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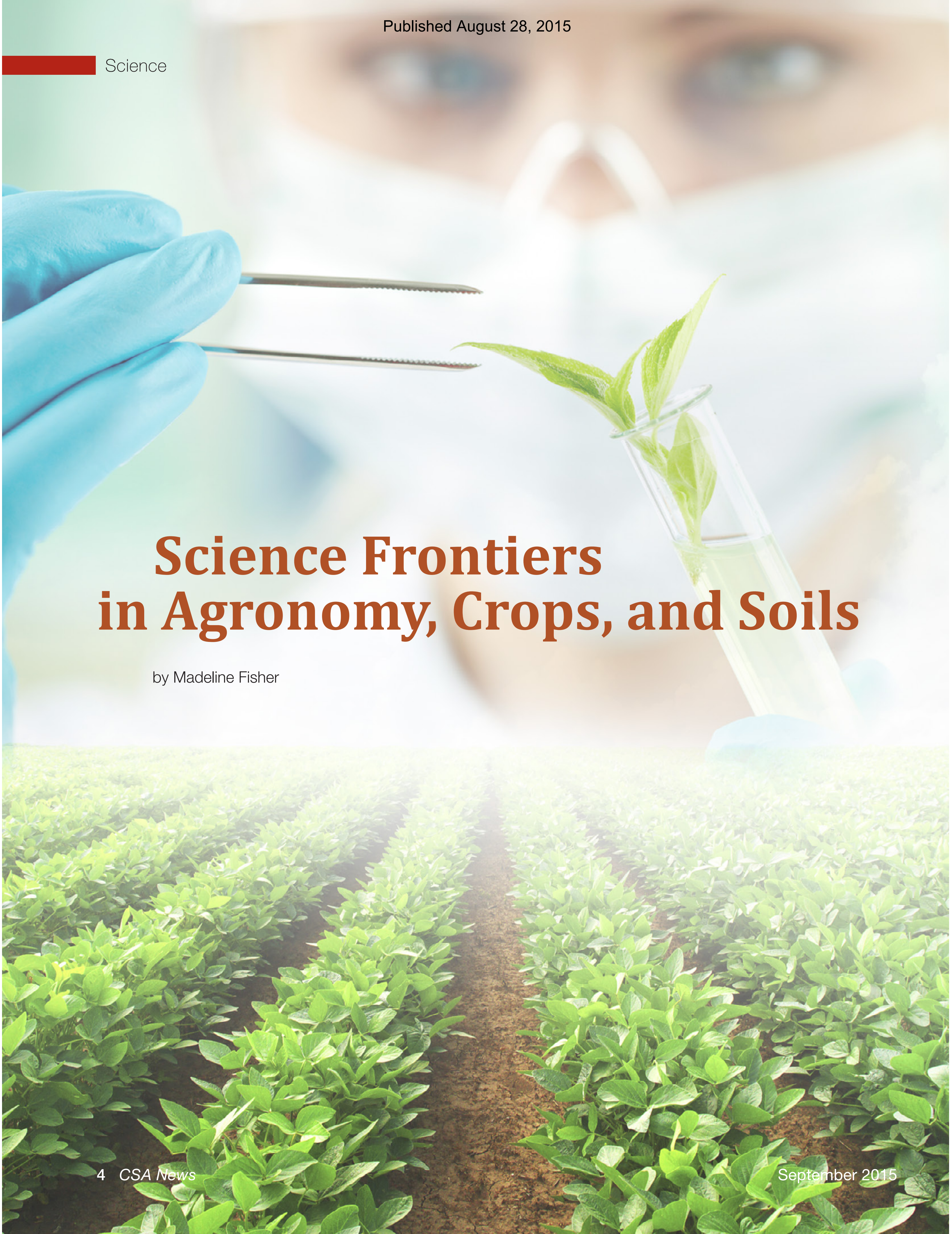

Science Frontiers in Agronomy, Crops, and Soils

by Madeline Fisher

Climate change. Food and water insecurity. Environmental damage. An estimated global population of 9 billion by 2050. The laundry list of challenges facing humanity and the planet today is undeniably discouraging. And not one item on the list can be put off until later. "These are critical problems that require solutions now—or actually required action a decade ago," says Jeff Volenec, a former president of CSSA. "And they only get harder to manage if we procrastinate."

