on humans. Use of antibiotics in livestock production was considered. (<https://youtu.be/fYFj5RB6cD4?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)

Implications of Soil Health for Human Populations and Communities – Overview by Dr. Linda Abbott, Director, Office of Risk Assessment and Cost-Benefit Analysis, U.S. Department of Agriculture, presented a framework of risk assessment to integrate information and organize studies describing the impact of soil health on human populations. Risk assessment can provide a useful framework to identify knowledge gaps, reveal scientific uncertainties, and influence policy decision makers in instances where unknown information may tend to stall the decision-making process. (<https://youtu.be/ri2ACI7oAT8?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)

Panel Presentation by Dr. Lynn Burgess, Professor Emeritus, Dickinson State

University, addressed synthetic organics, e.g., halogenated hydrocarbons, that are difficult to detect in soils, have unknown attributes, and have uncertain effects on human health. Examples were presented on the known risks of particular synthetic organic compounds on human populations, as well as speculation on the potential risks of others. (<https://youtu.be/5U7EXy8IEA0?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)

Panel Presentation by Dr. Daniel Richter, Professor of Soils and Forest Ecology, Duke

University, provided examples of how humans are exposed to lead in the environment and how that relates to the “frontier” of soil health research in urban environments. (<https://youtu.be/-xYCljx1xQU?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)

Panel Presentation by Dr. Daniel George, Associate Professor, Humanities Department,

College of Medicine, Penn State University, showed how hospital systems could support local sustainable agriculture and healthy soil research. Hospital programs and public policies for the benefit of food safety and soil health were presented. (<https://youtu.be/m43XvVzck8A?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)

Panel Presentation by Dr. Thomas Ducey, Microbiologist, Coastal Plain Soil, Water and Plant Conservation Research, U.S. Department of Agriculture - Agricultural Research Service,

addressed living and working in the “Stroke Belt,” an area in the southeastern United States that shows a higher risk of stroke in the human population. Correlations among environmental microbial communities, soil conditions, and risk of stroke were presented. (<https://youtu.be/XAsloV7-KO0?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)



PRESENTATIONS

Panel Discussion

Panelists discussed potential areas for new research in soil health and human health, focusing on problematic situations for human populations and community health, as opposed to individuals or clinical settings. (<https://youtu.be/w04KIP8nFyk?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)

Keynote Address 3 – Day 1 – Dr. Daphne Miller, Project Scientist, Center for Occupational and Environmental Health, School of Public Health, University of California, Berkeley, and Associate Clinical Professor, Department of Family Medicine, University of California, San Francisco, gave a summary of various interdisciplinary studies that benefit human and soil health. Dr. Miller described symptoms of diseases she witnessed throughout her career as a clinical physician, conjecturing they may have been related to agricultural practices. She also suggested potentially valuable avenues of research that could benefit both soil health and human health, including citizen discovery, community engagement, and advocacy. (<https://youtu.be/clq617u0UpU?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)

Keynote Address 4 – Day 2 – Emerging Topics Connecting Soil Health to Human Health – Dr. Howard Mielke, Research Professor, School of Medicine, Tulane University, explained the history of tetraethyl lead use and its research as a lens to view the relationships between the environment and human exposure to toxic elements. Dr. Mielke also explored the damaging health effects attributed to lead exposure and how soil remediation could play an important role in protecting public health in the future. (<https://youtu.be/b7EPZ58OPUs?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)

Food/Ag Policies and Human Health Policies – Overview by Dr. Catherine Woteki, Professor of Food Science and Human Nutrition, Iowa State University, addressed the current soil health and human health policy framework. Programs of the U.S Department of Agriculture, Food and Drug Administration, U.S. Environmental Protection Agency, and other agencies were described in relation to policies and research impacting human health and soil health. (<https://youtu.be/t2R39BwE8yg?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)

Panel Presentation by Mr. Bruce Knight, Principal and Founder, Strategic Conservation Solutions, highlighted the history of policies shifting from soil conservation to soil health and the nature of policy development and execution. The lack of transparent soil health programs within government institutions was described as concerning. Integration of soil health into future programs was outlined. (<https://youtu.be/IWGFrm1e1vc?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)



