US SUSTAINABILITY ALLIANCE

Water Stewardship in U.S. Agriculture: Innovations for a Changing Climate

A U.S. Sustainability Alliance Insight Paper

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Executive Summary

American farmers are engineering a quiet revolution in water management. Facing mounting pressure from climate volatility, water scarcity and rising input costs, producers across the United States are deploying innovative technologies and management practices that are measurably transforming how the nation grows its food. This is not a story of regulatory compliance or incremental efficiency gains. It is a story of producer-led innovation with measurable environmental and economic returns.

From precision irrigation systems that apply water with surgical accuracy to plants bred for drought resilience, from on-farm reservoirs that capture and reuse every drop to soil management practices that increase water-holding capacity, U.S. farmers are proving that resource constraints drive creativity. The results speak for themselves: water use reductions of 20-40% in many operations while maintaining or increasing yields, improved water quality through reduced runoff, enhanced soil health and greater farm profitability.

This paper examines the innovation ecosystem enabling this transformation and profiles producers who are achieving quantifiable results. Their stories demonstrate that sustainable intensification is not a theoretical concept but a practical reality unfolding across American farmland today.

Section One: The Innovation Catalyst

Water has always been agriculture's most essential input, but the relationship between American farmers and this critical resource is entering a new chapter. Three converging forces are catalyzing unprecedented innovation in agricultural water management:

1. Climate Volatility as the New Normal

The predictable patterns that guided planting decisions for generations are giving way to dramatic swings between deluge and drought. California almond farmer Christine Gemperle captures the challenge succinctly: "Climate change is real. We've moved into this pattern of weather where we're seeing either feast or famine, so we could have a year with 200% of normal rain and then it could be followed by three years of drought." This volatility demands management systems capable of maximizing capture during abundant periods while stretching limited supplies through dry spells.

2. Economic Imperatives

Rising energy costs, increasing water prices in markets where it's traded and growing competition for water from urban and industrial users are making inefficient irrigation economically untenable. At the same time, the cost-performance ratio of precision agriculture technology has reached a tipping point. What once required six-figure investments and specialized expertise can now be implemented more cheaply and more simply. The economics increasingly favor innovation over the status quo, making water efficiency a business necessity rather than a discretionary investment.

3. Technology Convergence

Modern water management draws on advances in different areas. Satellite imagery and remote sensing, wireless sensor networks, data analytics and artificial intelligence, GPS precision guidance and advanced materials science all play a part. When combined with traditional agronomic knowledge and producer ingenuity, these technologies enable precision in water management that was unimaginable a generation ago. Farmers can now monitor soil moisture in real-time, predict crop water needs days in advance and provide irrigation with zone-specific accuracy measured in inches rather than acres.

The result is a fundamental shift in mindset. Water management is no longer about applying as much as possible as easily as possible but about applying exactly what's needed exactly where and when it's needed. This transformation is being led not by regulators or researchers, but by farmers themselves, driven by the twin imperatives of economic survival and environmental stewardship.

Section Two: The Innovation Ecosystem

American agriculture's water stewardship transformation draws on an expanding toolkit of solutions ranging from cutting-edge technology to time-tested practices applied to modern challenges. Understanding how these techniques work together requires understanding both their diversity and the synergies between different approaches.

The Landscape of Solutions

Innovation in agricultural water management draws on both high-tech and nature-based techniques. Precision irrigation systems use sensors, weather data and algorithms to optimize application timing and volume. Plant breeding programs develop varieties with enhanced drought tolerance and water use efficiency. Soil health practices including cover cropping and reduced tillage increase water infiltration and retention. Water capture and reuse infrastructure extends limited supplies. Even long-established practices like rendering contribute by converting agricultural byproducts into valuable inputs while reducing water use associated with waste handling and disposal.

These techniques are not mutually exclusive. The most successful operations integrate different approaches tailored to their specific conditions, creating water management systems greater than the sum of their parts. A cotton farmer might combine drought-tolerant varieties with drip irrigation, cover crops and on-farm reservoirs. A rice producer might pair precision leveling with flow meters and recovery systems. The key is matching the right techniques to challenges.

This section highlights two foundational pillars of modern water stewardship: precision irrigation technology and plant genetics. Together, these represent complementary approaches, one optimizing water delivery and the other enhancing how plants use whatever water they receive. Across operations, the most effective water stewardship strategies integrate technology, genetics and soil management into coordinated systems rather than relying on any single solution.