Yet, there is something positive here, as well, Volenec adds. "These are also science issues that our Societies can do something about." Examine them carefully, in fact, and you begin to see the very hopeful prospect they contain: the opportunity to apply evidence-based solutions to the world's most pressing needs, while also pushing the agricultural and soil sciences to their frontiers.

This is precisely what motivated ASA, CSSA, and SSSA to develop a set of "Science Frontiers" over the past year. Released this June, the documents articulate each Society's scientific road map and research priorities for the next 5 to 10 years.

"We have some rapidly evolving policy and environmental conditions that affect our disciplines," says SSSA President-Elect Harold van Es. "So it was time to update our vision as soil scientists—and, for that matter, as agronomists and crop scientists—for where we need to go."

"We have key leaders in the science arena, and we think it's very important that our voices be heard when decisions are being made about future science needs and funding and policy priorities," adds ASA President Jean Steiner. That's the catch, however: How to be heard amid the cacophony of information, opinions, and appeals in Washington, DC?

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To have the best chance, the Societies started with a unifying "Grand Challenge" shared by all:

"The Grand Challenge is to sustainably improve the human condition for a growing population in a changing environment."

The Science Frontiers then lay out the most promising research opportunities each Society sees for meeting the unified challenge, while simultaneously propelling its own disciplines forward. In other words, "we felt that it was good to have a common message," van Es says, "but also to have an elucidation of what each Society particularly envisions in terms of future research needs."

The Science Frontiers are also limited in number, broad in scope, and simple in language—features that should facilitate communication with lawmakers and other important lay audiences.

"I really want to encourage all of our members to *internalize* the information in these documents," van Es says. "I think that having a document like this helps us as a scientific community to advance our disciplines and explain why we do the work that we do."

Some may even find them to be a source of inspiration. "I think the Grand Challenge really communicates why people bring such passion to science," Steiner says. "'Sustainably improve the human condition?' I mean, who wouldn't want to be a part of that?"

What follows are abridged versions of each Society's set of Science Frontiers. For the full versions, visit each Society's Science Policy Office website and its Science Frontiers page (e.g., www.crops.org/science-policy/issues/science-frontiers).

American Society of Agronomy

Agronomy is fundamentally a pragmatic science, focused on optimizing all aspects of crop production systems. This is why ASA chose "sustainable intensification" as its first Science Frontier, Jean Steiner explains. "It's also a term that you see a lot in the international arena and which should resonate outside our disciplines," she adds. At the same time, agroecosystems have tremendous—but undervalued—potential to deliver ecosystem services. Hence, frontier number 2.

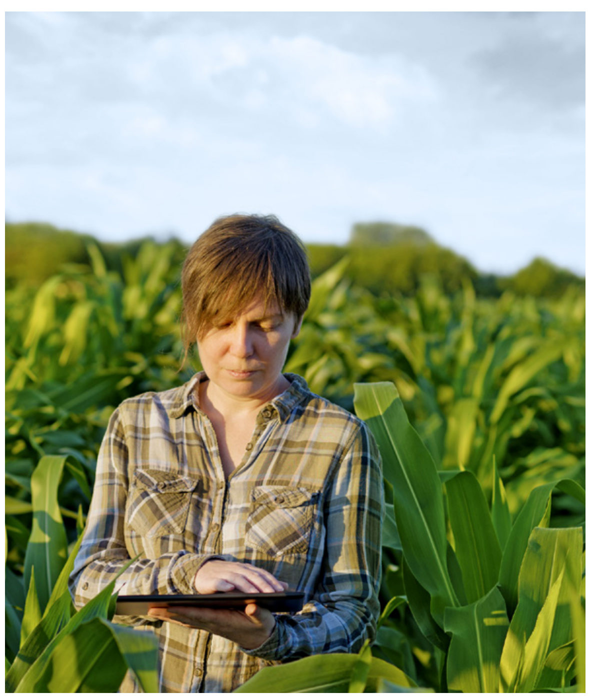
The third frontier tackles farming's social and economic aspects. "As you're developing production and ecosystem services, this is all done in the context of the people who own and manage the land, and the communities around them," Steiner says. "But there are a lot of gaps in our knowledge about how to meet the social and economic needs of agriculture."

Sustainable Intensification

The goal of sustainable intensification is to produce more food from existing farmland while minimizing pressure on the environment. It is a response to the challenge of greater demand from a growing population in a world where land, water, energy, and other inputs are in short supply and often used unsustainably. If efforts to intensify food production are not accompanied by attempts to restore ecosystem processes on the landscape, we will undermine our capacity to produce food in the future.

