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The cover image is aerial view of University of Minnesota East and West Bank campuses and the Mississippi River. Photographer Patrick O'Leary. Image via University of Minnesota.

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Editors

Contact Us

Open Rivers
Institute for Advanced Study
University of Minnesota
Northrop
84 Church Street SE
Minneapolis, MN 55455

Telephone: (612) 626-5054
Fax: (612) 625-8583
E-mail: openrvrs@umn.edu
Web Site: http://openrivers.umn.edu

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FEATURE

AGRICULTURE AND THE RIVER: THE UNIVERSITY'S ROLE IN SOCIETAL LEARNING, INNOVATION, AND ACTION

By Nicholas R. Jordan, Carissa Schively Slotterback, David Mulla, and Len Kne

Rivers are critical connectors across our communities, states, and national boundaries. They offer essential benefits in the form of drinking water, recreation, transport, food, and

Eroded stream and river banks allow excess sediment — primarily clay and silt — into waterways. Sediment is considered a contaminant and contributes to cloudy, murky water, which degrades habitat for fish and aquatic life. Image via MPCA Photos, Flickr.

aesthetics. At the same time, human activities, from agriculture to urban land use, affect rivers profoundly. The stewardship of rivers is a complex problem: rivers must meet many needs of society, which often conflict, and all sectors of society need to be involved in finding solutions. We believe that universities, especially land-grant universities such as the University of Minnesota, are well positioned to play a distinctive and necessary role in addressing these complex problems of rivers, stewardship, and water. In this article, we identify some of these problems and the approaches that University of Minnesota researchers and community partners are taking to address them, including discussion of the "The Forever Green Initiative" and the New Agricultural Bioeconomy Project.

Among the many urban and rural activities that affect the Mississippi River, agriculture is one of the most significant. Water is essential for the growth of crops and animals, of course, but there are many other links. Agriculture requires control of stocks of water stored in soil, and of the flow of water across landscapes. In the river basin, extensive constructed systems provide rapid drainage of precipitation from watersheds, so that soils can warm and dry rapidly in the spring, allowing summer crops to grow. Agriculture and water resources are also linked by their vulnerability to extreme weather events—both droughts and heavy rainfall create challenges—and by the need for rivers to transport products. Therefore, we must think about the future of agriculture if we are to think about the future of the river. In this essay, we argue that the future holds major opportunities for agriculture to improve water resources, if society can seize them.

The agriculture-water relationship—now and in the future—is complicated; it has been marked by polarized debate and controversy in recent years. Complexity, uncertainty, and controversy increase further when possible climate change becomes part of the conversation. Forecasts of climate change in the basin project significant changes in water, including heavier rainfall events, and longer intervals between rains. If these forecasts prove accurate, there will be substantial impacts on both agriculture and water. There is much uncertainty surrounding many of the projected impacts, making it far from clear how agriculture and water systems sectors can and should respond. Yet, food and water are indispensable life-support systems of civilization, and their continued availability—and the health of critical elements of these systems, such as rivers and farm economies—must be ensured. Therefore, the challenge of managing these intertwined life-support systems in a time of potential climate change cannot be ignored. Such complex or "wicked" problems are very difficult for society to manage, because they are intrinsically complex and dynamic, with many interconnected and poorly understood facets in flux. Crucially, different people understand these problems very differently, in terms of their basic nature and potential solutions, making the problems intrinsically controversial.

The University's Role

How can society address wicked problems such as the nexus of agriculture, water, and the river? We believe that all societal sectors must play a role, including private, public, and civil-society sectors, and that universities are positioned to play a distinctive and necessary role. The University of Minnesota can play a central organizing role in addressing these problems. We argue that the university must become fully engaged in these problems, and above all seek to promote society's capacity to cope with their complexity, controversy, and uncertainty. The best coping strategies involve processes of societal adaptation that involve ongoing learning, innovation, and collaborative action. We believe that the university has particular roles to play in all three elements. We briefly sketch the university's roles, and then discuss them in the context of the interconnections among water, agriculture, and climate change.

