Addressing challenges at the food–water–energy nexus

by Kaine Korzekwa
A changing climate is making many things different for all those who work in agriculture, from the producers and their families to the Extension specialists and researchers from multiple disciplines. When coupled with a growing world population, the problems seem impossible to solve. The need to conserve energy and water juxtaposed with the need to increase food production seem at odds and make us wonder if it’s even possible to do both.

But solutions are possible, and researchers that integrate multiple areas into the food–water–energy nexus approach have some ideas. These ideas, however, require creative solutions and collaboration between everyone touched by agriculture.

There are many avenues to pursue this problem. For ASA–CSSA–SSSA Fellow Jerry Hatfield, a laboratory director with the USDA-ARS, it all comes down to soil.

“If you look at the food–water–energy nexus, the foundation of that is really soil,” he says. “And if you go and look at our soil resources today compared with where they were 50 to 100 years ago, we have to admit we have been degrading our soils, largely using practices we deem conventional.”

Midwest corn and soybean cropping systems are losing roughly 1,000 lb carbon acre\(^{-1}\) yr\(^{-1}\), he adds. That loss, along with the depletion of nutrients, is part of what’s making producers’ resource base—the soil—more fragile and sensitive to extreme events like the heavy spring rainfall and dry summers that are becoming the norm.

A fragile soil surface causes it to have poor structural stability, be more compacted, and lack oxygen plants need. When plants experience drought conditions during critical times in the growing season, most importantly the grain-filling period, yields greatly suffer.

“The recent Intergovernmental Panel on Climate Change report told us that land degradation is one of the biggest and most important challenges that humanity faces,” Hatfield says. “Our future food supply, which needs to continually increase, depends upon our soil resource and the water and nutrients it can supply to our crops.”

The problem isn’t just present in the Midwest or the United States. Soils worldwide are degrading over time and experiencing even more extreme weather variations. Degraded soils that result in an inadequate food supply can impact all aspects of life, from nutrition to human migration.

Soil properties, weather, topography, and management combine to impact yield stability, which is the historical trends of crop yields across time. ASA–CSSA Fellow Bruno Basso of Michigan State University’s Department of Earth and Environmental Sciences studies yield stability using artificial intelligence and big data.

“The frequency of extreme climate events, such as precipitation intensity, flooding, heat waves, and droughts, is thought to be increasing as a result of climate change and global warming,” he explains. “This can lead to lower yields, thus less food for a growing population, increased losses of fertile topsoils through surface runoff, water and wind erosion, losses of soil carbon from a lower amount of crop residues returned to the soil, shorter growing cycles, more invasive species, weeds, and pests.”

Two Strategies: Adaption and Mitigation

Researchers have defined two parallel strategies to tackle these problems given climate change and a growing population: adaptation and mitigation. In this context, adaptation is something that can be done short term to address the impacts of climate change while mitigation can help deal with the causes of climate change in the longer term, Basso explains.

This “nexus approach” is the lens through which Basso and Hatfield approach their research. Derived from the Latin word “nectere,” meaning to tie, bind, or connect, nexus points to an integrated systems approach that first tries to understand the connections, synergies, and trade-offs between different parts of the agroecosystems with multiple and often conflicting objectives. Designed to provide solutions to policymakers and stakeholders, it works to address the challenges posed by positive synergies and conflicting trade-offs.

“You look at the problems we face and realize the importance of having the most efficient production in terms of our light, soil, water, and nutrient resources and trying to bring all of those things together,” Hatfield explains. “It’s a challenge for all of agriculture, not just agronomists, plant breeders, soil fertility specialists, researchers, and others. It’s a systems problem that has to do more than answer ‘how much can we produce?’ We have to think about how efficient we can be in using the resources we have to ensure the long-term stability of the three components: food, water, and energy.”

Basso and Hatfield—and other researchers working in the food–water–energy nexus—develop and research solutions to tackle these issues, many of which show positive results. Critical to their work are direct partnerships with producers.

Hatfield, for example, works with farmers in Iowa and across the Midwest to try new management techniques and test their effectiveness. He helps producers adopt practices like no-till, cover crops, and diversification of rotations. Fields that practice cover crop and no-till experience a positive carbon balance and very quick soil improvement, he says. Within two years, they’ve seen a doubling of the microbial biomass in the upper 12 inches of soil.

In a laboratory study, a cover crop cocktail greatly increased microbial biomass and activity compared with a monoculture cover crop or no cover crop. This led to increased productivity, nutrient availability, and yield of crops coming off of those soils in the lab. It also improved soil quality characteristics such as soil aggregate.
stability. Hatfield and his team are excited to test this in the field.

"Coupling our laboratory work with field trials and then ultimately in partnerships with producers is very powerful," he says. "Working with producers gives us access to long-term yield monitor data, some even dating back to 2003. We can look at that data and how it’s related to the soils within that field and see what’s really going on. In much of our work, yields improve and become more uniform. It’s when we are able to show that and lay it out in front of folks that they begin to understand what we are trying to do and how all these dynamics work together."

Balancing Food Production with Energy Conservation

Basso also says it is possible for society to balance food production with energy conservation. Other actions that can help include reducing food waste pre- and post-harvest, producing more food where it is needed, expanding the production of bioenergy crops on marginal lands, and using advanced digital agriculture technologies to reduce the application of wasteful inputs in areas of no response. For example, some of his most recent work showed that 25% of the area of agricultural fields in the Midwest have consistently low productivity with little response to inputs like fertilizer.

His work in digital agriculture and big data is useful for studying interactions among food, water, and energy. Artificial intelligence, or better, he says—agricultural intelligence—techniques offer the capacity to analyze data at a high magnitude. Tractor-mounted GPS, drones, and other tools can track data on everything from spatial-temporal variations in yield stability to inputs like seed, water, fertilizer, and agrochemicals.

Combining all of this data can increase use efficiency and reduce waste. When data from each part of the nexus are gathered and analyzed, solutions arise that don’t solely prioritize one over the other, the researchers say.

"I believe there is still a significant amount of research in agronomy that does not fully capture interactions and synergies of the soil–plant–atmosphere continuum," Basso says. "Field-based research needs to be integrated with systems research in order to increase our ability to cost-effectively transfer technologies over different space and time scales."

Addressing challenges at the food–water–energy nexus will require region-specific solutions and policies as well as global ones. Colder areas may experience more frost-free days that extend the growing season, but climate change will still bring extreme weather events, for example. On a larger scale, policies should specifically aid to conserve and enhance biodiversity.

There is also a need to promote approaches and financial markets that reward beneficial agricultural practices and products, both Basso and Hatfield say. A common pushback to diversifying crop rotations, for example, is a lack of market demand for certain crops, so they say this must also be part of the conversation.

"The farmers’ role in accomplishing these lofty goals is critically important,” Basso says. “Thus, policymakers must help shape agriculture to allow farmers to be economically viable while satisfying the community needs and the environment at large.”

Hatfield says that he hopes their work leads to a mind shift from a traditional “genetics by environment” approach to one of “genetics by environment by management.” Because it’s the farmers that do the management piece, it’s critical to include them in the process and also look at the soil as part of the environment, he says.

"When we begin to restore the soil by using this nexus approach, we see an improvement in quantity of food but also the quality, such as higher protein, oil, and micronutrient content,” Hatfield says. “Our whole goal is to take agriculture to the next level in terms of efficiency and yield stability, so we can benefit farmers and the growing population but also the environment as we continue to address our changing climate.”