For example, food crops remove nitrogen, phosphorus, and other nutrients from water and soil, necessitating their replenishment. But if nutrients are not applied according to sound agronomic principles, they can damage air, soil, and water quality.

Supplies of fertilizer are also limited: nitrogen because of its energy-intensive production process, and phosphorus because it comes from finite geologic deposits. Water supplies for irrigation are likewise limited. Therefore, future food security and environmental quality depend on making more efficient use of nutrients and water, while rapidly increasing crop yields from land already in production.



Enhancement of Ecosystem Services Provided by Agriculture

Agriculture is multifunctional; it depends on ecosystem functions but can also complement these functions. Indeed, study of natural and managed ecosystems, including agroecosystems, has shown that these systems provide services that generate goods essential to life.

Ecosystem goods include clean air, water, and soil; diverse plant and animal communities; and wildlife habitat. Through agricultural and plant production, soil can provide multiple services including food, feed, fiber, and fuel production, as well as carbon storage, erosion control, nutrient cycling, and water filtration and storage. Improving and maintaining the quality of soil through proper management and care is therefore critical to producing these goods.

While ecosystem services are difficult to value monetarily, they have intrinsic value because of the way they support our health and economy. As society realizes the value of these services and goods, new markets for them are developing. To ensure that these markets are based on sound science, it is critical to understand the multifunctional relationships occurring in major agroecosystems that will enhance the ecosystem services that can be provided.

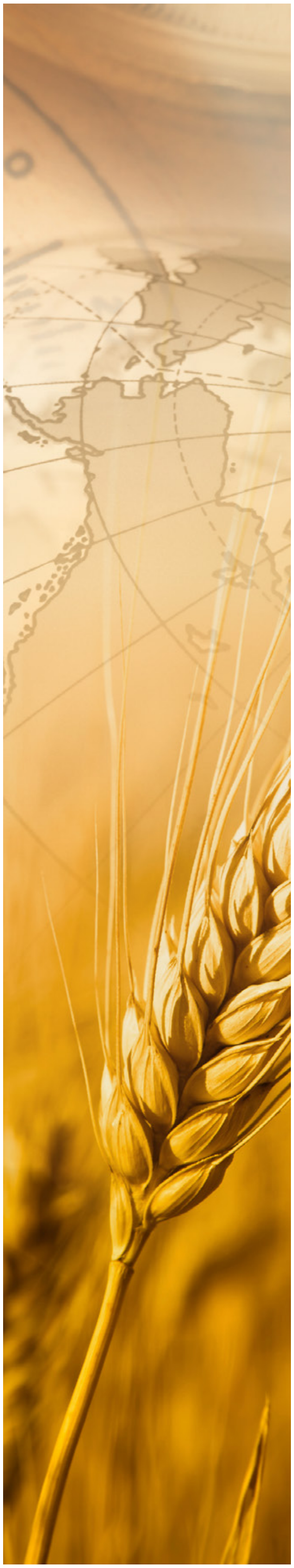
Socially and Economically Viable Agriculture Systems

Agricultural systems are the foundation of human health, economic development, and political stability. At the same time, the viability of any farming system depends largely on its contribution to the economic security of key actors in the farm and food system. Productive and sustainable agricultural systems will be achieved through high-quality, interdisciplinary, and integrated research, and continuing education, extension, and application.

U.S. farmers are under multiple, often competing, demands, such as to increase crop yields with fewer inputs, fulfill consumer preferences, and make a living—all with increasingly scarce natural resources such as land and water. To evolve farming systems that meet all these demands, national agricultural policy, research programs, and food markets must develop a more holistic perspective on how farms benefit society.

This goal can be reached through two parallel efforts: an incremental, ongoing approach aimed at developing more efficient agricultural techniques, increasing productivity, and enhancing landscape quality; and a transformative approach, in which multiple research areas are brought together to design innovative farming systems that balance competing demands.

Middle photo and rightmost photo courtesy of USDA-NRCS Texas



Crop Science Society of America

As much as researchers value the idea of interdisciplinary work, Jeff Volenec thinks many of them—him included—still struggle to look beyond their specialties to the bigger picture. This made trying to develop a set of inclusive Science Frontiers to address the unifying Grand Challenge, "a bit of a grand challenge" in itself, he jokes.