Learning

In the face of complexity and controversy, identification of pathways forward must draw on principles of transdisciplinarity, meaning that many different knowledge sources and world views must come together to develop and improve understanding. Learning how to work this way must be informed by systemic understanding of factors on many scales and dimensions, and take into account the diverse interests, ethics, experience, history, and capabilities of affected people and communities. Critically, this learning must be deliberative and anticipatory. It must strive to come to judgment about what courses of action should be undertaken for the common good, and it must be prudent in considering possible future scenarios to which society must adapt. Such learning processes are widely seen as critical to the very future of civilization, but capacity to organize and sustain them is scarce at present. Learning must be first organized, and then sustained, as complex problems evolve, with the understanding always incomplete and in need of revision and expansion. We contend that large public universities are almost uniquely capable of initiating, facilitating, and providing ongoing support for the necessary learning.

Innovation

The second critical role for the university is to support innovation linked to learning. Public research universities, such as the University of Minnesota, are able to provide a wide range of support for innovation (spanning technology, knowledge and other human capital, and social/organizational forms of innovation). If the societal learning process envisioned above can identify a particular pathway forward, then the comprehensive university can serve as a central node (or cluster of nodes) in a network of innovation that spans the full range of innovation needed to pursue a pathway forward. Again, we see public research universities as having a unique capacity to organize and integrate the coordinated innovation that is necessary.

Coordinated Action

Implementation of innovations to meet critical societal needs must involve carefully planned and staged activities that test and refine the necessary innovations across social, knowledge, and organizational domains. Public, private, civil-society, and knowledge institutions (like universities) have essential roles in sharing and management of resources and risk. The products of coordinated innovation must prove their legitimacy in economic, legal, political, and cultural domains. A variety of coordination and collective action challenges and tensions must be managed. We contend that the university is the only institution with a compelling interest in supporting the full scope of implementation and coordination work that is needed to address complex opportunities and challenges such as the agriculture/water/river nexus.

Finally, learning, innovation, and coordinated action are not stand-alone processes. Rather all three must be linked together into a larger system that can orchestrate and articulate each of the three, all of which are ongoing simultaneously across a range of scales and domains.

Working for the River: The Forever Green Initiative

Of course, it will be very challenging for the university to address the future of the river by playing the roles outlined above. Each requires significant shifts in some aspects of how the university approaches learning and research. However, we believe that such new roles are best learned by practice. We now turn to a brief portrait of the Forever Green Initiative (FGI), a broad-based project, now in its fifth year but building on many years of groundwork. The FGI is working to play all of the roles described above—learning, innovation, and coordinated action—in relation to the future of agriculture, water, and climate in the Upper Midwest. Based at the University of Minnesota, the FGI is a broad-based project, involving many partners in commercial, research, and conservation sectors. FGI's goal is to substantially increase the quantity and variety of marketable agricultural products produced by Midwest agriculture and thereby to achieve previously unattainable solutions to the state's water-quality challenges. The FGI has been underway, as a formal initiative, for almost five years, funded by both public and private sectors. FGI is organized and governed as a network; currently, it links about 100 faculty, graduate students, and research staff at the University of Minnesota, and many partners in the public, private, and non-profit sectors, and at other universities.

FGI is guided by this widely shared premise: by carefully measured addition of biological diversity to current agriculture, we can sustainably provide food and water to society, and adapt to a changing climate. To support this diversification, FGI is developing a broad portfolio of some 15 winter-tolerant and perennial crops. New breeding technologies are being applied to make rapid improvements in these species, along with new methods for designing sustainable farm production systems, for utilizing the crops in new products, and for "de-risking" potential investments in these crops and technologies for entrepreneurs and investors.