Part A: Precision Irrigation Technology
Insights from Gustavo Oberto, Lindsay Corporation

The Center Pivot Revolution

When center pivot irrigation was introduced in the mid-20th century, it revolutionized agriculture by enabling efficient mechanized irrigation of large-scale farms. Traditional center pivot systems represented a massive improvement over flood irrigation, but they operated on a one-size-fits-all principle. The entire pivot applied the same amount of water regardless of soil variability, crop differences or microclimatic conditions across the field. Modern systems bear little resemblance to their predecessors.

For the Lindsay Corporation, a 70-year leader in irrigation technology, the evolution of center pivot systems reflects a fundamental shift in how the industry approaches innovation. As Gustavo Oberto of Lindsay explains, "We build solutions by farmers, for farmers. That's why it is so important to us that the team building our products and technologies has first-hand knowledge of how those solutions are working in the field." This producer-centric philosophy has driven the transformation from basic mechanized irrigation to sophisticated precision management platforms.

Today's Smart Irrigation Ecosystem

Contemporary precision irrigation integrates different data sources and control technologies. Variable Rate Irrigation (VRI) systems can adjust application rates for individual zones within a field, responding to differences in soil type, topography or crop development stage. Management at field-zone resolution enables farmers to address variability that would otherwise result in over-irrigation in some areas and under-irrigation in others.

The intelligence extends beyond the hardware. Modern irrigation management platforms integrate weather forecasts, soil moisture sensors, satellite-derived crop stress indicators and agronomic models to automate irrigation adjustments. Lindsay's FieldNET Advisor platform, recognized by the American Society of Agricultural and Biological Engineers, exemplifies this integration. As Oberto says, "For 70 years, Lindsay has been a leader in crop and irrigation research, using technology to simplify the science of agronomic irrigation. With our award-winning FieldNET Advisor innovation, we've empowered growers to produce healthier crops, develop more sustainable farming practices and help them maximize yields to increase their bottom line."

The newest generation of center pivot technology represents what Oberto calls "a self-aware, always-there robot in the field, capable of at-scale crop health management and ground-breaking machine health features." These systems don't just apply water, they monitor crop conditions, diagnose their own maintenance needs and adapt to changing field conditions autonomously.

Pictured: Lindsay Corporation's Zimmatic system (credit: Lindsay Corporation)

Remote monitoring and control have become standard. Farmers can check system status, adjust schedules, or respond to alerts from their smartphones regardless of where they are. This connectivity enables responsive management that would be impossible with manual operation and allows producers to react immediately to weather events or crop stress signals rather than waiting for their next field visit.

Economics and Adoption Pathways

The economics of precision irrigation adoption vary considerably based on crop value, water scarcity and farm size. For high-value crops facing water constraints, the return on investment can be compelling. Water savings of 15-30% are commonly achieved, translating to reduced pumping costs and, in water-limited situations, the ability to irrigate additional acres with the same allocation. Yield stability improvements during stress periods provide additional economic value.

Cost-share programs through USDA's Natural Resources Conservation Service (NRCS) and state agencies help bridge the investment gap for many producers. Programs like the Environmental Quality Incentives Program (EQIP) can cover 50-75% of installation costs for qualifying conservation practices, accelerating adoption of water efficiency technologies that deliver long-term benefits but might otherwise face prohibitive upfront costs.

What's on the Horizon

Oberto describes the smart pivot as introducing "the next era of mechanized irrigation. It delivers never-before-seen insights and efficiency to a grower's operation, changing the way they - and the industry - look at and use center pivots."

The next generation of irrigation technology will use artificial intelligence and machine learning to optimize management decisions autonomously. Systems are being developed that learn from outcomes over multiple seasons, continuously refining irrigation strategies for specific fields and crops. Integration with other farm management platforms will enable irrigation decisions to consider factors like nutrient availability, pest pressure, and harvest timing as part of a holistic system.

Oberto says, "Lindsay is committed to providing the latest technology to growers to help scale their organization and maximize yields." Improvements in sensor technology and data analytics will enable even more precise water application while reducing complexity for farmers, making sophisticated water management increasingly simple and intuitive.

Pictured: Lindsay Corporation's Zimmatic system (credit: Lindsay Corporation)

Part B: Plant Genetics & Breeding Innovation

Insights from the American Seed Trade Association

While irrigation technology addresses how water is delivered, plant genetics determines how efficiently crops use whatever water they receive. Decades of breeding progress have generated substantial improvements in crop water use efficiency, and modern genomic tools are accelerating gains. As the American Seed Trade Association (ASTA) emphasizes in its official climate comments to the USDA: "Better seed means better life, and better seed starts with plant breeding."

