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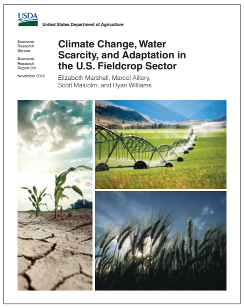

Find the full report at *www.ers.usda.gov/publications/err-economic-research-report/err201*

Climate Change, Water Scarcity, and Adaptation in the U.S. Fieldcrop Sector

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What Is the Issue?

U.S. agriculture faces a changing production environment due to shifts in global climatic conditions. Climate models predict wide-ranging impacts on local temperature and precipitation patterns, with broad implications for crop yields, crop-water demand, water-supply availability, farmer livelihoods, and consumer welfare.

Adaptive farming strategies can help producers reduce the costs of climate change. Farmers can respond to climate-induced shifts in relative profitability by changing crops, rotations, production methods, and amount of cropland cultivated. Shifts in the extent and intensity of irrigation have also been widely proposed as a response to warmer conditions. The reallocation of production acreage and methods in response to climate change may be constrained, however, by limits on the regional availability of cropland and water resources. This report explores regional patterns of change in fieldcrop production and in the intensity and extent of irrigation under various climate projections of future temperature and precipitation patterns. We look specifically at changes in growing conditions and crop yields, changes in profitability due to shifting comparative advantages, and constraints on irrigation water supply.

What Did the Study Find?

Projected changes in climate are likely to alter growing conditions across important agricultural regions in the United States. Key findings of this study at the national level include:

- Average yields are projected to decline as a result of climate change for corn, soybeans, rice, sorghum, cotton, oats, and silage under both irrigated and dryland production as early as 2020, relative to projected yields assuming no climate change.
- Changing climate conditions generally increase the profitability of irrigated production relative to dryland production before midcentury. After that, the premium received by irrigated crops declines across several climate projections and crops. The declining benefits of irrigation are driven by: shifting patterns of precipitation, which affect both costs of irrigation (through volume of water applied) and the yield premium achievable through irrigation; temperature-related crop yield impacts for both irrigated and dryland production; and differences in carbon fertilization impacts on crops grown under dryland production versus those that are predominantly irrigated.

- Future irrigated crop acreage declines as a result of climate change across analysis years 2020 through 2080. Before midcentury, the decline is largely driven by regional constraints on surface-water availability for irrigation. Beyond midcentury, the decline reflects a combination of regional surface-water shortages and declining relative profitability of irrigated production.

- Averaged across climate projections, production drops for all crops due to climate change in 2020, relative to baseline production levels for that year. In 2040 and beyond, wheat, hay, and barley production levels increase as average yields increase, resulting in above-reference production levels for all three by 2080.

Summary table

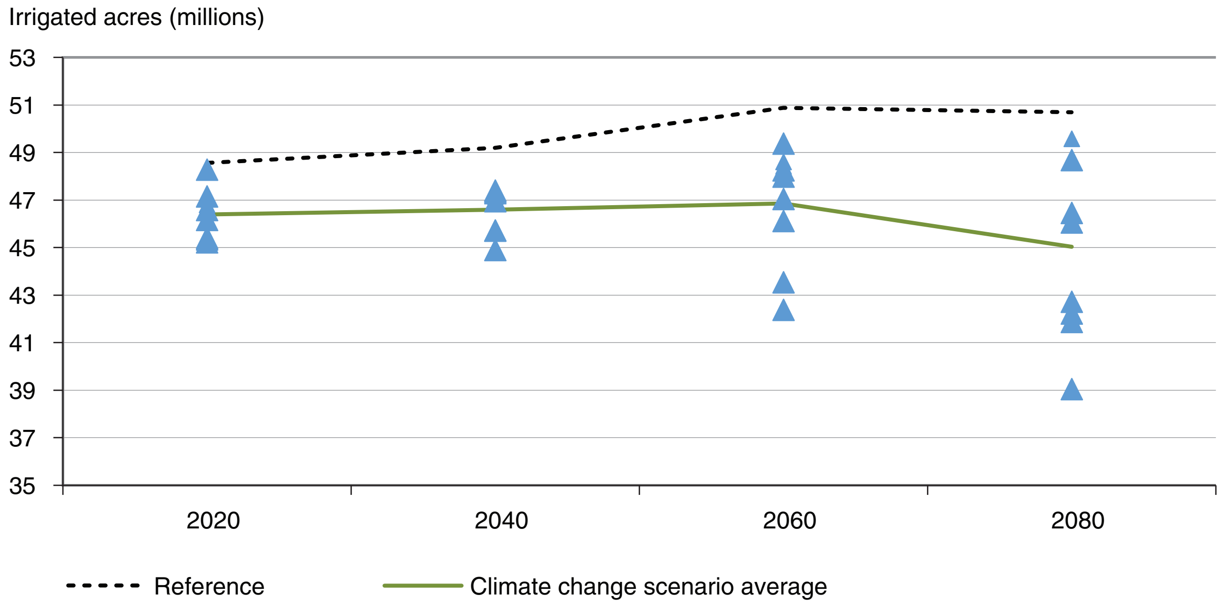
Percent change in U.S. production (averaged across climate scenarios) relative to reference conditions