FGI is fundamentally driven by a major new opportunity that is now emerging from agriculture. The agricultural sector is entering a highly dynamic phase, propelled by the emergence of a new, more broadly based agricultural "bioeconomy." This new bioeconomy is building on the strengths of current agriculture by integrating new crops and providing feedstocks for a wide range of new bio-based products. These include a wide range of food, nutrition, health, industrial products, and fuels, propelled by diverse entrepreneurship and technological innovations in processing and manufacturing. In the U.S., the industrial bioeconomy was estimated at approximately $110 billion in 2010, and the economic sector is projected to grow rapidly over the coming decade, with potential to create some 12,000 permanent jobs in Minnesota alone. The emergence of this bioeconomy is also driving increases in total agricultural production: diversifying agriculture with new crops enables substantial increases in total production by making better use of soil, water, nutrients, and solar energy. Together, these increases in the quantity and variety of marketable agricultural products are creating major economic opportunities that are driving rapidly growing investments.

How can these economic trends in agriculture **also** provide a new opportunity to expand and enhance water resources, and thus to improve the health of the river? The opportunity exists because the emergence of the new bioeconomy is creating demand for certain agricultural crops that can be used to **both** provide revenue for farmers and the agricultural sector ***and*** improve water quality. Previously, most farmers were unable to grow many perennial and winter-tolerant annual crops, because no markets existed. Now, emerging markets can provide substantial revenue from these crops, by production of high-value feedstocks for the growing bioeconomy. Water quality improves because these crops enable new land and water management strategies that improve water quality. For example, winter-tolerant annual oil-seed crops such as camelina and pennycress can provide substantial yields of oils suited to many industrial, edible, and fuel applications, while providing water conservation benefits of cover crops. Emerging perennial grass crops such as cordgrass can provide large yields of biomass feedstocks while providing benefits of riparian buffers. Emerging perennial grain crops such as intermediate wheat grass (Kernza) can supply food systems with sustainably sourced ingredients for most food made from wheat. Careful scientific analysis (e.g., MPCA Nitrogen in Minnesota Surface Waters report) has affirmed the potential of these options for addressing water-quality challenges associated with agricultural practices. Indeed, much evidence suggests that extensive and carefully targeted diversification of agriculture with new, revenue-producing crops is the only feasible option for meeting overall water-quality goals for many Midwest states.

Water-quality benefits result because diversification of perennial and winter-tolerant crops increases the coverage and protection of soil, reducing the runoff, erosion, and loss of soil and nutrients that can occur when farmland is not covered by living plants. Our current agriculture is dominated by crops that grow during the summer, requiring large inputs of fertilizer and leaving bare soils for much of the year. By adding perennial and winter-tolerant crops, we can improve water quality because these crops are actively transpiring during most of the year, including many periods in fall, winter, and spring when summer crops are absent. For this reason, perennial and winter-annual crops—working in tandem with summer annuals—can capture solar energy, water, and nutrients with high efficiency. Water quality benefits result because water runoff is minimized, as are losses of soil and nutrients into waterways. In addition, these crops can enhance soils and wildlife, including pollinators, fish, and game. Adding perennial and winter-tolerant crops to our current agriculture—where these will be profitable for farmers and efficiently protect water quality—is a very promising opportunity to address water-quality challenges that affect the Midwest and its rivers. To capitalize on this opportunity, learning, innovation, and coordinated action are needed, as outlined above. The goal is to add crops such as camelina and Kernza to our current agricultural production systems, while also developing profitable markets for these new crops. FGI is working toward that goal.