Breeding for Drought Tolerance

Plant breeders have pursued water efficiency through multiple pathways. Some varieties have deeper, more extensive root systems that access moisture in lower soil profiles. Others have modified leaf characteristics that reduce transpiration water loss while maintaining photosynthesis. Still others show improved stomatal regulation that optimizes the trade-off between CO_2 uptake and water vapor release.

According to ASTA, "Plant breeders have been improving seeds for thousands of years. Thanks to our growing scientific understanding of plant sciences, breeders today can develop better seeds with greater efficiency and precision than ever before. This means more resilient crops that can thrive despite pressures from drought, flooding, extreme temperatures, and evolving insects and diseases. Better seed allows farmers to grow more, using less land and fewer resources and in turn, provides consumers with access to wider varieties of safe, affordable and nutritious foods."

The breeding process traditionally required growing thousands of lines across multiple environments and seasons to identify superior performers under water-limited conditions. Modern genomic tools have dramatically accelerated this timeline. Molecular markers linked to drought tolerance traits enable selection of promising lines at the seedling stage rather than waiting for field performance data. Gene editing technologies offer the potential to introduce specific beneficial traits more precisely and rapidly than conventional breeding alone. As ASTA notes, "evolving breeding innovations like gene editing hold tremendous promise for unlocking solutions to some our most pressing global challenges, from climate change mitigation to food security."

Quantifying Genetic Gains

The cumulative effect of breeding progress is substantial, with modern varieties producing significantly more yield per unit of water than those available one to two generations ago. In corn, water use efficiency improvements have contributed significantly to the historic yield gains achieved over recent decades. Modern hybrids produce more grain per unit of water consumed than varieties from a generation ago. Similar progress has occurred in wheat, cotton, soybeans and other major crops.

Research quantifying these gains shows that genetic improvements in drought tolerance have enabled production expansion into more marginal rainfall environments while stabilizing yields in traditional growing regions during stress periods. These gains complement irrigation efficiency improvements, with drought-tolerant genetics performing particularly well under managed water deficit irrigation strategies.

Matching Genetics to Water Management

The future of agricultural water efficiency lies in integrated systems where variety selection is optimized for specific irrigation capabilities and field conditions. A field with limited water allocation might use a drought-tolerant variety managed under deficit irrigation, while an adequately watered field could use a variety selected for maximum production under optimal conditions. Precision agriculture platforms are beginning to incorporate varietal characteristics into irrigation management algorithms, enabling true integration of genetics and management.

ASTA's mission of "developing better seed, giving producers more accessibility and more variety to feed a growing population in a changing climate" reflects the critical role that plant breeding plays in agricultural water stewardship. A variety bred for full irrigation performs differently than one selected for water-limited conditions. As farmers adopt more sophisticated irrigation management, having genetics tailored to those systems becomes increasingly important for optimizing both water use and crop productivity.

Section Three: Innovation in Action - Producer Case Studies

The true measure of any innovation is its performance in the field. These three case studies showcase American producers who are achieving measurable results through strategic water management. Their experiences offer insights for peers facing similar challenges and demonstrate the diversity of solutions being implemented across different crops and regions.

Case Study One: McCarty Family Farms - Vertical Integration and Water Innovation in Kansas Dairy

The Producer: McCarty Family Farms in Rexford, Kansas, represents four generations of dairy farming innovation. More than 100 years ago, the family started dairy farming in northeast Pennsylvania, milking cows by hand in a small barn without electricity. In 2000, brothers Mike, Clay, Dave and Ken McCarty relocated to northwest Kansas seeking opportunity for growth and sustainability. Today, their operation includes approximately 20,000 dairy cows across five farms in Kansas, Nebraska and Ohio, plus an on-farm milk condensing plant and grain storage facility. The operation employs more than 200 people and has achieved B Corp certification, recognizing high standards of environmental and social performance.

The Challenge: As the operation grew in Kansas, the McCarty brothers faced the dual challenge of managing water resources efficiently in a semi-arid climate and reducing the environmental footprint of transporting large volumes of milk to processing facilities. Traditional dairy operations ship raw milk long distances to processing plants, requiring significant transportation resources and water inputs throughout the supply chain. Additionally, dairy operations in Kansas must manage water carefully, using it for cow hydration, milk cooling, barn cleaning and crop irrigation. The challenge became how to create a vertically integrated system that maximized water efficiency while maintaining economic viability and animal welfare.

The Innovation: In 2012, McCarty Family Farms took a pioneering step by building an on-farm milk condensing plant - the only one of its kind in North America. This facility processes up to 2.2 million pounds of milk daily, using an innovative evaporative condensing process to extract milk's natural water content before shipping condensed milk to Danone's Fort Worth, Texas plant. The reclaimed water, approximately 100,000 gallons per day, is then reused multiple times across the operation.

