American Security Project

Innovating Out of The Climate Crisis: Agricultural Technology

Briefing Note

Quick Facts

- More than 10 percent of U.S. carbon emissions stem from agriculture—only slightly less than the emissions of all of the country's residences and commercial businesses.
- Unlike other sectors, carbon dioxide (CO2) is not the primary greenhouse gas (GHG) in agriculture. Nitrous oxide (N2O), a byproduct of spreading fertilizer and manure on fields, and methane, predominantly from digestion in cattle and other ruminants, are agriculture's main sources of emissions.
- Agriculture's emissions pack a punch. Methane's global warming potential is about 30 times more than that of CO2's over the course of century. Nitrous oxide's is even greater—some 270 times more. They degrade in the atmosphere much faster than CO2, however, so reducing emissions of these gases can minimize near-term warming.
- The impact of climate change on U.S. agriculture is projected to vary by region, with particular challenges in the Corn Belt and the South. In general, U.S. farmers are likely to face higher temperatures, changing rainfall patterns, and more extreme weather, leading to higher pest and disease pressure and reductions in crop output and quality.
- By mid-century, there will be 3 billion more people on Earth. Global food production will need to rise by as much as half to feed them, even as temperatures rise by 3°C or more.
- Farmers will need to switch to different crops, adopt new varietals resistant to heat or drought, or apply new production practices to adapt to these pressures.

Economic Competitiveness

- Agriculture, food, and related industries support 21 million jobs and $1 trillion in U.S. GDP, representing more than 10 percent of total employment and 5 percent of total GDP. The United States is by far the world's largest agricultural exporter by value, besting its nearest competitor by some 60 percent.
- Nonetheless, rural communities are under strain. They are home to 46 million Americans, but that number is falling over time in the face of slow employment growth and higher poverty rates relative to urban areas, particularly among children. Economic damage from climate change will likely exacerbate these trends.
- Political attention to international investment in U.S. farmland is rising. Bills in both the House and the Senate propose to limit or bar farmland purchases by foreign countries, particularly China, citing national security concerns. Yet, political anxiety about China should be tempered by facts: 62 percent of foreign-owned farmland is held by Canadians and Europeans. China accounts for less than 1 percent of foreign holdings.

By: Lindsay Iversen

Challenges & Opportunities

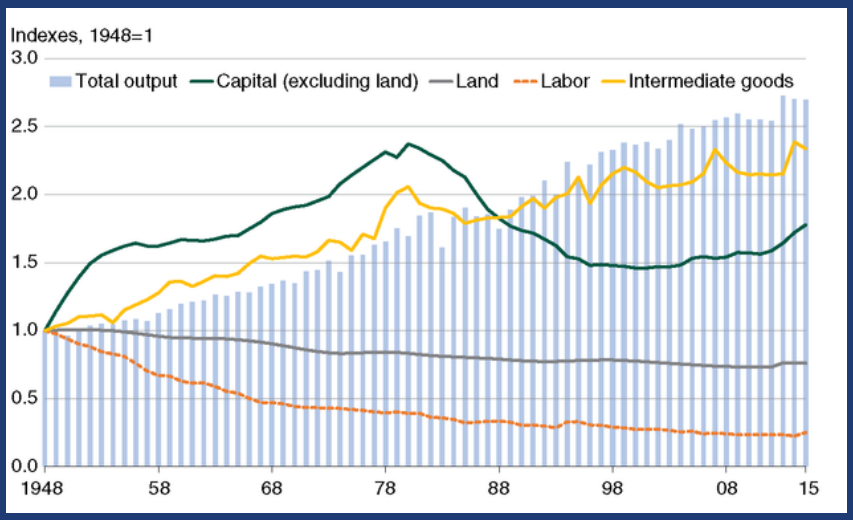
- Climate change could reduce profits for critical U.S. crops like corn, soy, wheat, and cotton by more than a third in the next 50 years under a high-emissions scenario. Up to half those losses can be avoided if farmers switch to crops more suited to their new climate, but in some hard-hit areas, adaptation may not be possible. As much as five percent of U.S. farmland could become unusable, with the South particularly vulnerable.