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Panel Presentation by Dr. Susan Mayne, Director, Center for Food Science and Applied Nutrition (CFSAN), U.S. Food and Drug Administration (FDA), proposed a future in which policy could be shaped to prioritize soil health once scientists demonstrate links between soil health and public health. Currently, CFSAN is focused on understanding the presence of contaminants in food, but some of FDA's resources could be channeled to incorporate soil health priorities for protecting consumers. (<https://youtu.be/3UvWCL4yufY?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)

Panel Presentation by Dr. Thomas Burke, Professor and Chair, Health Risk and Society, Bloomberg School of Public Health, Johns Hopkins University, focused on the many pathways, including soils, in which humans are exposed to contaminants such as lead. A systems approach to incorporate soil health into public health debate was presented. (<https://youtu.be/VWw8cwx-M5D4?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)

Panel Discussion

Panelists briefly discussed and answered questions about policy issues surrounding soil health and human health. Topics included contaminants, current and future programs, and other information networks and regulations. (<https://youtu.be/hJ0n5IX90jM?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)

Funding Opportunities and Challenges – Panel Discussion

Panelists discussed and fielded questions about opportunities for funding research and programs in the intersection of soil health and human health. Panelists represented various institutions that currently fund research and/or programs in these or related areas. Panelists included: **Dr. LaKisha Odom**, Scientific Program Director, Foundation for Food and Agriculture Research (panel chair); **Mr. William Hairston**, Director of Product Development – SeedGrowth, Bayer Crop Science; **Dr. Heather Henry**, Program Administrator, Superfund Research Program, National Institute of Environmental Health Sciences; **Dr. Luis Tupas**, Deputy Director for Bioenergy, Climate, and Environment, National Institute of Food and Agriculture, U.S. Department of Agriculture; and **Paul Wolfe, JD**, Program Officer, Mississippi River Program, Walton Family Foundation. (<https://youtu.be/wLBiYN1qiRI?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP> retrieved 2/11/2019)

Keynote Address 5 – Day 2 – Conclusions from the Conference on Connections Between Soil Health and Human Health – Dr. David Collier, Professor of Pediatrics and Health Disparities, Brody School of Medicine, East Carolina University, gave closing summary comments. Dr. Collier summarized key issues on the soil-plant-human microbiome, contaminants and exposure, human and plant nutrition, and other connections between soil health and human health. Environmental toxicology, obesity, soil as a matrix and vector of disease, functional foods, communication, climate change, sustainability, vulnerable populations, databases, and systems approaches were high-priority topics explored. (https://youtu.be/b7ob_Tbh5Cg?list=PLdFVkeklZuqzXJwiWGU2j1WjiA2F5daFP retrieved 2/11/2019)



PRESENTATIONS

Breakout Sessions

Following the plenary technical sessions, attendees were assigned to one of ten 90-minute breakout sessions. Breakout groups were tasked to use the information presented by keynote speakers and presenters to identify the top research priorities within each technical area. Ultimately, all breakouts had the same assignment: develop one recommendation on the single most important research opportunity that should be pursued in the immediate future. The priority was to be transdisciplinary to both soil health and human health. A spokesperson for each of the breakout sessions made a short presentation summarizing the priority.

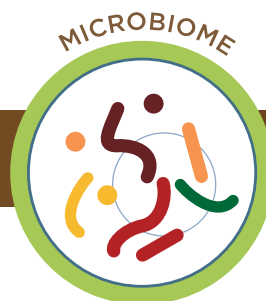
Recommendations were offered based on four aspects:

- importance to advancing scientific understanding;
- current research gaps;
- specific research ideas; and
- comments offering justification and support.

These ideas were discussed in the context of the five technical panel topics:

- Soil health and human nutrition;
- Soil health and food safety;
- Chemistry, bioavailability, fate, and transport of toxins in field soils;
- Interconnections of the soil-food-human-microbiome; and
- Soil health and human populations / communities.

The information in each breakout session was organized into a matrix, from which participants developed consensus for a single recommendation to the entire conference in a short oral presentation.





RECOMMENDATIONS

Top 10 Recommendations to Advance Science and Policy Connections Between Soil Health and Human Health

Based on information presented in keynote talks, panel discussions, and breakouts, recommendations were made by conference attendees, grouped post-conference by similarity in focus.