The water reclaimed from milk condensing follows a carefully managed cycle. It first cools freshly harvested milk from 101°F to 38°F. The same water is then provided to cows as safe drinking water. After consumption, the water used to flush manure from barns becomes enriched with natural nutrients. This nutrient-rich water is ultimately applied to crop land for irrigation, closing the loop.

Beyond the condensing plant, McCarty Family Farms implements comprehensive water management practices. Precision irrigation systems utilize Variable Rate Technology (VRT) and real-time soil sensors to optimize water application for crop production. These systems ensure water and nutrients are applied at agronomic rates that maximize crop productivity while protecting surface and groundwater resources. The operation follows strict Nutrient Management Plans (NMPs) developed in partnership with environmental consultants to utilize nutrients from manure effectively, reducing the need for commercial fertilizers while protecting water quality.

Regenerative agriculture practices enhance the system's water efficiency. Cover cropping, reduced tillage and organic matter additions improve soil structure and water-holding capacity. By returning manure to fields, the operation improves soil's ability to retain water and reduces runoff. These soil health improvements create a foundation for more resilient crop production with reduced irrigation requirements.
The operation's commitment to water stewardship earned recognition as a Kansas Water Technology Farm, acknowledging their leadership in implementing science-backed water conservation solutions.

Pictured: Mike, Clay, Dave and Ken McCarty (credit: McCarty Family Farms)

Pictured: McCarty Family Farms' dairy herd (credit: McCarty Family Farms)

The Outcome: The integrated water management system gives measurable environmental and economic benefits. The milk condensing plant alone reclaims approximately 100,000 gallons of water per day for reuse, dramatically reducing freshwater withdrawal needs. By condensing milk on-site, the operation reduces milk shipping volume by 75%, putting significantly fewer trucks on roads and reducing transportation-related greenhouse gas emissions while simultaneously capturing water for productive reuse.

The multiple-use water system maximizes value from each gallon. Water that cools milk, hydrates cows, cleans facilities and irrigates crops represents a closed-loop approach that would be impossible in a traditional dairy operation. Economic benefits include reduced freshwater pumping costs, less use of commercial fertilizers through effective nutrient management, and improved crop productivity from enhanced soil health.

The operation's sustainability achievements extend beyond water management. They produce 30% more milk per cow with fewer resources while improving animal health and longevity. They became the first farm globally to achieve the highest animal welfare status from Validus. Carbon footprint analysis completed in partnership with Danone provides benchmarks for continuous improvement across all environmental metrics.

The Insight: McCarty Family Farms demonstrates that vertical integration can enable water management approaches impossible in traditional supply chains. By processing milk on-farm rather than shipping it raw, the operation gains access to a water resource — milk's natural water content — that would otherwise be unavailable for reuse. This creates entirely new opportunities for water efficiency.
As Ken McCarty notes, the operation's philosophy centers on continuous improvement. "We're young and ambitious and looking for additional environmental sustainability initiatives, which are always either underway or being planned." This way of thinking drives the operation to view each challenge as an opportunity for innovation rather than a constraint.

The partnership model with Danone has been crucial to enabling these investments. The cost-plus business relationship provides pricing stability that allows for long-term investments in sustainability infrastructure like the milk condensing plant. "Creating jobs that are sustainable is key to the future of areas like rural Kansas and the agricultural community," Ken McCarty emphasizes. The environmental and economic objectives reinforce each other when supply chain partners share sustainability goals.

The operation's success shows that water stewardship in animal agriculture requires thinking beyond individual practices to system-level integration. Water used for one purpose becomes the resource for the next purpose. Nutrients in water become crop fertilizer rather than potential pollutants. Soil health improvements reduce future water needs. Technology enables precision management, but the real innovation lies in designing systems where each component enhances the others.

For dairy operations facing water constraints or seeking to improve sustainability performance, McCarty Family Farms demonstrates that significant gains are achievable through strategic innovation, willingness to challenge conventional supply chain models, and commitment to managing water as a precious resource.

Pictured: McCarty Family Farms (credit: McCarty Family Farms)

Case Study Two: Christine Gemperle - Adaptive Water Management in California Almonds

The Producer: Christine Gemperle is a second-generation almond farmer who, with her brother Erich, farms 135 acres across two orchards in California's Central Valley. Their father immigrated from Switzerland in the 1960s and started almond farming in the early 1970s. After earning a master's degree in fisheries biology and working on salmon conservation, Gemperle returned to farming, and she and Erich established Gemperle Orchards in 1997. They handle day-to-day operations themselves, with help from family during harvest. The 40-acre orchard in Ceres draws water from the Tuolumne River and groundwater, while the 93-acre orchard in Gustine, on the west side of the San Joaquin Valley, faces particular difficulties with salinity and federal water allocations.