The New Agricultural Bioeconomy Project

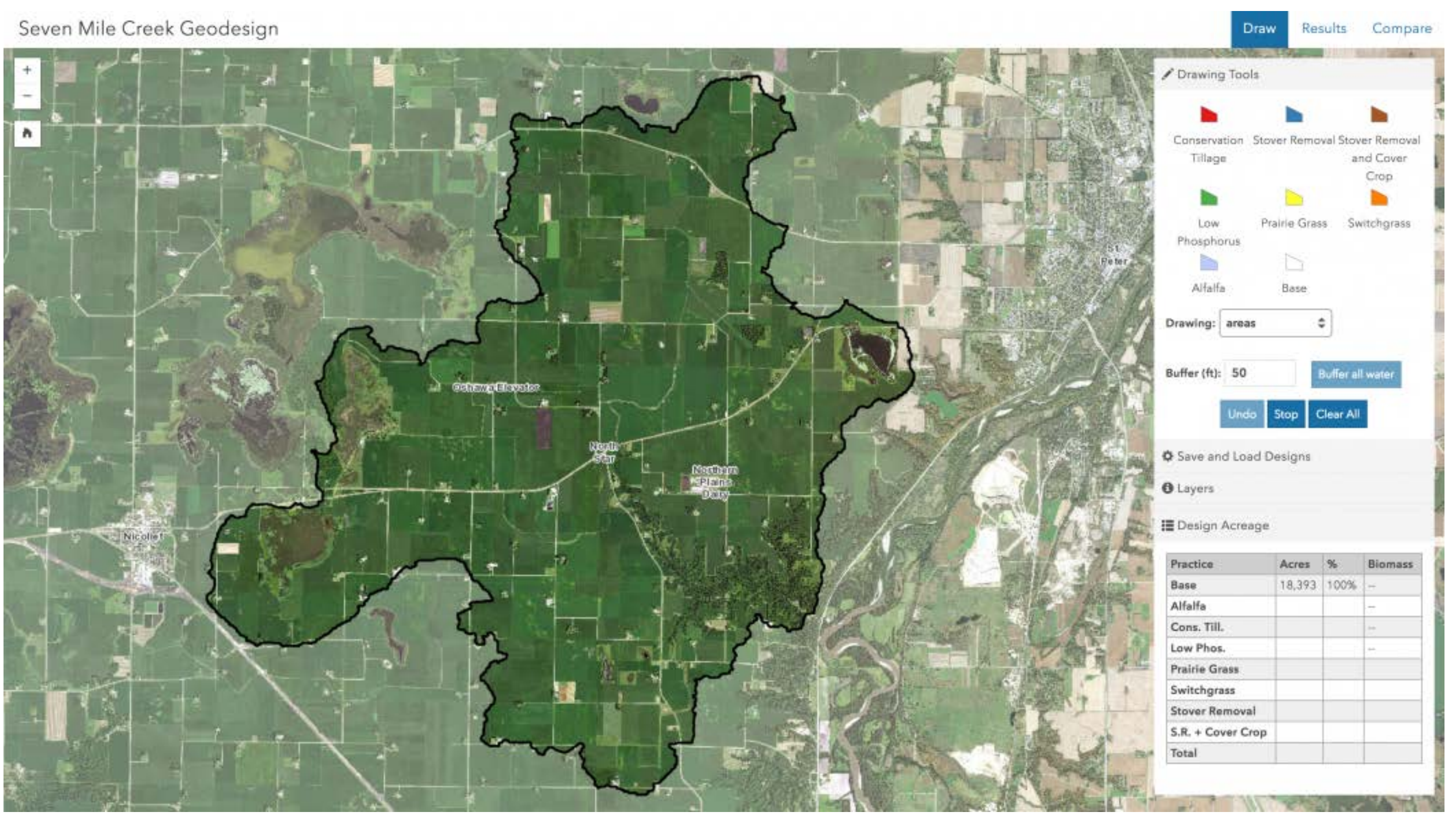
One promising on-the-ground effort that illustrates the FGI approach of societal learning, broad-based innovation, and coordinated action is the New Agricultural Bioeconomy Project. The project is associated with FGI's portfolio of work. It is exploring watershed-scale agricultural scenarios that produce win-win outcomes for the watershed's economy and its water resources. The project is based in the 24,000-acre Seven Mile Creek Watershed in Minnesota, which flows into the Minnesota River and ultimately into the Mississippi River. The project was initiated in 2012 by the University of Minnesota and engages researchers from a wide range of disciplines including agronomy, soil science, urban planning, extension, applied economics, and geographic information sciences. Critically, the project also engages stakeholders from a broad range of organizations, including local communities, state regulatory agencies, agricultural commodity groups, environmental advocacy NGOs, economic development organizations, and farmers. While the project is based in Minnesota, the complexity of issues and stakeholders is representative of many other communities at the nexus of water and agriculture.