	Average % change in production			
	2020	**2040**	**2060**	**2080**
Barley (bushels)	-1.9	-0.6	-3.5	1.0
Corn (bushels)	-8.1	-8.7	-13.8	-16.2
Cotton (bales)	-7.9	-6.1	-5.6	-5.9
Hay (dry tons)	-4.0	-0.6	2.7	4.2
Oats (bushels)	-8.7	-10.7	-16.1	-20.8
Rice (cwt)	-2.2	-2.5	-4.2	-6.1
Silage (dry tons)	-6.9	-9.5	-13.1	-14.4
Sorghum (bushels)	-15.1	-5.4	-14.0	-17.0
Soybeans (bushels)	-8.1	-8.8	-11.9	-14.3
Wheat (bushels)	-2.8	1.3	5.6	11.6

Source: USDA, Economic Research Service

Summary figure

Extent of irrigated fieldcrop acreage under reference weather and under climate change projections



Note: This is a simplified version of figure 7. Markers represent irrigated acreage under nine possible climate futures representing growing conditions derived from multiple general circulation climate models under multiple carbon emissions assumptions between 2020 and 2080. Reference line represents irrigated acreage assuming a continuation of growing conditions averaged over 2001-2008.
Source: USDA, Economic Research Service.

Commodity prices rise as a result of climate change under most climate projections. Despite higher prices, producer welfare (aggregated across fieldcrop sectors) also declines due to declining yields and crop returns.

Climate-induced impacts on relative profitability of cropping systems, farm returns, irrigated acreage, and production levels vary regionally. These differences reflect regional variation in cropping patterns, reliance on irrigation, and the direction and magnitude of climate change impacts. Key regional findings include:

- Production returns decline in the ***Corn Belt*** across all climate projections, reflecting the sensitivity of corn yields to increasing temperature stress.
- Agriculture faces increased water scarcity in major irrigated areas, with projected surface-water reductions (relative to reference use levels) ranging from 20 percent to more than 50 percent across areas of the ***central and southern Mountain, Pacific, and Plains*** regions by 2060.
- Across the ***northern tier of the Pacific, Mountain, and Northern Plains*** regions, projected reductions in irrigated area are driven by increased precipitation and declines in the relative profitability of irrigated cropping systems. In the ***southern Pacific and Mountain*** regions, climate-induced surface-water shortages combine with declining irrigation returns to reduce irrigated area under most climate scenarios.
- In the ***Southern Plains***, increasingly limited water supplies reduce irrigated acreage, although climate effects on surface-water supplies are dwarfed by projected reductions in groundwater withdrawals from the Ogallala aquifer.
- In the ***Delta*** region, the relative profitability of irrigated production generally increases under climate change, creating an incentive for expanding irrigated acreage. Water-supply constraints, however—primarily limits on groundwater availability—prevent that expansion.

How Was the Study Conducted?

This analysis draws on downscaled projections of temperature and precipitation under reference climate conditions as well as nine climate change scenarios for 2020, 2040, 2060, and 2080. Climate data, and the potential regional surface-water shortages associated with each climate projection, were calculated based on scenarios developed for the USDA Forest Service's Resources Planning Act (RPA) assessment of renewable natural resources. Nine future climate projections were explored, which include three different General Circulation Models (GCMs) applied to each of three of the emissions scenarios in the Intergovernmental Panel on Climate Change Special Report on Emission Scenarios (SRES). We entered changes in climate parameters into a crop-growth simulator to estimate their effect on crop yields and per-acre irrigation demand under alternative climate scenarios. We combine projected surface-water shortages and groundwater withdrawal reductions to derive regional constraints on irrigation water supply for each climate projection. ERS' Regional Environment and Agriculture Programming (REAP) model was used to project shifts in regional agricultural production and irrigation patterns, crop prices, regional farm income, and producer and consumer welfare, given climate-induced changes in crop yields and crop water demand, regional estimates of reductions in irrigation water availability, and market price effects.