The Challenge: In spring 2013, Gemperle opened a letter that made her panic. California was two years into what would become the state's worst drought in recorded history, and she had already experienced steady reductions in irrigation water allocations from Shasta Lake reservoir. The letter informed her she would receive just 20 percent of the water she typically needed for the Gustine orchard. She said: "When you first get that news, you kind of put your head in your hands. You sit there and breathe, and you're like, 'Okay. What are we going to do?'"

California's Central Valley is one of the few places globally with the climate needed to grow almonds. The state produces more than 80 percent of the world's supply. While drought was always part of life in California, this was different. Climate change was driving up temperatures, increasing evaporation from reservoirs and soil and reducing snowpack to historic lows. For permanent crops requiring 25–30-year investments, the drought represented a warning sign of things to come.

Pictured: Christine and Erich Gemperle in Germperle Orchards (photo: Matt Hannon)

The Innovation: Faced with severe water restrictions, Gemperle tried a variety of adaptations. During the 2012-2016 drought, she achieved 20% annual reductions in water use while protecting her investment in prime-age trees.

In her first year, she simply reduced water application. The second year became more strategic as she worked with researchers to implement deficit irrigation, applying water only when absolutely critical. Under this approach, irrigation generally doesn't begin until April, as trees can pull residual moisture from soil until then, with water most needed when nuts are forming. This strategy allowed Gemperle to understand how water behaves in soil and maximize efficiency of available supplies. While the approach reduced overall almond crop slightly, the trees weren't damaged and she didn't lose her entire investment to drought.

Infrastructure investments proved essential. After a difficult water year in 2007, the family made the costly changeover from flood to micro-irrigation at the Ceres orchard. This expensive but highly efficient system helped them survive the subsequent 2012-2016 drought. At the Gustine orchard, where federal water allocations were cancelled and salinity presented additional challenges, they installed an advanced micro-drip system delivering mists of water directly to each tree, supplemented by recycled municipal water.

Gemperle also gave over part of her farm to a 20-year UC Davis experiment breeding robust almond trees better adapted to local conditions. The research helped her select new tree generations that tolerate her soil's salinity. Researchers also put the farm on a water budget, revealing she had been irrigating too early in the season.
Cover crops became another key innovation. She said: "Over time, the soil became richer and retained water better. Cover crops created resilience for her trees and allowed them to better handle dry weather."

Most recently, Gemperle participated in an innovative groundwater recharge pilot program. During California's January 2023 storm series, her orchard intentionally flooded with storm runoff, allowing water to percolate into aquifers. "I used mostly TID [Turlock Irrigation District] surface water for my allocation this summer, and a few times I pumped water from the well to subsidize," she explained. "But I figure with this recharge, I've put back twice as much as I pumped out … and that feels good to be a net benefit to the aquifer in my little world."

When aging trees died in a recent dry year, Gemperle prepared to replant 92 acres with an integrated approach: chipping old trees to improve soil and increase water-holding capacity, installing what she called the "Cadillac of irrigation systems" for super-targeted efficiency, and planting cover crops to enrich soil before establishing the next generation of trees.

Pictured: Christine Gemperle in Germperle Orchards (photo: Matt Hannon)

The Outcome: The integrated water management strategies have enabled Gemperle Orchards to survive California's most severe droughts while maintaining economic viability. During the 2012-2016 drought, each year her orchards used 20% less water, achieved primarily through innovative conservation. The deficit irrigation strategy, while reducing crop size slightly, protected the long-term investment in trees and orchard infrastructure.

The micro-irrigation systems provided critical flexibility during water restrictions. The groundwater recharge participation demonstrated agriculture's potential as part of regional water solutions, with Gemperle returning more water to aquifers than she extracted. Soil health improvements from cover crops and whole orchard recycling create resilience for handling future climate variability.

Gemperle's broader perspective on water conservation is informed by her fisheries biology background. "I'm always thinking about how we can conserve better, and how we can save our water. That's always at the forefront of my mind. I thought, 'why not do it where I can do it,' because it's important! I've watched the water supply arguments and roadblocks and challenges for years. I'm going to do something. Maybe it's just little me, but maybe it grows into something bigger and greater."

The Insight: Gemperle frames water management challenges as signals requiring constant adaptation rather than insurmountable obstacles.