Development and Use of Transdisciplinary Research Organizations and Infrastructure

- ✓ Capitalize on long-term agricultural experiment stations by using them to engage the medical community and industry in tracking bioavailability of nutrients, toxins, and pathogens from soil to plants to humans, including the human microbiome. This includes studying farm laborers and consumers relative to food consumed and chemical exposures.
- ✓ Develop a network of permanent research sites in different regions (initially, at least three in the United States: East, Midwest, and West) that allows comparison of conventional, organic, and regenerative agricultural production systems, along with urban areas and native habitats (e.g., forests) for their nutrient uptake and other properties. Such a network would attract other researchers bringing additional tools, analyses, and expertise to the effort, such as food-supply chain companies, the Centers for Disease Control, and the U.S. Department of Agriculture.
- ✓ Create a “Center of Excellence” to quantify the positive and negative impacts of increasing soil organic matter and associated management systems across the entire agricultural and food value chain. With a community of diverse researchers contributing quantitative data to value chain analysis, determine how to maximize benefits and minimize adverse impacts on human health through agricultural and food handling management practices.

Strategic Transdisciplinary Research and Outreach

- ✓ Integrate vast existing data in a summary review of soil health-human health, including gaps, knowns, unknowns, and immediate actions. Integrate stakeholders. Form a working group to integrate the transdisciplinary knowledge. Isolate strategies and references to communicate effectively to many diverse stakeholders, including students and academicians, as well as Agricultural Extension personnel.
- ✓ Communicate the soil health-human health relationship to all stakeholders. Determine how to actively engage and enlist actions from agricultural producers to deliver healthier soil and make it a driver in the bigger nutrition and health picture.



RECOMMENDATIONS

Priority Transdisciplinary Research Themes

- ✓ Understand soil health and regenerative systems around the world and their impacts on the environment and the global food system. Validate methods for soil health measurement across soils and regions. Involve farmers in research efforts. Use existing programs in Agricultural Extension and Farm Bill programs to assist in implementation, motivation, and education.
- ✓ Understand the fundamental microbiome structures and functions related to land management, soil health, and human health. Connect existing research on the human microbiome to the soil microbiome.
- ✓ Determine how the known suite of soil health practices can impact human wellness, economy, and the environment. Determine the mechanism linking soil management with nutrition (density) and content of the food produced.
- ✓ Characterize human-soil interactions for exposure analyses, health impacts, and avenues for intervention. Communicate results with scientific, grower, and technical stakeholders at various scales and locations.
- ✓ Identify specific partners to increase and optimize bioavailability in soil health agricultural management systems to decrease contamination and promote community well-being.

The appendix to this report contains additional recommendations offered by the ten breakout groups and each group's discussion matrix.





NEXT STEPS

Next Steps

Immediate next steps recommended by attendees during a plenary discussion included the following.

- ✓ Leverage conference participants to form a working group that can promote/facilitate creation of transdisciplinary soil health-human health research teams.
- ✓ Promote attendance and presentation at conferences by members of our new community (e.g., a medical doctor attends a soil science/agricultural conference to present in a soil and human health conference, an agricultural/soil scientist attends a human health conference for the same).
- ✓ Convene periodic theme-specific conferences focused on different attributes of the soil-human health continuum.
- ✓ Develop of a web-based information repository.
- ✓ Advocate for sources of funding that facilitate transdisciplinary research teams involving both soil health and human health scientists in cooperative research.
- ✓ Develop a critical review of the literature for publication in a transdisciplinary journal.





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Among the experts who contributed to this conference was Dr. Lily Pereg, a member of the faculty of the University of New England (Australia), who offered the Overview presentation and chaired the panel for the Microbiome session. Dr. Pereg died tragically in January 2019. She was an excellent scientist, a faithful colleague, and a delightful person whose presence and influence were obvious throughout this conference. Her enthusiasm for her subject and her bright smile lit up the room. We feel the loss of her friendship, and we are left to wonder forever about the scientific accomplishments that might have been.

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APPENDIX

Appendix

The top research or strategic priority that emerged from a consensus of each breakout group was presented in a plenary session. However, all research proposals were documented for further discussion or reference. These additional research ideas are listed here (unedited from breakout session notes), sorted by topic area. They are offered for consideration in developing research projects and programs connecting soil health and human health.