In the first stage of this work, the university team convened a diverse stakeholder group and collaborated with them to explore tradeoffs and impacts of food and biomass production on economic value, water quality, carbon

Stakeholders worked in groups to explore potential scenarios for biomass production in the Seven Mile Creek Watershed. A large touchscreen display allows participants to work collaboratively on designs. They are provided with several reference layers to help them decide where to make design choices. Image courtesy of Carissa Schively Slotterback.

sequestration, and habitat. Thus far, the university team, including but not limited to the authors of this essay, facilitated a two-phase collaborative stakeholder process that included an initial exploration of stakeholders' values and broader trends that will shape the future of agriculture and environment in the coming years. Using well-established approaches to facilitating collaboration among stakeholders representing diverse perspectives, the university team engaged stakeholders in jointly exploring potential design strategies that could be applied to the landscape in order to achieve outcomes that were both economically viable and environmentally beneficial. This joint exploration shows what broadly inclusive societal learning processes look like, on the ground. The groups arrived at strategies that were perceived by most participants, across the range of participating sectors, as enhancing the common good for the region by enhancement of current agricultural land use.

The stakeholders then had the opportunity to shift to a second, innovation-focused stage, which built upon the design strategies they had produced. To begin this stage, participants were invited to engage in an intensive process of design thinking. In this process, participants worked to design carefully diversified landscapes that used perennial and winter-hardy crops to enhance total agricultural production in the watershed, add value to current crop production, and to expand and enhance water resources (and soil and wildlife as well). This shift enabled the group to identify innovative landscape designs that could enhance both the regional farm economy and regional water resources. These accomplishments of the group were enabled via geodesign,