In the end, though, CSSA succeeded, producing a scientific agenda that encompasses plant breeding, turfgrass science, grazinglands research, and more. "There's a place for everyone," Volenec says. "It's a very broad umbrella." Yet, it also contains a definite call to action, he adds. "We need to do something about climate change and the environment—those are critically important. And, then, the reason we do all of this is to improve human food and nutrition."

Crop Frontier: Crop Improvement and Adapting to Climate Change

As the climate changes, higher temperatures and heat waves affect the growth and development of crops, influencing potential yields. Moreover, changes in precipitation patterns alter the water supply for crops, and pest regimes shift, exposing crops to new diseases and pathogens.

Therefore, plant genomic tools are needed that can identify beneficial genes and assist in their rapid incorporation into improved cultivars. New genomic information will also enhance our ability to correlate a plant's genetic makeup with its agricultural performance for plant breeding purposes in a way never before possible. And research focused on efficient and reliable methods of identifying desirable crop germplasm will ensure that new varieties with the right genetic makeup will be delivered to farmers.

In short, these advances will accelerate the development of superior crops, helping safeguard against famine and marketplace catastrophes resulting from fluctuations in rainfall, diseases, and pests, and enabling greater food security around the world.

Human Frontier: Connections between Food and Health

People's nutritional health and well-being depend entirely on plant foods. Not all plant foods, however, contain all essential nutrients, nor do they usually contain enough of any given nutrient to meet daily dietary requirements in a single serving.

Thus, a variety of plant foods is required for adequate nutrition. Unfortunately, many people do not consume a sufficiently diverse diet. Approximately two billion of the world's population suffers today from malnutrition, including undernutrition, micronutrient deficiency, and overweight and obesity. Researchers are now learning how plants manufacture nutritional components and package them in their edible portions. This knowledge can be used to manipulate and improve the nutritional quality of our food crops.

Agricultural systems are the primary source of all micro- and macronutrients for all people. Therefore the nutrition and health sectors must turn to agricultural interventions as a primary, sustainable tool for ensuring global food security. Changes to agricultural systems and policies are also needed to ensure that people are eating diets rich in essential nutrients and various health-promoting compounds.

Global Frontier: Sustainable Environmental Management

Agriculture's essential goal is to provide food, feed, fiber, and fuel, while ensuring long-term sustainability of farming systems. Our use of these systems is constantly evolving in response to new knowledge and technologies, market demands, and changing climate. Meanwhile, population growth is creating greater competition for precious land and water resources. The challenge is to continue increasing crop yields, while protecting our shared environment through better crop and soil management.

Potential innovations include: crop cultivars that resist certain pests or tolerate weather extremes; remote sensing of plant and soil properties for site-specific management; and model simulations of crop yield that incorporate historic and real-time weather data to evaluate the benefits of different management practices.

Continuing education of producers and consumers is also necessary to enhance food security and the food system. Adoption of new technologies typically begins with innovative policies and progressive farmers. Adoption rates then depend on the educational services available to implement new management practices, along with good economic returns to farmers.

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Critical Needs

Amid all the excitement and discussion that the Science Frontiers are bound to generate, Jean Steiner hopes something vital won't be missed: the "critical needs" section at the end of each Society's Science Frontiers document.

"All of our sciences, including those well beyond our three Societies, are concerned with the loss of federal funding for research, the adequacy of our future workforce, and the erosion of support for education and extension, which in many ways is even more serious than declining research funding," she says. On top of this, many researchers are struggling with rapidly evolving computational tools that are changing not only how research is done, but how questions are posed in the first place.

In other words, while articulating the Societies' scientific priorities is obviously a must, just as crucial is voicing what scientists need to get their work done. "What are the practical challenges," Steiner asks, "that are making it hard for us to take on these important scientific challenges?"

Those identified by the ASA, CSSA, and SSSA science policy committees are below:

- Augment federal funding for food and agricultural science within relevant federal agencies
- Empower and employ the future science workforce
- Cultivate the application of innovative, science-based practices through education and extension
- Improve computational capabilities by integrating databases for genetic resources and agricultural research and equip a workforce trained in digital data infrastructure
- Promote innovation through public-private partnerships

For a longer description of each need, visit the Science Frontiers documents online (e.g., www.soils.org/science-policy/issues/science-frontiers).

