Food and Water: A Crisis of Uncertainty**

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Summary
Agriculture in the United States is experiencing structural change, including trends towards larger farms with less diversity of product and less biodiversity, coupled with globalization and the resulting demands of global market forces. At the same time, agriculture is increasingly threatened by uncertainty and instability from global climate change. The impacts of global climate change on water availability alone, in the form of more extreme precipitation events over time (e.g., droughts, floods, and intense precipitation events) will exacerbate impacts of temperature shifts and warming that are anticipated to reduce agricultural productivity over time. The stresses of reduced reliability of water supplies for crops (whether rain-fed or irrigated) and livestock cannot or has not been adequately addressed by policy makers. In fact, farm policies being currently deliberated by the U.S. Congress would subsidize crop insurance for irrigated agriculture more than $500 million more per year than nonirrigated agriculture, at the expense of continued depletion of aquifers upon which many important grain crops in large areas of the country are dependent. While U.S. agriculture has a long history of adaptation to change, it is highly likely the confluence of uncertainty from the aforementioned events will create stresses to the agricultural system that may not allow for adaptation in a timely manner without significant financial, food security, and defense impacts to the U.S. and globally.

Current realities

Agricultural systems globally are increasingly homogenized, specialized, and intensified, resulting in biodiversity loss that threatens global food security. The Food and Agriculture Organization (FAO) estimates that 90 percent of global food energy and protein comes from just 15 plant and 8 animal species; and that wheat, rice, and corn provide more than half the world's plant-based caloric intake. Water accessibility, quantity, and quality are threatened by increased demands, competing uses, unsustainable overuse and pollution, and the impacts of climate change and agricultural practices. In the U.S., water availability and quality is threatened by oil and fossil fuel extraction practices and the unsustainable depletion of aquifers and ground water. The globalization of markets has created wide swings in food (commodity) prices and availability, driven by food and fuel policies and weather-related events. The complexities and uncertainties of unmitigated climate change impacts and associated weather variability; changes and movement in pestilence, diseases, and their vectors; water accessibility and quality issues; and global competition for food, land, water, and other natural capital creates a global food security crisis of potentially epic proportions.

Climate change models have long predicted impacts that are increasingly observed around the globe. However, climate change models are still subject to uncertainty: they remain fairly coarse, exhibit disagreement between models, and produce at best decadal results of potential impacts that are not region-specific. Although U.S. agriculture has long been associated with adaptability to change, the uncertainties of temperature changes and extreme weather events from climate change — including daily and diurnal temperature fluctuations — can stress crops and livestock, reduce productivity, and, driven by vulnerabilities of reduced genetic biodiversity, make regional or larger-scale disasters possible, even in the near-term.

The U.S. lacks a federal or unified water policy or law. The Ogallala aquifer, located largely under the U.S. states of Texas, Kansas, and Nebraska, provides a key example of water accessibility issues at stake. Though largely non-renewable, the Ogallala is subject to variable

state management policies, laws, and intra-state compacts, and increased demands from urban growth and agriculture. Parts of the aquifer have dropped 80 to 100 feet in the past 15 years. Despite conservation attempts in some areas, droughts have led to increased irrigation, and federal farm policies currently being debated would further subsidize irrigation.

Global market forces impact food supplies and prices; flooding in China in 2013 led to massive failures of wheat crops, which increased U.S. exports by 25 million bushels. Though high production elsewhere helped stabilize global supplies and prices, such incidents in the future could lead to price spikes, food shortages, and global disruptions with economic and security impacts. Water quality impacts from agricultural intensification and nutrient loading have led to localized and regional water quality issues, including algal blooms and dead zones due to hypoxia and eutrophication, with human and wildlife impacts.

A U.S. surge in oil and gas is being fueled by new technologies making previously inaccessible reserves economically accessible. Hydraulic fracturing (aka "fracking") is used in thousands of wells in the U.S. and is expanding rapidly. A single well can use 1 million to 5 million gallons of fracking fluid, the exact contents of which are largely unknown due to proprietary claims by drilling companies. Flow-back water from these wells contains salts, hydrocarbons, heavy metals, isotopic tracers, and other impurities. Because these substances can contaminate groundwater, fracking can aggravate and/or create water shortages.