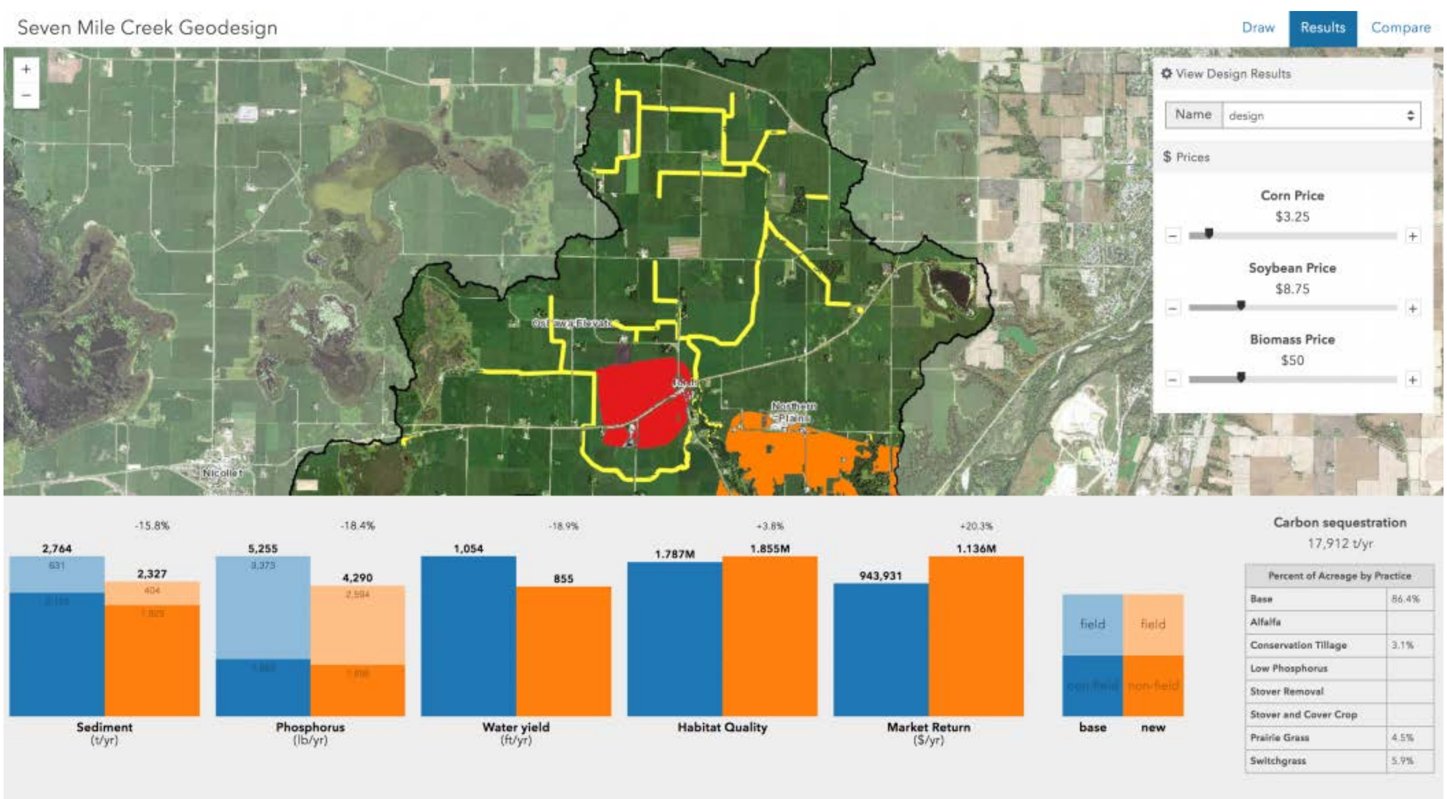


Seven alternative practices can be applied to the landscape. Participants draw on the map using tools that quickly create shapes or buffer waterways. Image courtesy of U-Spatial.

a novel decision-support and visualization tool that allowed them to develop potential landscape designs and assess their performance. This decision support and visualization tool consists of a mobile 55” multi-touch display linked to a spatial geodatabase that contains information about topography, soil, land use, hydrology, and habitat characteristics for the watershed. In addition, the tool contains data and modeling about how placement of each of the alternative landscape management practices (e.g. tillage, fertilizer, cover crops, perennial crops) will affect provision of environmental benefits (e.g. controlling runoff and erosion to improve water resources, carbon sequestration, production of food, and renewable energy). Stakeholders were able to quickly and iteratively try many designs with immediate feedback. When asked about the process, one participant stated:

There’s a real key benefit of this process. You know, getting different kinds of people together. Having them discuss a problem, communicate, and working out some things and they may not all agree from the get go of a course, . . . but if they have at it with the decision making software and you can kind of look at your landscape model and the benefits. Not only the cost benefits, but environmental as well, you know, and that’s kind of the . . . objective decider for the group.

This second stage engaged additional economic development stakeholders and explored issues of supply chain relative to biomass production, harvest, and processing. The researchers facilitated a scenario planning process that accounted for broader agricultural and economic trends and again utilized the geodesign system to assess the biomass demand, landscape design options, and economic and environmental benefits. Various biomass processing facility types were considered in these scenarios as a demand driver for biomass crops that could be integrated into the agricultural landscape. Following the completion

