AGRICULTURE SOLUTION

Soil and Nutrient Management

Overview

Roughly half of all agricultural GHG emissions in the U.S. come from soil-management practices such as tillage, fertilization, and irrigation. However, numerous scientific studies show that management systems designed to improve soil health can also aid carbon sequestration and reduce GHG emissions.

At the same time, they provide important environmental co-benefits: they can improve water quality, suppress pathogens, and support safer pollinator habitats and biodiversity in general. They can also benefit farmers and ranchers by increasing a soil's available water-holding capacity and nutrient availability, improving drought resilience, reducing input costs, and mitigating erosion.

Scaling up these practices can increase carbon sequestration and reduce GHG emissions across the agricultural sector and result in significant air and water quality improvements that can directly benefit agricultural workers.

Market Challenges

Knowledge Gaps

Soils have different carbon-sequestration potential. Calculating the actual sequestration potential for different practices in each soil or group of similar soils will help provide farmers and ranchers with accurate carbon management recommendations. This will require integrating new and affordable soil carbon measurement technologies with digital soil mapping and simulation modeling.

At the same time, in order to improve nitrogen use efficiency (NUE) and therefore reduce losses from sources of essential agronomic nitrogen such as fertilizers, soil organic matter, crop residues, cover crops, and animal manures, we need a better understanding of how soil nitrogen availability and plant nitrogen demand change over time and space. Foundational research that integrates the dynamics of nitrogen availability (regulated by soil processes, weather, and other variables) with the dynamics of plants' nitrogen demand would enable better nitrogen management and recovery.

High Costs for Measurement Technologies

We need credible and transparent mechanisms for verifying the quantity of carbon sequestered in soil to confirm that practices are successful in capturing and storing atmospheric CO_2. Current technologies that calculate carbon stocks by measuring soil carbon and soil bulk density are time consuming and expensive. Consequently, developing soil-carbon testing technology that is economical, accurate, and standardized is fundamental to scaling soil-carbon sequestration. Further modeling is also needed fornitrogen management and systems level assessment at watershed-to-regional scale so that conservation practices can be quantitatively evaluated. Without low-cost methods of estimating sequestration potential on individual farms, many researchers and policymakers continue to rely on average sequestration estimates.

Economic Incentives and Market Demand

The costs and benefits of adopting carbon reduction practices are often unclear to farmers and agricultural producers. Many of these uncertainties are due to a lack of standardized scientific measurement of sequestration and understanding of carbon saturation, the heterogeneity in soil sequestration levels, and the variability in implementation across farms. Even if better estimates existed, potentially high upfront costs also limit adoption rates.

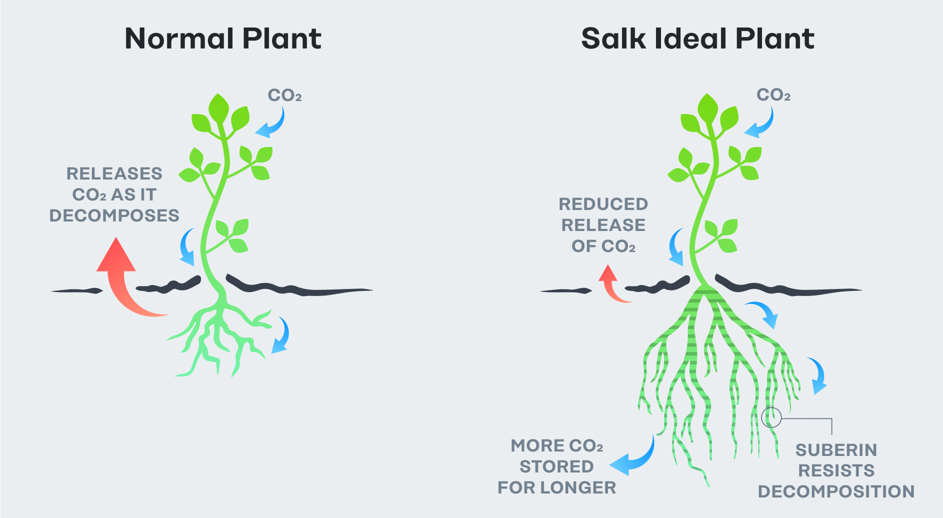
Reducing GHG from the agriculture sector is further complicated by the current nature of commodity cropping systems, which are dominated by monocrops and rely on commercial inputs. For example, the livestock industry has consolidated to put downward pressure on production costs and the fertilizer industry is increasingly concentrated in order to maximize profits through market scale. If these consolidated producers do not see the business case for soil management practices and technologies, GHG reductions may not occur at scale.