Scientific opportunities and challenges

Climate-friendly agricultural systems and technologies, and adaption to climate change and water shortages, in the form of drought-resistant crops and crops resistant to rust, other anticipated diseases, and new disease vectors are receiving limited but increased attention. However, the identified uncertainties and variables make it difficult to assess whether the highest priority activities and technologies are being pursued, or whether current policies and activities are appropriate or adequate.

Continued investments in climate change models to increase accuracy and predictability to finer geographic scales and more real-time or short-term impacts are necessary to help inform policy decisions and prioritize investments and activities relative to climate change mitigation and adaptation, particularly for agriculture. What we do not know is far more critical than what we do know. Long-predicted climate change impacts (e.g., weather and precipitation extremes) are already being observed, but unpredicted anomalies are also being observed, e.g., "stalled" surface temperature increases, which have been variously attributed to volcanoes, ocean sinks, the presence of other pollutants (e.g., sulfur dioxide), or cyclical solar intensity. Just as possible is a reversal or a sudden rapid heating, which might be accompanied by more extreme weather and/or may trigger feedback loops that exacerbate extreme impacts, all of which may overwhelm resources and our ability to adapt — agriculture included.

Science-based modeling of potential pest and disease outbreaks based on known and anticipated climate change and related impacts to crops and/or livestock, as well as the ability to contain and/or treat such outbreaks, is critical to understand food security and related vulnerabilities based on our current over-reliance on genetically homogenous agricultural production systems. Gene banks may preserve critical germplasm, but may not offer solutions in time to avert crises, or to recover from crises in a timely manner.

Policy issues

- Global mandatory climate change policies must be enacted. The United Nations Framework Convention on Climate Change (UNFCCC) process seems broken, and

bilateral and multilateral agreements between nations are a band-aid approach. The United Nations (U.N.) should integrate existing overlapping conventions to address climate change, biodiversity, desertification, poverty eradication, and sustainable development. Economics and legal ramifications add complexity, but should be addressed systematically and by heads of state via the U.N. process. U.S. accession to treaties and conventions is complicated by required Senate passage, and the fact that the U.S. did not ratify the Kyoto Protocol to the UNFCCC or the Convention on Biological Diversity (CBD).

- U.S. federal policies are needed to address water quantity, usage, conservation, and quality. Existing fractured state approaches are inadequate and inequitable legal quagmires. A multistakeholder approach based on a National Academy of Sciences assessment of these issues is warranted, to be led by a neutral third-party facilitator, and include appropriate federal agency representatives, sectoral stakeholders, and the general public.

- International collaboration on water, including a recent High-Level International Conference on Water Cooperation hosted by the Government of Tajikistan (including U.S. State Department participation) and the Shared Waters Program of the U.N. Development Program should continue and be expanded.

- Use and overuse of natural resources such as water and fossil fuels have environmental and public health impacts that do not remain localized. Fracking for oil and gas extraction should be banned and discontinued until its long-term impacts to environmental and human health are thoroughly investigated via a global, scientific, transparent assessment, undertaken by a multisectoral U.N. scientific advisory panel. Full public disclosure of all chemicals used in fracking and cost-benefit analyses of remediation and cleanup are essential components of a credible assessment.

- Sustainable agricultural intensification and food security should be a topic of federal and global efforts, led by the FAO, and must include economic analysis and the internalization of current economic externalities such as the use, impacts, and movement of natural resources and water in the global marketplace. Sustainable supply chain initiatives are circling this issue quite inefficiently, and require global harmonization and standardization of metrics and tools. This assessment should include a realistic approach to match agricultural production to localities and regions best suited to efficient production to maximize efficiencies and minimize inputs. Efficient nutrient utilization technologies such as nitrification inhibitors can help address economic, climate change, and water quality issues simultaneously. Increased biodiversity (seeds/crops, livestock, soil biota) must be an explicit focus of agricultural sustainability and food security measures; the CBD has laid the groundwork for these efforts.

- The U.S. Congress should remove distorting subsidies from the U.S. Farm Bill. This includes direct payments, $500 million in targeted crop insurance irrigation subsidies, and federal crop insurance subsidies. U.S. Department of Agriculture payments to farmers should be associated with established income caps and require adherence to conservation requirements and conservation plans.

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