HUMAN NUTRITION

- Leverage long-term cropping system experiments to understand the effect of management on crop nutrients, specifically trace elements.
 - ◆ Do the same thing under identity-preserved supply chain within food company setting, tracing from farm to final product?
- How do we create a network of research sites where all of these topics can be addressed by transdisciplinary teams of researchers? Could be built on existing long-term cropping system experiments, but the research teams and questions could be more transdisciplinary in nature. Redefine “agronomy” as also including nutrition, food safety, etc. Rebuilding more inclusive way (women, minorities). Specifically, can we trace heavy metals, nutrients, microbes from soil → plant → gut, phytochemicals throughout. Build app for different researchers to access data.
- Impact of organic amendments/SOM content on phytochemical/flavonoid content of crops (impact of drought, fertilization, etc.)
- Impact of phytonutrients/flavonoids on human health/risk reduction
- Quantitative: cultivar (grain) and regenerative practice → 1. soil health? (economic, environmental outcomes) 2. Nutrient value? Human physical and mental health.
- Qualitative: what influences farmer adoption of these practices?
- Measuring carbon levels in soil → effect on nutrient levels in food crops and nutrient density and water quality (nutrient run-off)
- Analyze how to solve climate, social health, water quality, food security nutrition, etc. problems via alternative crop – land use “lock chart” allocations.
- How does soil type (amendments and organic residual) management affect human nutrients in crops [food security] and community well-being and access to these nutrients?

FOOD SAFETY

- Study pathogen survival in different regions and soil amendments.
- Interventions that remove contaminants from soil that protect food safety and allow the soil



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to heal both plant and environment

- Agriculture and food consumption practices that promote microbial plant and food diversity
- Soil microbiome/rhizosphere impact on uptake by plants of toxins, contaminants

FATE AND TRANSPORT

- Link pesticide reduction with cover crop use to weather and hydrology modeling and toxicology to understand human health impacts of practices like cover crops.
 - ◆ Build on this with in-field practices and edge-of-field monitoring
- Potential impacts of soil health indicators on pathogen prevalence/suppression
- Potential management practices for mitigating pathogen risks (risk assessment)
 - ◆ i.e., impact of no-tillage on leaf-splatter/survival of E. coli, etc.
 - ◆ impact of soil health on prevalence of pathogens in livestock (manure)
 - ◆ impact of soil health on aflatoxin in soil/crop/storage
 - ◆ fungal inoculants
- Impact of cover crops on catching leaching nutrients
- Repeating fate/transport studies through bioavailability lens
- Using radioisotopic tracers to identify fate/transport of antibiotics in various soil types/ climate/management systems
 - ◆ Impact on microbiome
 - ◆ Potential of bio stimulants/inoculants to degrade antibiotics
- Bioavailability of metals/micronutrients based on farming practices ten sites bringing together all the tools → effect on soil health research ideas
- Outreach materials for urban agricultural communities
 - ◆ i.e., extension docs and fact sheets
 - ◆ metals, toxicology, etc.
 - ◆ how soil health of the urban agriculture communities interacts with these aspects

MICROBIOME

- Evaluate technologies for pathogen detection, monitor, and control
- Do soil microbiomes drive human microbiomes?
 - ◆ Health
- Systemic analysis of child microbiome and health outcomes and developmental cognitive metrics
- Bioinformatics of soils taken in the soil surveys are needed. But what is the right type of analysis and soil condition/storage, etc. PFLAs...or?



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- Query – What data are out there? What do they look like?
- If, universal method for soil sampling, storage and analysis? What is gained?
- Concern: transient alterations and what does/would it mean?
- Global soil biodiversity initiative
- Management strategy impact on microbiome

COMMUNITY HEALTH

- Identify unique community health partners who have a stake in these health issues (i.e. stroke, lack of room, obesity, others) to help support research and public supply.
- Assessing impact of management soil type/soil health/cc on bioavailability of toxins/heavy metals in soil and edible portion of plants
 - ◆ Impact of composts/biosolids/organic amendments
 - ◆ Impact of tillage on airborne dust
- Evaluating soil health
 - ◆ Bioavailability – methods on there
- Microbiome – what, how? Need functional genres – do we know what they are? May be do-able with...for analysis
- Urban gardens
 - ◆ Impact on human health via veggie access (missing micronutrients)
 - ◆ soil health connection
- Other soil context
 - ◆ Soil compaction → flooding
 - ◆ Developing greenspaces → community well-being

WHAT I THOUGHT I'D HEAR BUT DIDN'T

- Stakeholder: farmers, community, risks assessors, epidemiology, technology development
- Summarization of the evidence that exists (and an appendix of references) (e.g., for use by NGO's to communicate with the public in our outreach and education campaign and for use by academics and extension in their educational program)
- A list of what we could take action on now and (summary of what we know, what we don't now, and what we can do now





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