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The Inevitability of Climate Adaptation in U.S. Agriculture

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Globally, greenhouse gas (GHG) emissions have risen and are likely to continue to rise into the immediate future. As a result, the Intergovernmental Panel on Climate Change (IPCC) and the U.S. National Climate Assessment (NCA) expect climate change to continue, producing higher temperatures and changes in precipitation and extreme weather. Even under aggressive GHG reduction scenarios, some level of climate change is still expected.

Rose (2015) makes an argument for the inevitability of climate change. There are also magnitude and timing arguments that can be made (McCarl, Norton and Wu, 2015; IPCC, 2014). In particular, the IPCC future projections (IPCC, 2013) are summarized in Figure 1 and show temperature change under four alternative emission scenarios (called Representative Concentration Pathways, or RCPs). IPCC (2014) considered these projections and formed alternative futures as represented by the vertical lines and arrows that appear in the Figure.

A changing climate implies changing conditions for agricultural production in States, with among other things shifts in growing seasons, seasonal temperature extremes, precipitation patterns, and weather events. Midwestern farmers in the United States, for instance, could eventually experience annual average temperatures 10°F higher than today with 30 to 50 additional frost free days and 0 to 9 additional consecutive dry days a year. The changes will vary from place to place across the United States and across countries, altering relative crop and livestock production possibilities. The net effect, however, at least in the near future, could be increases in agricultural production that benefit consumers but decrease producer revenue. Over the

longer-run, climate change could be potentially damaging on net, as more extreme environmental changes increasingly stress agricultural production systems.

The state implications of climate change for agriculture will depend on the level of climate change and the ability to adapt. How society evolves and to what degree it manages the climate through GHG mitigation policies and/or geo-engineering solutions will determine the level of climate change. Geo-engineering strategies manage the earth's radiative balance with extreme technological solutions such as injecting aerosols into the upper atmosphere, placing shields in space to reduce incoming solar radiation, or sucking carbon dioxide (CO₂) directly out of the atmosphere. Adaptation, on the other hand, manages the climate change that occurs and maximizes returns in the new environment. Adaptation, however, is constrained by current knowledge, technology, markets, institutions, infrastructure, and policies. Planning decisions today will shape these dimensions and shape agriculture's ability to adapt in the future.

Emissions

Globally, GHG emissions have risen from 27 billion metric tons of CO₂ equivalents (GtCO₂-eq) in 1970 to 49 GtCO₂-eq today (in 2010). Future GHG emissions are uncertain and depend on population and economic growth, energy markets, technology, and climate policy. Scenarios of potential futures without additional policies to manage climate change indicate that GHG emissions could reach 58 to 96 GtCO₂-eq by 2050 and rise or fall beyond 2050 to 46 to 136 GtCO₂-eq by 2100 (Table 1). When there is a

Table 1: Future Global Atmospheric Concentrations, GHG Emissions Changes and Temperature Changes*

Type of scenario	Concentrations in 2100 (CO ₂ -eq ppm)	CO ₂ -eq emissions		Change in CO ₂ -eq emissions relative to 2010		Change in global average annual temperature by 2100 (°F)
		2050	2100	2050	2100	
Baseline futures	> 1000	74 to 96	85 to 136	52 to 95%	74 to 178%	3.9 to 12.9
	720 to 1000	58 to 75	46 to 84	18 to 54%	-7 to 72%	2.7 to 9.3
Climate policy futures	650 to 720	44 to 57	23 to 39	-11 to 17%	-54 to -21%	2.3 to 7.0
	580 to 650	30 to 61	-17 to 25	-38 to 24%	-134 to -50%	1.6 to 6.5
	530 to 580	26 to 52	-41 to 20	-47 to 7%	-183 to -59%	1.4 to 5.4
	480 to 530	21 to 37	-7 to 13	-57 to -25%	-114 to -73%	1.1 to 4.8
	430 to 480	14 to 29	-9 to 11	-72 to -41%	-118 to -78%	0.7 to 3.9

*Note: 5th to 95th percentile results shown for temperature changes, and temperature changes are relative to 1986-2005.

Source: IPCC WGIII (2014).

global climate change reduction goal, projected emissions range from 14 to 61 GtCO₂-eq in 2050 and negative 41 to positive 39 GtCO₂-eq in 2100, depending on the stringency of the goal. Negative emissions reflect the deployment of technologies that on net remove and store CO₂ from the atmosphere. Projections for the most stringent climate goals have emissions of 14 to 29 GtCO₂-eq in 2050, which is 41% to 72% below today's emissions. The most aggressive climate objectives of course have the highest projected economic costs and require a significant degree of international coordination in controlling emissions.