Her experience demonstrates that surviving California's climate extremes requires multiple overlapping strategies rather than single solutions. Efficient irrigation infrastructure provides immediate water savings. Deficit irrigation and precise timing optimize what water is available. Soil health practices build resilience. Research partnerships identify better-adapted genetics. Participation in large-scale initiatives like groundwater recharge positions agriculture as part of regional solutions.

"I guess I've resigned myself that I'm going to adapt to climate change … it may work and it may not," she said. Her willingness to experiment, invest in innovation, and collaborate with researchers exemplifies the adaptive mindset enabling California almond farmers to maintain productivity despite intensifying water constraints: "It's about finding balance."

For permanent crops facing decades of climate uncertainty, that balance requires continuous learning and evolution of water management practices.

Pictured: Honeybee on almond blossom (credit: University of California)

Case Study Three: Scott Matthews - Precision Water Management as Mathematical Optimization

The Producer: Scott Matthews farms in Weiner, northeast Arkansas, where his family has been farming for approximately 120 years. He grows rice and soybeans in rotation on approximately 1,800 acres. Matthews represents generations of accumulated water management **knowledge which he applies through modern precision technology.**

The Challenge: Over Matthews' three decades of farming, his region has changed from having abundant water to being designated a critical groundwater area, meaning the aquifer is depleting at worrying rates. Rice traditionally involves substantial water runoff from fields — a practice that wasn't considered problematic when water was plentiful and inexpensive. As water availability declined and costs rose, what was once standard practice became both economically and environmentally unsustainable.

The Innovation: Matthews's approach to water conservation evolved systematically over years, with each improvement opening doors to further innovations. The foundation was building reservoirs and a tailwater recovery system. When irrigating rice or soybeans, water flows into the tailwater recovery system and returns to reservoirs for reuse rather than leaving the farm. This closed-loop system captures water that would otherwise be lost.

Precision leveling came next. "Our ground is naturally flat, but it still has to be flooded and one of the techniques we have adopted is called precision leveling, where the ground is mechanically leveled to a grade," Matthews explained. Beyond reducing water requirements, precision leveling enabled adoption of more advanced technologies. Multi-inlet rice irrigation (MIRI) represented the next evolution. After precision leveling, Matthews noticed fields were still "cascading the flood" — water was flowing from top to bottom through each field sequentially, which wasn't as efficient as it could be. MIRI uses poly tubing running along field edges to distribute water more uniformly, but implementation requires precise calibration.

Pictured: Scott Matthews (credit: Farm Progress)


Pictured: Scott Matthews' farm (credit: Scott Matthews via USSA)

"To ensure that we're using precisely the right amount of water, we take a number of different measurements as part of our math equation," Matthews explained. These measurements include overall field area, area of each paddy and levee and flow rates in gallons per minute from flow meters attached to water sources. GPS technology provides accurate field measurements, while more recently, drone technology has added another dimension. "The drone not only helps us to get the acres even more exact, it also measures elevation," Matthews said. Post-harvest, drone elevation data is overlaid with yield maps to identify any spots not being watered efficiently. He continued: "If we find a spot in a field that's not getting watered efficiently, even though it has been graded, we'll go back and correct that problem as soon as we possibly can to increase the overall yield of that field."

Understanding rice's specific water functions guides Matthews' management. Water serves dual purposes. Approximately eight weeks after planting, a nitrogen application is followed immediately by flooding to push nitrogen down and hold it in place. The flood then suppresses weeds by acting as an oxygen barrier that prevents weed seed germination, protecting crop quality at harvest and during milling.

The Outcome: The integrated system has achieved remarkable results: 40% reduction in water use, with Matthews noting "it will only get better." Perhaps most significantly, runoff during the growing season has become rare. "Thanks to our irrigation practices, it's very rare that we run water out of the field during the growing season, which has been one of the greatest benefits." The efficiency improvements have been so substantial that the tailwater recovery system now receives less water than originally anticipated because there's simply less runoff to capture.

Beyond water quantity, the economic benefits are clear. Reduced water application translates directly to lower pumping costs in a critical groundwater area where water is both scarce and expensive. Improved irrigation efficiency contributes to better yields through more uniform water distribution and optimized nitrogen placement. The drone-enabled yield mapping and elevation analysis create a feedback loop for continuous improvement, identifying and correcting inefficiencies that might otherwise persist unnoticed.

The Insight: Matthews frames water management as an ongoing optimization challenge rather than a solved problem. "I'm never satisfied. I always think that we could and should be doing more to be good stewards." This mindset of continuous improvement drives incremental gains that compound over time. "For me, it's all about achieving better irrigation efficiency in a critical groundwater area. I know it's a lot of work and a lot of technology. But any time we can improve by just one percent, it's going to make a difference to our costs and our yields."