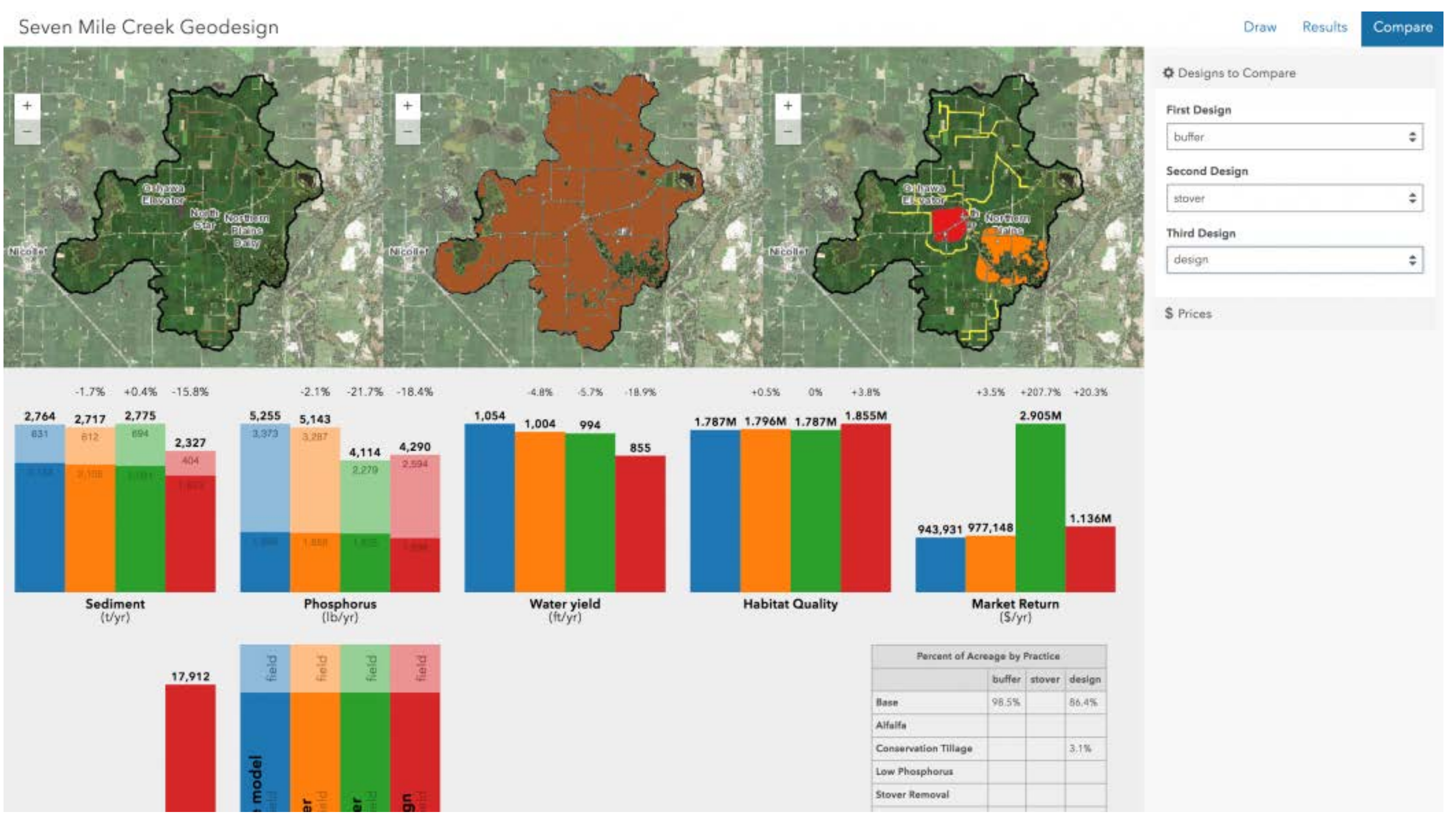


At any time, participants can submit a design to be evaluated. Within a few seconds, they are provided with performance of the design in terms of water quality, habitat, and financial parameters. Image courtesy of U-Spatial.

of the innovation stage, the researchers and stakeholders remain active collaborators on implementation work teams focused on biomass facility recruitment strategy, alfalfa production for a local dairy, and downscaling watershed models to farm scale.