- More than 50 percent of the United States is agricultural land, but not all farms are created equal. Large operations—those over 1,000 acres—account for just 8 percent of farms but more than 70 percent of farm acres. The same holds true in terms of sales: farms with less than $350,000 in sales account for nearly 90 percent of farms but less than 20 percent of production. The three percent of farms selling more than $1 million in crops annually accounts for nearly half of total production. Climate policies and innovations targeting these large farms can have an outsized impact on the whole sector.

- Nitrogen fertilizers and improved seeds have driven a dramatic increase in U.S. arable crop productivity since WWII. Producing more food with the same or fewer resources creates the opportunity to use land for other purposes, including conservation.

- This productivity has come with an environmental cost. Half or more of nitrogen fertilizer is never taken up by plants. It is lost through emissions as N2O or as runoff, fueling toxic algae blooms and dead zones in downstream waterways.

Fertilizers and improved seeds have fueled agriculture output growth while labor needs have fallen.



Source: Agricultural Productivity in the United States, 1948-2015.

- Cattle are among the world's most resource-intensive foods, as they produce methane as a byproduct of digestion and nitrous oxide as their manure breaks down in soils. Through better breeding, higher quality feed, and improved manure management, the United States beef industry now emits less carbon per kg of beef than much of the rest of the world. To sustainably satisfy the expected 300 percent growth in global beef demand by 2050, however, much more progress is needed.

- Better soil management practices, such as reducing soil disturbance through low- or no-till practices, planting cover crops to protect soil between cash crop harvests, and rotating crops to replenish nutrients and prevent pest establishment, could sequester as much as a billion tons of CO2 per year globally and raise farm incomes. But, just five percent of harvested cropland in the U.S. uses cover crops, and just 21 percent use no-till practices.

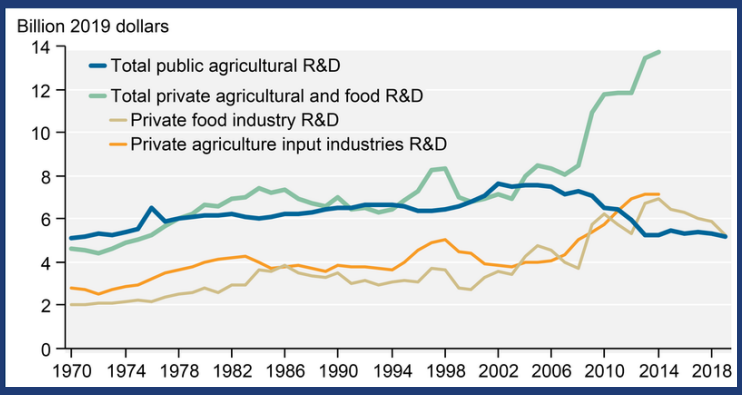
- The reasons for slow adoption are multifaceted. A majority of U.S. cropland is farmed by renters, rather than owner-operators. Their leases are often geared toward short-term returns, but soil health can take time to restore. For all farmers, the cost of the transition is a primary issue. Farmers are increasingly concerned about climate change, though, and experimentation with practices like cover cropping has risen over the last decade.

Policy and Regulatory Frameworks

- Over the last 20 years, public investment in research and development in food and agriculture has fallen by nearly 30 percent, while private investment has nearly doubled. Public sector research tends to focus on basic science, farming and husbandry techniques and practices, and conservation—precisely the kind of research needed to address climate challenges.

- The Farm Bill has included a title for agricultural research since 1977, but few of the programs under that title receive mandatory funding; instead, they must be supported through additional discretionary spending. In the last Farm Bill, passed in 2018, the research title received just $694 million in mandatory spending while total agriculture spending under the bill was $218 billion.

Public and private agricultural and food research and development (R&D) expenditures, real (inflation-adjusted) dollars, 1970-2019



Source: Agricultural and Food Research and Development Expenditures in the United States.

- A recent analysis argues that federal R&D could be targeted more effectively to reduce emissions from agriculture. Today, the majority of federal research into climate-smart agriculture is focused on soil carbon sequestration. But reducing methane emissions from cattle and other ruminant digestion receives just 2 percent of R&D spending, despite accounting for 28 percent of agriculture's emissions.