His approach to irrigation reflects a broader philosophy. Water management isn't about applying more or less based on intuition but about calculating precisely what's needed and delivering exactly that amount. Each field becomes a system of variables—area, elevation, soil characteristics, water flow rates—that can be measured, analyzed, and optimized. Technology provides the measurement tools, but success requires understanding the agronomic principles underlying the equations.

In a critical groundwater area facing long-term water availability challenges, Matthews' approach shows that dramatic conservation gains are achievable when producers combine understanding of crop physiology, precision measurement, mathematical optimization and commitment to continuous improvement. Every year brings changes to conserve soil or water, reflecting the philosophy that stewardship is not a destination but an ongoing responsibility.

Across all three case studies, common themes emerge: closed-loop water systems, precision measurement, integration of multiple practices, and a continuous improvement mindset. Together, these illustrate that the largest water savings come not from single technologies, but from system-level redesign.

Matthews's experience also demonstrates how conservation innovations build sequentially. Reservoirs and tailwater recovery captured wasted water. Precision leveling reduced water requirements and enabled multi-inlet irrigation. MIRI improved distribution uniformity. Flow meters quantified application rates. GPS and drones provided precise spatial data. Each technology amplified the benefits of previous investments, creating a management system far more efficient than any single practice could achieve alone.

Pictured: Scott Matthews' farm (credit: Scott Matthews via X)

Section Four: Public-Private Partnership

While producer ingenuity drives water management innovation, public programs play a crucial role in accelerating adoption and scaling solutions across the agricultural landscape. The partnership between farmers and the USDA's Natural Resources Conservation Service exemplifies how strategic public investment can leverage private innovation to deliver environmental outcomes.

NRCS Conservation Programs

The Environmental Quality Incentives Program (EQIP) and other NRCS initiatives provide financial and technical assistance to agricultural producers implementing conservation practices. For water management, this includes cost-sharing for irrigation system improvements, water measurement and monitoring equipment, structures for water capture and storage, and precision agriculture technologies that enhance water use efficiency.

These programs do more than simply reduce upfront costs. They provide technical standards ensuring implemented practices achieve intended conservation targets. They connect producers with expertise and peer networks that accelerate learning. They create data documenting performance and impact that builds the knowledge base for continuous improvement.

The programs explicitly recognize that environmental benefits and economic viability must align for conservation to succeed at scale. By improving the economics of adoption, cost-share programs enable producers to make investments that bring long-term benefits but might otherwise face capital constraints or extended payback periods.

Accelerating Innovation Adoption

The impact of these partnerships is visible across agricultural regions. Areas with active NRCS engagement show more rapid adoption of water-efficient practices than similar regions without program presence. Producers who participate in cost-share programs often become local leaders in water stewardship, sharing their experiences and demonstrating results to peers.

As water challenges intensify, the importance of these public-private partnerships will only grow. Scaling water stewardship across millions of acres of American farmland requires resources beyond what individual producers or even agricultural industries can provide alone. Strategic public investment that uses and accelerates private innovation represents an efficient model that can achieve nationwide results.

Section Five: Strategic Implications

The water management transformation underway in American agriculture extends far beyond individual farm benefits. It carries strategic implications for U.S. competitiveness, sustainability leadership and climate resilience.

Global Competitiveness and Sustainability Credentials

As international markets increasingly prioritize sustainability attributes, American agriculture's water stewardship makes it more competitive. Buyers and consumers globally are scrutinizing environmental performance of supply chains. Demonstrable progress in water efficiency strengthens the sustainability credentials of U.S. agricultural products in premium markets where these attributes command value.

This matters particularly as agricultural exporters compete on more than just price and quality. The ability to document responsible water management through metrics, certifications and transparent reporting becomes a market advantage. American producers implementing sophisticated water stewardship are well-positioned to meet evolving buyer expectations and access markets where sustainability is a prerequisite for participation.

Water efficiency → **Climate resilience** → **Trade competitiveness**

Climate Resilience and Adaptation

Water management innovation directly enhances agricultural resilience to climate extremes. As rain patterns become less predictable and extreme weather events more frequent, farming systems with sophisticated water management capabilities will better withstand stress periods while capitalizing on favorable conditions.

This resilience benefits individual farms through reduced production risk and more stable profitability. It benefits regions by sustaining agricultural productivity even as climate conditions shift. It benefits the nation by maintaining reliable food production capacity despite increasing environmental volatility. In essence, water stewardship innovation represents practical climate adaptation that is already achieving results in farmers' fields.