Current work illustrates the third stage of FGI's approach, which focuses on carefully coordinated implementation. By supporting a range of partners in taking measured steps together, the project aims to manage the risks and costs, and maximize the benefits of a substantial innovation in local agriculture: producing alfalfa and winter-hardy "cash-cover crops" in and near the Seven Mile Creek, in a spatial pattern across the watershed that cost-effectively produces environmental benefits in addition to revenues for farmers and materials for the local economy. These winter-hardy crops protect and enhance soil and water resources over fall, winter, and spring, and produce good yields of valuable commodities before giving way to summer crops like corn. By implementing these innovations in a series of carefully staged steps, project participants are working to realize the full potential of the project to benefit the local farm economy, meet local health and infrastructure needs related to municipal water supplies, and improve the flows of water from Seven Mile Creek into the Minnesota and Mississippi Rivers.

The project will achieve these outcomes by coordinated action to leverage economic growth opportunities for farmers and rural communities that are arising from increased market demand for products produced from certain crops and cropping systems. By changing land use and farming practices to meet this demand, farmers can play a major role in meeting water needs at far lower public cost than building treatment facilities or purchasing land or restrictive easements. More broadly, we aim to create a scalable model of private- and public-sector collaboration that will 1) focus investments needed to achieve these low-cost, multiple-benefits approaches to



The design process is iterative. Participants can compare the performance of up to four designs in search of a win-win scenario. Image courtesy of U-Spatial.

water service provision; 2) connect producers of perennial and winter-annual crops to markets that provide revenue to producers; and 3) support ongoing learning, innovation, and coordinated action for implementation and adaptation to change.

Conclusion

Managing the nexus of agriculture, water, and the river presents society with a complex or wicked problem challenge, but also many opportunities. Collectively, society has a great deal of capital—intellectual, human, social, and financial—that can be used to manage the problems and seize the opportunities. Yet, this capital is dispersed, and its owners are reluctant to spend it in the highly fragmented, polarized, and uncertain conditions that surround current discourse and debate around agriculture, water, and climate. The university is, among social institutions, uniquely capable of convening and supporting the societal learning, broad innovation, and coordinated action that are essential to address issues related to agriculture, water, and a climate for the common good. However, the university must learn to do such complex work better, and in full engagement with a wide range of collaborators. The Forever Green Initiative and the New Agricultural Bioeconomy Project are deliberate experiments in which the University of Minnesota is practicing and refining its new roles and relationships. In ten years, we hope that the results will become very clear, through an increased diversity of the agricultural landscape and improved health of the river.

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About the Authors

Nicholas R. Jordan is a professor in the Agronomy and Plant Genetics Department at the University of Minnesota. In his teaching and research, he focuses on organizing systemic change in food and agricultural systems.

Carissa Schively Slotterback is an associate professor of urban and regional planning in the Humphrey School of Public Affairs at the University of Minnesota. Her research is focused on stakeholder engagement and decision making related to environmental, land use, and transportation planning. She is particularly interested in how stakeholders perceive impacts and use information in making decisions, focusing on impact assessment, collaborative decision making, and sustainability planning approaches.

David Mulla is a professor and the W.E. Larson Chair for Soil and Water Resources in the Department of Soil, Water, and Climate at the University of Minnesota. He is an internationally recognized scholar in agricultural watershed modeling and management for improved water quality.

Len Kne brings extensive experience with GIS and Information Technologies in higher education, construction, government, and non-profit organizations to his work at U-Spatial, a center at the University of Minnesota providing support for spatial research. He is on the faculty of the Master of Geographic Information Science program and teaches project management and spatial databases. He is looking forward to the day when everyone is thinking spatially.