- USDA programs to support conservation are diffuse, small, and voluntary. USDA spent just $1.8 billion through core conservation programs in 2021—far less than was needed to meet even current farmer demand. To meet climate needs, moreover, farmer demand will need to grow considerably. Just 21 million acres were covered by these programs in 2021, or 2 percent of total farmland.

- The 2022 Inflation Reduction Act (IRA) bolstered federal investment in core conservation programs including Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (CSP), the Regional Conservation Partnership Program (RCPP), the Agricultural Conservation Easement Program (ACEP) and more. In total, the IRA allocates $19.5 billion of additional money over the next five years to implement climate-smart agriculture and conservation practices.

- Although conservation programs are popular with farmers across the political spectrum, it remains to be seen whether it will become a major sticking point in Farm Bill negotiations. Congress is divided on whether to continue building investment with additional climate-related funding.

- The Partnership for Climate-Smart Commodities, launched in 2022 through the existing Commodity Credit Corporation, is dedicating $3.1 billion to pilot projects of up to five years to help farmers grow and market climate-friendly crops, as well as trialing new methods to quantify GHG sequestration through agriculture.

- The Obama Administration established ten regional Climate Hubs to provide targeted climate adaptation resources to farmers throughout the United States and its territories. These hubs are under-resourced, however, and poorly publicized to farmers.

Technology and Innovation

- Scientists are developing new cultivars of important food crops to make them more resilient to climate change. Researchers have discovered a gene, for example, that makes plant roots grow deeper into the ground, giving the plants better access to nutrients, more protection against drought, and potentially better capacity to store carbon further underground. Engineers inserted a bacterial gene into certain varieties of corn to make them more tolerant of drought, and genetic editing using CRISPR is now being used to build crops' resistance to diseases and pests.

- Researchers at the University of Illinois are working to improve photosynthesis itself, in the hopes of making crops grow more efficiently. In early experiments in tobacco plants, their alterations improved growth by nearly a fifth.

- Precision agriculture techniques, including GPS-guided tractors, sensors that gauge fertilizer and pesticide needs down the centimeter, and variable-rate sprayers that can adjust how much product is sprayed at any given moment, can help farmers improve efficiency by up to a fifth. It can also help reduce overall pesticide and fertilizer use and minimize runoff. If most farmers adopted these techniques, they could reduce emissions by about 27 million metric tons of CO2 equivalent per year by 2030.

- Most nitrogen-based fertilizers like ammonia are made with fossil fuels. Globally, 70 percent of ammonia is made from natural gas; in the U.S., 88 percent of ammonia is used as fertilizer. Scientists are working to make green ammonia, generated with renewable energy rather than fossil fuels, more cost-competitive.

- New fertilizer formulations are testing chemical and biological ways of reducing nitrogen loss. Urease inhibitors can prevent urease in the soil from breaking certain fertilizers down into ammonia gas, which can easily evaporate. Nitrification inhibitors temporarily reduce the populations of soil microbes that can digest fertilizers and make them unavailable to plants. And slow-release fertilizers can make more fertilizer available to plants over time, rather than solely at the time of application. Depending on the crop and soil conditions, these technologies can reduce nitrogen loss and improve yields, but adoption remains low due in part to high costs.

- Managed grazing practices, in which cattle, sheep, and other grazing animals are rotated through pastures to spread out grazing pressure and allow land to recover, can sequester as much as 21 gigatons of CO2 by 2050. These techniques can also improve plant and insect biodiversity without sacrificing productivity.

- To reduce methane emissions from cattle and other ruminant animals, scientists are developing feed additives to alter the animals' microbiomes. Adding red seaweed supplements to cattle feed reduced methane emissions by up to 60 percent in one early trial. Another compound, 3-NOP, has been shown to reduce methane emissions by 30 percent, and potentially to boost growth. In both cases, though, the supplements need to be fed to the cattle regularly—a difficult prospect for pastured animals.

This briefing note is part of ASP's *Innovating out of the Climate Crisis* programming, which seeks to explore innovations in technology and policies in key clean energy areas. These innovations will help facilitate our collective ability to adapt to climate change, ultimately leading to a more resilient nation.

INNOVATING
OUT OF THE CLIMATE CRISIS