Technology Leadership and Innovation Ecosystem

The precision agriculture and water management technology sector represents a significant economic opportunity beyond farm-level benefits. U.S. leadership in agricultural technology innovation creates export opportunities for equipment, software and services. It sustains rural manufacturing and technology jobs. It establishes U.S. standards and platforms that shape global agricultural development.

Maintaining this leadership requires continued innovation and adoption. The producer-led demand for more sophisticated water management drives private sector R&D investment. Public research institutions contribute foundational knowledge. The resulting innovation ecosystem positions American agriculture at the technological frontier while generating economic activity throughout rural communities.

Water as Competitive Advantage

Regions and producers who proactively advance water stewardship gain themselves an advantage as water constraints tighten. In areas facing water scarcity, efficient use becomes vital for maintaining production. In regions still water-abundant, proactive stewardship builds social license to operate and can avoid restrictive regulation.

The strategic imperative is clear. Water management excellence provides competitive advantage at different levels, from market access to operational resilience to regulatory positioning. Producers and regions that lead this transformation will be best positioned for long-term success as water becomes an increasingly critical factor in agricultural competitiveness.

Conclusion

American agriculture is experiencing a water management revolution, but the transformation is just beginning. The producer case studies in this paper demonstrate what's possible when innovation, technology and agronomic expertise converge. Measurable results are being achieved: 20-40% reductions in water use, maintained or improved yields, enhanced environmental outcomes, stronger farm economics. These are not projections or pilot studies but results on working farms today.

What's Working

Several factors enable this success. Technology has reached price points and usability levels that make sophisticated water management accessible to mainstream producers, not just early adopters. Economics increasingly favor efficiency as water costs rise and environmental expectations grow. Public programs provide strategic support that accelerates adoption. Perhaps most importantly, farmers themselves recognize water stewardship as both an environmental imperative and a competitive advantage, driving demand for solutions and willingness to embrace change.

The integration of different approaches, from irrigation technology to plant genetics to soil health practices, creates synergies that give results exceeding what any single practice could achieve. This holistic thinking, evident in all three case studies, represents a maturation of water management from applying inputs to managing complex, interconnected systems.

What's Needed to Scale

Translating these successes from thousands of farms to millions of acres requires the addressing of several challenges. Continued advances in technology must focus on reducing complexity and cost while improving performance. Data integration across platforms remains fragmented and producers need seamless systems that unify information from different sources into insights they can act on. Technical assistance capacity must expand to support more producers implementing sophisticated practices.

Investment in water infrastructure, both on-farm and regional, needs to accelerate. Reservoirs, distribution systems, reuse facilities and measurement infrastructure require capital that many producers and water districts struggle to access. Innovative financing mechanisms and expanded public programs can help bridge this gap.

Knowledge sharing and peer learning networks accelerate adoption more effectively than any other mechanism. Expanding platforms for producers to share experiences, compare results and learn from both successes and failures multiplies the impact of every innovation. Organizations like the U.S. Sustainability Alliance play a crucial role in facilitating these connections.

The Path Forward

Water stewardship in American agriculture is not a single destination but a continuous journey of improvement. Climate change ensures that yesterday's techniques must evolve for tomorrow's conditions. Technology advancement creates new possibilities requiring ongoing learning. Market demands and social expectations continue to raise the bar for environmental performance.

Yet the trajectory is clear. American farmers are proving that agriculture can prosper while reducing resource consumption, that economic and environmental objectives can align, that innovation arises from necessity. The water management transformation underway today is securing American agriculture's productivity and competitiveness for decades to come while demonstrating global leadership in sustainable intensification.

The producers profiled in this paper are not outliers but vanguards. Their innovations will become tomorrow's standard practices as technology improves, economics evolve and peer learning spreads knowledge. The future of American agriculture is being written today in farmers' fields, one drop at a time, by producers who understand that water stewardship is not a constraint on success but a foundation for it.

Freshwater represents less than 3% of Earth’s water, yet agriculture remains the largest global user of this limited resource. As the world approaches ten billion people by 2050, the challenge of producing more food with less water grows increasingly urgent. Through the innovations presented, American farmers are demonstrating how that challenge can be met and are offering not only inspiration but practical, scalable models for agricultural water stewardship worldwide. This is American agriculture at its best: innovative, resilient, productive, and sustainable. Scaling these successes will require coordinated action among producers, technology providers, researchers, and policymakers to reduce barriers to adoption, expand technical assistance, and invest in both on-farm and regional water infrastructure.

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