Technologies

High Sequestration Crops and Soil

R&D VALIDATION SCALE

Because of the suberin (a natural carbon polymer) in their roots, Salk Ideal Plants release significantly less CO_2 when they decompose than their normal counterparts.



Crops and soil can sequester larger amounts of carbon. High carbon-input crop phenotyping, for example, can be achieved by genetically modifying crops or by perennializing grain, seed, and other crops to keep their root residues in the soil. Another approach is to apply biochar (plant matter turned to charcoal) or compost to cropland, which can improve soil health.

Crop Productivity

R&D VALIDATION SCALE

Used largely as animal feed, soy (shown here) is a critical piece of the global food system. Demand for soy is projected to increase significantly over the coming decades. Innovations in crop productivity can help meet this demand without extensive land use changes.

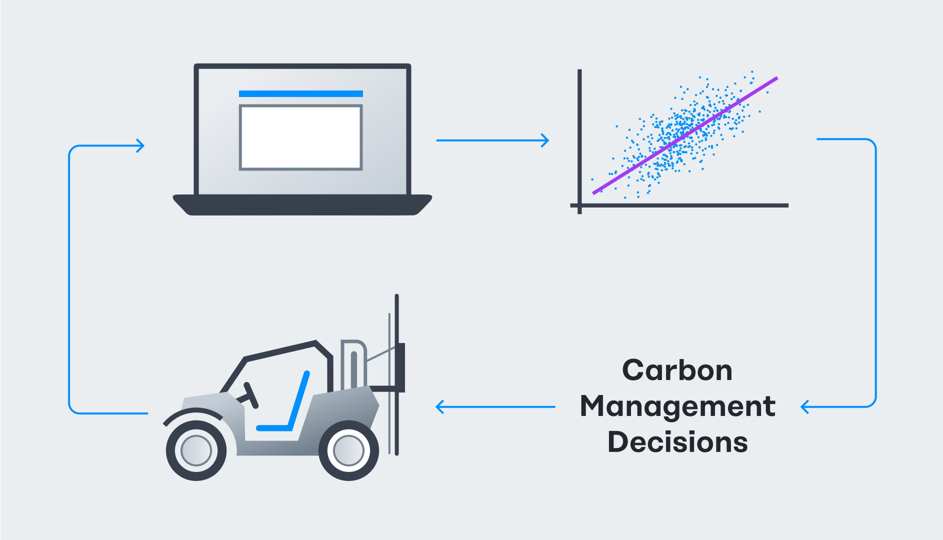
Feeding a growing and increasingly affluent global population without extensive changes in land use will require dramatic growth in agronomic yields. These yields must rise despite growing pressure from climate-change–induced variability, reduced soil quality, and pests.

To make this happen, we need technological solutions to rapidly transform crops, improve climate resiliency, and use new modes of production. For the greatest impact, producers should apply these innovations to the large-acreage crops, including wheat, soy, rice, and maize, that underpin the global food system.

Measurement Technologies

R&D **VALIDATION** SCALE

Developing accurate, low-cost, and efficient technologies for measuring soil carbon and nitrogen stocks in the field will be critical for scaling soil carbon sequestration and reducing nitrogen losses to the environment, respectively.



We need accurate, low-cost, and efficient technologies to quantify soil carbon and nitrogen stocks in the field. Current technologies to measure soil carbon and bulk density are time-consuming and expensive. Developing remote-sensing soil-carbon technology that is economical, accurate, and standardized is fundamental to quantifying and scaling soil carbon sequestration.

Nitrogen measurement technologies also have the potential to significantly improve nitrogen use efficiency, thereby reducing nitrogen losses to the atmosphere (as nitrous oxide) and to water (as nitrate).

Low-GHG Fertilizer

R&D **VALIDATION** SCALE

Microbial fertilizers could help reduce N_2O emissions. Step 1: Identify millions of isolated microbes in diverse soils, creating a sophisticated map of the soil microbiome. Step 2: Characterize key microbes' genetic potential to fix atmospheric nitrogen and live in a symbiotic relationship with cereal crop. Step 3: Fine-tune these microbes so they release nitrogen through the roots to meet the growing crop's nutritional needs.