Inevitability of Adaptation

Even with the most stringent emissions futures, atmospheric concentrations of GHGs increase (Table 1). Concentrations increase with additional emissions despite future annual emissions lower than today because GHGs accumulate in the atmosphere. The long atmospheric lifetimes of GHGs mean that concentrations in the atmosphere today include emissions from previous decades and centuries, where the atmospheric lifetime depends on the type of GHG. Only when annual emissions are below the rate of natural and man-made withdrawal will concentrations decline.

Rising concentrations will increasingly prevent outbound radiation from escaping into space, and the resulting trapped energy contributes to climate change, including changes in average global temperature, the most publically prominent climate change indicator. By 2100, global average temperature could be anywhere from 0.7 to 12.9°F warmer than today according to the IPCC (Table 1). Even with the lowest GHG emissions futures, global average temperatures are projected to rise by 0.7 to 3.9°F by 2100. Some level of future climate change is therefore inevitable.

U.S. Climate Change and Agriculture

Climate change represents far more than just changes in temperature, with changes expected in a broad set of variables relevant to agriculture—temperature, precipitation, CO₂ levels, extreme weather, and potential extreme events. Also, climate change will vary by country, potentially favoring some countries and disadvantaging others. Climate changes would also vary dramatically within the United States—north to south and east to west. U.S. farmers, for example, could experience increases in average annual temperatures locally of 3 to 15°F by the end of the century depending on future global emissions and a farmer's particular location, with warming

greatest in more northern and inland states, including the Midwest and the Great Plains (Figure 1). For some U.S. farmers, climate change could imply longer growing seasons and earlier planting dates with enhanced crop growth due to elevated atmospheric CO₂ levels. But, climate change could also imply increases in consecutive dry days and the number of hot days each year, and increases in the frequency of heavy rainfall, extreme heat and severe drought, as well as increased frequency of weeds, diseases, and pests, crop and livestock heat stress, and reduced snowpack with water supply consequences.

Adaptation in Agriculture

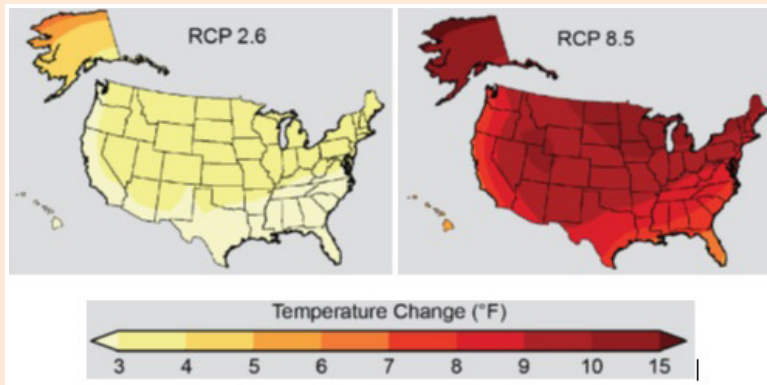
Adaptation is nothing new for agriculture. U.S. Farmers are adept at adapting to dynamic market conditions, weather, new technologies and knowledge, and policies. We see adaptation in year to year strategies to manage risks and exploit opportunities, and across states in differences in production systems suited to local productivity and economic conditions. Adaptation is evident in the expansion of corn production in response to renewable fuels policy, as well as the differences we observe in the agricultural output of California, Wisconsin, Texas, and New York.

Also, climate change is but one of many long-run forces shaping agriculture production. Technology, infrastructure, and policies (conservation, farm, energy, and trade) can shape U.S. agriculture for decades. Climate change will shape long-run agriculture with gradual shifts in temperature and precipitation. However, there are dimensions to climate change that may require more significant adaptation such as changes in the variability of weather and extreme weather events like droughts.

In general, there are three types of potential on-farm adaptation responses:

Adjusting management practices:

Figure 1: U.S. Temperature Change for a High (RCP 8.5) and Low (RCP 2.6) Global Emissions Future*



*Note: With respect to Table 1, RCP 8.5 and RCP 2.6 fall in the >1000 and 430-480 CO₂-eq ppm 2100 concentration levels respectively. Values are changes between average annual temperatures for 2071-2099 relative to 1970-1999.

