USDA Economic Research Service
U.S. DEPARTMENT OF AGRICULTURE

A report summary from the Economic Research Service *July 2024*

Climate-Induced Yield Changes and TFP: How Much R&D Is Necessary To Maintain the Food Supply?

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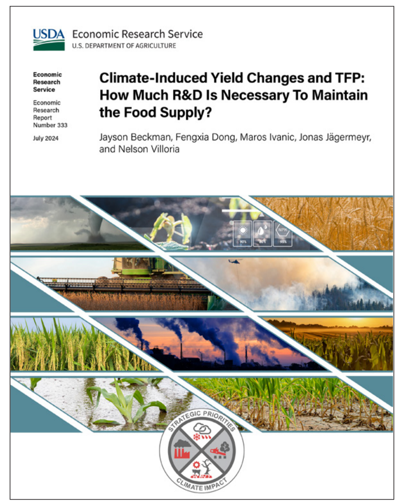

What Is the Issue?

A rising global population—with changing diets and an increasing demand for animal-based products, along with a changing climate—puts pressure on both the existing and future global food supplies. A changing climate could lead to warming temperatures and an increased likelihood of extreme weather events such as droughts and floods, impacting agricultural productivity and crop yields. Reduced crop yields diminish agricultural productivity, affecting not only agricultural quantities but also food prices and ultimately food security. This challenge arises at a time when increasing incomes contribute to an increased demand for food—especially for meat, where crops are a crucial input for animal feed. While increasing agricultural productivity through total factor productivity (TFP)—a measure of the efficiency with which agricultural inputs are combined to produce output—could help mitigate any yield decreases, this comes at a monetary expense in the form of research and development (R&D) needed for achieving it.

What Did the Study Find?

The objective of this study is to further understand the future of the agricultural food supply and demand under climate change. To do so, we first use two pieces of literature to summarize yield and TFP projections to understand the impacts of climate change on the global food supply.

- Most past research shows a climate-induced decline in yields globally for corn only. In contrast, rice, soybeans, and wheat yields all are expected to experience an increase, with wheat particularly benefiting from improved yields in land in higher latitudes. In the United States, research shows declines in yields for corn and soybeans, but increases in wheat by 2050 as a result of climate change.

The global supply of corn, rice, soybeans, and wheat varies by the R&D assumptions and the subsequent changes in TFP.

- Under the scenario of no additional R&D expenditures, global production for all four crops increased. The increase is smallest for corn—5.2 percent compared with more than 22 percent for other crops.
- Wheat production was estimated to increase the most.

Total agricultural production across the four crops is estimated to increase in the United States across all R&D scenarios, but impacts to crops are different.

- U.S. corn production decreases if no additional R&D expenditures are made (beyond 2016 expenditures)—from 385 million metric tons in 2016 to 352 million metric tons in 2050. Production for the other three crops is estimated to increase, although at a slower rate than the global change.

After reviewing the previous research, USDA, ERS researchers used global estimates of population and gross domestic product to project changes in food demand. Half of corn and three-quarters of soybeans were assumed to be used for feed, while rice and wheat were assumed to be directly consumed as food. Combining these demand estimates with supply (from TFP and yields), the production-consumption gap for the four crops was calculated.

- If no additional R&D expenditures are made (beyond 2016 expenditures), then TFP growth would be insufficient to meet global demand for the four crops.
- TFP growth in the other scenarios, which consider various degrees of R&D expenditures, is shown to be able to keep pace with global demand.
- The United States, a major exporter of the four crops, could experience a decrease in the country's production-consumption gap if R&D expenditures are small.

How Was the Study Conducted?

To assess the potential impact of climate change on food supply and demand, yield change estimates were determined for corn, rice, soybeans, and wheat, referred to as the Global Gridded Crop Model Intercomparison yields, as provided by Jägermeyr et al. (2021). These estimates were based on climate projections from global climate models and global gridded crop models. Estimates were used from a climate change scenario of Representative Concentration Pathways, a characterization of how greenhouse gases will change in the future (RCP) 8.5, and from Shared Socioeconomic Pathways, which projected socioeconomic global changes (SSP) 5. This scenario projects high greenhouse gas emissions. The yield changes were combined with TFP estimates across four scenarios (data are from Fuglie et al., 2022), where R&D assumptions determine the rate of TFP growth. While many climate projections extend until 2100, the focus of this report is on 2050, as projection accuracy diminishes over longer timeframes. Following Beckman et al. (2023), averages around the timeframe of interest are provided. These averages helped smooth out any spikes in a given year that might have resulted from weather-related variations rather than climate-related changes. Data for 2048–52 were used for the average of 2050, and data for 1983 (the beginning of yield estimates) through 2016 served as the baseline (TFP projections start at 2016). How these food supply changes could impact agriculture was examined by considering how food demand might change by 2050 through changes in population and consumption.