Soil Science Society of America

Like agronomists and crop scientists, soil scientists are acutely aware of the pressing issues facing the planet, such as climate change, food insecurity, and environmental degradation. They also recognize the social factors that can impede progress, including scientific illiteracy and public mistrust of science.

That's why in developing its Science Frontiers, SSSA spent less time identifying the main problems confronting society and much more time on clearly defining their connection to soil. The science policy committee looked carefully at soil science's relationship to climate change, for example, and to water quality and human health, explains Harold van Es. "So it was a process of harvesting the issues that are already out there and then linking those to our science and pointing out where our science is critical."

Food, Energy, and National Security through Soil Education

Healthy soil is a key to national security. Degraded soils are associated with food insecurity and with degraded water and environmental quality. Food insecurity is also related to higher global energy demand, which is expected to jump 50% by 2030.

Soil degradation is caused by biophysical, social, economic, and policy factors, and a clear relationship exists between soil degradation and increasing population numbers. If judiciously managed and properly restored, on the other hand, world soils have the capacity to grow enough nutritious food for today's and tomorrow's populations. To eradicate malnutrition, however, soil quality must be restored sooner than later, especially in highly populated, developing countries.

Achieving these goals relies on infrastructure, support services, and political will. Therefore, educational outreach is needed along with soil and ecosystem restoration. Adoption of conservation production systems is especially critical for developing countries to attain food security and stability. By pursuing soil security, the world can attain economic security, promote public health, and adapt to climate change for a fraction of what other types of initiatives cost.

Climate Change and Soil Processes

Soils are intricately linked to climate through the carbon, nitrogen, and water cycles. In fact, soils and soil disturbance are major sources of greenhouse gases (GHGs), including methane, nitrous oxide, and carbon dioxide. Simultaneously, soils may provide a sink for GHGs. An altered climate will therefore affect soil processes and properties while soils will also affect climate.

One means to reduce climate impacts on soil is to store soil organic matter. Soil erosion by wind and water, for example, will increase with increasing rainfall intensity or with drought. Increased soil organic matter can offset these impacts, as well as improve soil structure, fertility, and water storage. But more variable precipitation and higher temperatures will also enhance GHG emissions, complicating mitigation.

Our challenge in mitigating GHG emissions from soil is to understand how climate change will influence the complex interactions involved. Specifically, we need to elucidate the biological and geochemical soil processes controlling carbon and nitrogen transfers from managed ecosystems and implement practices to reduce emissions and increase carbon capture.

Healthy Soils, Healthy People

Healthy soil is a vital living ecosystem that sustains plants, animals, and people. Soils host a quarter of the world's biodiversity and have provided antibiotics and other medicinal tools. Soils are both a source of and a means to eliminate disease. Exploration of the life cycles and management of soil-borne pathogens can help reduce food contamination and improve human health. Yet only a small fraction of soil microbial communities has been studied.

Soil microbial diversity needs to be harnessed to develop new pharmaceuticals. We must also understand soil's capacity to treat and deactivate pathogens in waste materials and contaminated waters.

Soil is resilient if it is nurtured. Managing for soil health is accomplished by disturbing soil as little as possible, adding organic matter, growing diverse species of plants, eliminating practices that cause salinization, and keeping the soil covered at all times. There is a critical need to understand better the mechanisms that control soil health and ways to prevent soil degradation resulting from inappropriate agricultural practices, deforestation, pollution, and expanding urban areas.

Soil and Water Quality

Clean water is a vital resource. Healthy soils prevent pollution of water by resisting erosion, capturing rainfall and nutrients, and degrading and detoxifying chemicals and wastes. The physical, biological, and chemical processes in soils are what make all of this possible.

Soil and water conservation management practices can help protect water quality. However, these methods often don't restore damaged water systems, due to incomplete implementation and lasting legacies of past management. Many have therefore questioned their efficacy and called for stricter measures. But part of the issue is simply the complexity of managed ecosystems. Pollution sources in watersheds need further study to better target mitigation practices and enhance watershed modeling efforts related to water quality.

Furthermore, increasing applications of domestic and industrial waste to soil can exceed its treatment capacity, resulting in contaminated soils that degrade drinking water and reduce crop productivity. At the same time, properly treated wastes provide recycled carbon and nutrients. The challenge is to better manage the risks of applying wastes so as to reap the benefits while protecting soil resources.

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