While nitrous oxide (N_2O) emissions tied to nitrogen fixation and decomposition of crop residues are particularly challenging to mitigate, there is substantial potential to reduce emissions arising from fertilizer application and manufacture. Development and adoption of technologies such as enhanced efficiency fertilizers and microbial fertilizers could reduce the need for synthetic or organic fertilizer and reduce N_2O emissions. Developing ammonia for use in fertilizer is also highly emissions-intensive and can be made cleaner through direct electrochemical and solar conversion processes, in addition to processes that could provide low-cost green hydrogen to traditional ammonia production.

Policies

Phase: Research and Development

RESEARCH & DEVELOPMENT | VALIDATION & EARLY DEPLOYMENT | LARGE SCALE DEPLOYMENT

Federal investment in research and development (R&D) supports economic growth, drives down costs for key technologies that can be used domestically and exported abroad, and promotes U.S. leadership on clean energy and climate. Investment in R&D for soil management is driven primarily by the Agricultural Research Service (ARS) and the National Institute of Food and Agriculture (NIFA). Further R&D for soils comes from the Department of Energy's (DOE's) national labs and the Advanced Research Projects Agency-Energy (ARPA-E) ROOTS program.

Federal policymakers should increase investment and enact programmatic reforms to ensure a focus on advancing R&D for:

- Soil carbon measurement technologies;
- Next-generation nitrogen management in crop production;
- High carbon sequestration crops, including enhanced root systems; and
- Low-GHG fertilizer.

For more, see the deep dives on

→ **Public Sector R&D**
→ **National Laboratory Reform**
→ **Stimulating Clean Energy Entrepreneurship**

Phase: Validation and Early Deployment

R&D | VALIDATION | SCALE

Before we can deploy promising soil-management technologies at scale, we must demonstrate and validate their cost and performance in real-world conditions. Demonstration projects reduce the economic and institutional risks of new technologies, so the federal government should support existing efforts and, where needed, develop a robust portfolio of demonstration projects for soil-management and carbon sequestration best practices that can illustrate their benefits.

For more, see the deep dive on

→ **Demonstrating and Validating New Technologies**

Phase: Rapid, Large Scale Deployment

R&D VALIDATION **SCALE**

Federal Crop Insurance Reform

The Federal Crop Insurance Program (FCIP) could be a powerful lever for improving soil management practices. Offering a discount on federal premiums in exchange for producer risk management strategies, such as conservation practices that reduce erosion, build soil carbon, and increase nitrogen-use efficiency, could increase soil carbon sequestration and GHG reduction significantly. Linking a performance-based benefits program to the adoption of risk-management strategies will require filling gaps in knowledge, technology, and data, as well as continuous program learning and improvement.

For more, see the deep dive on

→ **Federal Crop Insurance Reform**

Reform Conservation Programs

The U.S. Department of Agriculture (USDA) is the largest provider of financial assistance to farmers and ranchers who seek to improve environmental outcomes on their land. These programs also provide important technical assistance to farmers and ranchers. Funds such as the Environmental Quality Incentives Program and the Conservation Stewardship Program have improved environmental outcomes, water quality, and soil health on agricultural lands. Funding conservation programs to achieve ongoing performance improvement linked to climate benefits would meet these important goals and strengthen existing land conservation policy. Eligibility could also be expanded to more types of land and a wider swath of participants.

Strengthen Soil Erosion Standards

Conservation compliance has two parts: soil conservation and wetlands protection. While conservation compliance has been highly successful in reducing soil erosion, croplands still lose over a billion tons of topsoil every year. Strengthening the soil erosion standard, applying soil erosion reduction requirements to all soils (not just Highly-Erodible Land (HEL)), and more robustly enforcing the adoption of conservation-compliance policies could reduce erosion and improve soil health.

Additional Resources

- **Clearing the Air: A Federal RD&D Initiative and Management Plan for Carbon Dioxide Removal Technologies**
- **Paustian, K., Larson, E., Kent, J., Marx, E., and Swan, A. 2019. Soil C Sequestration as a Biological Negative Emission Strategy. Frontiers in Climate 1:1 11**
- **Soil Health Institute White Paper on Addressing Climate Change Through Soil Health**
- **NRDC, Covering Crops: How Federal Crop Insurance Program Reforms Can Reduce Costs, Empower Farmers, and Protect Natural Resources**

  Chambers, A., Lal, R., and Paustian, K. 2016. "Soil carbon sequestration potential of U.S. Croplands and Grasslands: Implementing the 4 per Thousand Initiative." *Journal of Soil and Water Conservation 71*:68-74. doi:10.2489/jswc.71.3.68A