Source: NCA CH2 (2015).

continuing with the same production activity but adjusting inputs in response to the changing climate, such as shifting planting dates, increasing irrigation, or cooling livestock.

Changing production systems: shifting to an alternative, but existing, cropping or livestock system, e.g., altering crop or livestock mix, shifting rotations, abandoning or converting land.

Adopting new technology: adopting new technology developed for new climate conditions, e.g., new drought tolerant plant varieties, better water retention management strategies, or improved fertilizer or pest management.

Farmers already have the capacity to adapt to some climate change with a variety of response options at their disposal. Current knowledge, technology, markets, institutions, infrastructure, and policies give them the capacity and flexibility to make adjustments and adapt to new circumstances. However, adaptation potential is constrained by current capability in each of the above dimensions. Planning and investments, public and private, can increase farmers' adaptive capacity through:

Research – developing improved climate resilient practices, inputs, and technologies.

Extension and outreach – providing training and sharing of new knowledge (techniques and technologies).

Information networks – facilitating the informal direct exchange of practices and experiences and nurturing of new ideas amongst farmers.

Government policies – developing institutions, infrastructure, and market access, and helping to manage commodity risk.

Significant public and private sector planning and investments support today's farming, including substantial local research and outreach. U.S. agriculture's capacity to adapt to climate change in the future will be defined by today's planning and resulting developments for the potential climate challenges of tomorrow. Of course, the need to adapt will depend on future emissions and the corresponding shifts in potential temperature, precipitation, weather variability, and extreme events.

Economics of Adaptation

Farmers will adapt if it is valuable

to do so, changing practices to avoid losses or pursue opportunities. Economic studies have explored past producer behavior to understand how farmers have responded to changing climatic conditions. This research has found farmers adjusting livestock species mix, numbers, and stocking rates, as well as shifting land between livestock and crop activities, all in response to changing average temperatures and precipitation (Seo and Mendelsohn, 2008a, 2008b; Mu and McCarl 2011). Economic modeling has also evaluated the potential future implications of climate change for U.S. farmers and consumers, finding adaptation to be a fundamental part of the story. Climate driven changes in planting dates, varieties, crop mix, land use, irrigation, and amendments reduce potential climate damages and may even result in net benefits (Adams et al., 1999; Reilly et al., 2003). Similarly, while crop, forage, and grazing yields could be significantly affected by a changing climate (with the potential for increased or decreased yields), changes in agricultural output are expected to be far less dramatic due to adaptation changes in inputs and land use (Reilly et al., 2007). Adaptation at a broader macroeconomic level is also expected with changes in agricultural trade patterns, regional food prices, regional food consumption, and non-agricultural consumption as resources shift between agriculture and non-agriculture sectors in the economy. Adaptation responses, from the farmer to the global economy, moderate the consequences of climate change. Economic studies like those mentioned above illustrate the value of past and future adaptation to agriculture.

Implicit in these studies is the capacity to adapt. Knowledge, technology, markets, infrastructure and policies define capacity and constrain the possibilities for adaptation. Planned improvements in these conditions can increase the capacity to further manage detrimental effects, as well as

opportunities. Farmers will not be affected equally by climate change. Local climate change and adaptation capacity will determine their situation.

Adaptation Challenges and Opportunities

Significant local changes in agricultural potential may result with climate change—changes that represent major shifts in production possibilities and profitability. Some existing crop and livestock lands may have significantly reduced productivity, while other lands become increasingly viable for agricultural production for the first time. Improving the capacity to adapt for these diverse circumstances will be a challenge. Research, education, and capital investments for maintaining existing production will be important, as will additional investments, market access, and policy planning to support and environmentally manage new agricultural systems and production locations. In addition, some communities may require economic

support or re-training as agricultural production potential diminishes relative to other locations. Initiatives, like USDA's regional climate hubs, capacity building partnerships, and decision support-tool development, will contribute to the future climate resiliency of U.S. farmers and agriculture communities.

Some degree of climate change is expected to occur even under the most aggressive GHG emissions reduction scenarios. It is, therefore, likely inevitable that farmers will have to adapt to new temperature, precipitation, weather extreme, and extreme event conditions. The need to adapt will depend on the level of climate change. Farmers are adept at adapting to evolving conditions; however, future climate change could be significant. The ability to adapt depends on the state of knowledge, technology, markets, infrastructure and policies, and could be enhanced with adaptation planning in research, extension and outreach, information networks, and government programs and policies.

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