Smart irrigation technology covers 'more crop per drop'

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Global Engineering and Research (GEAR) Lab researchers (from left to right) Georgia Van de Zande, Carolyn Sheline, and Fiona Grant pilot a low-cost precision irrigation controller that optimizes system energy and water use at a full-scale test farm in the Jordan Valley. Credit: John Freidah

In agriculture today, robots and drones can monitor fields, temperature and moisture sensors can be automated to meet crop needs, and a host of other systems and devices make farms more efficient, resource-conscious, and profitable. The use of precision agriculture, as these technologies are collectively known, offers significant advantages. However, because the technology can be costly, it remains out of reach for the majority of the world's farmers.

"Many of the poor around the world are small, subsistence farmers," says Susan Amrose, research scientist with the Global Engineering and Research (GEAR) Lab at MIT. "With intensification of food production needs, worsening soil, water scarcity, and smaller plots, these farmers can't continue with their current practices."

By some estimates, the global demand for fresh water will outstrip supply by as much as 40% by the end of the decade. Nearly 80% of the world's 570 million farms are classed as smallholder farms, with many located in under-resourced and water-stressed regions. With rapid population growth and climate change driving up demand for food, and with more strain on natural resources, increasing the adoption of sustainable agricultural practices among smallholder farmers is vital.

Amrose, who helps lead desalination, drip irrigation, water, and sanitation projects for GEAR Lab, says these small farmers need to move to more mechanized practices. "We're trying to make it much, much more affordable for farmers to utilize solar-powered irrigation, and to have access to tools that, right now, they're priced out of," she says. "More crop per drop, more crop per area, that's our goal."

Drip irrigation systems release water and nutrients in controlled volumes directly to the root zone of the crop through a network of pipes and emitters. These systems can reduce water consumption by 20 to 60% when compared to conventional flood irrigation methods.

"Agriculture uses 70% of the fresh water that's in use across the globe. Large-scale adoption and correct management of drip irrigation could help to reduce consumption of fresh water, which is especially critical for regions experiencing water shortages or groundwater depletion," says Carolyn Sheline SM '19, a Ph.D. student and member of the GEAR Lab's Drip Irrigation team. "A lot of irrigation technology is developed for larger farms that can put more money into it—but inexpensive doesn't need to mean 'not technologically advanced.'"

GEAR Lab has created several drip irrigation technology solutions to date, including a low-pressure drip emitter that has been shown to reduce pumping energy by more than 50% when compared to existing emitters; a systems-level optimization model that analyzes factors like local weather conditions and crop layouts, to cut overall system operation costs by up to 30%; and a low-cost precision irrigation controller that optimizes system energy and water use, enabling farmers to operate the system on an ideal schedule given their specific resources, needs, and preferences. The controller has recently been shown to reduce water consumption by over 40% when compared to traditional practices.

To build these new, affordable technologies, the team tapped into a critical knowledge source—the farmers themselves.

"We didn't just create technology in isolation—we also advanced our understanding of how people would interact with and value this technology, and we did that before the technology had come to fruition," says Amos Winter SM '05, Ph.D. '11, associate professor of mechanical engineering and MIT GEAR Lab principal investigator. "Getting affirmations that farmers would value what the technology would do before we finished it was incredibly important."

The team held "Farmer Field Days" and conducted interviews with more than 200 farmers, suppliers, and industry professionals in Kenya, Morocco, and Jordan, the regions selected to host field pilot test sites. These specific sites were selected for a variety of reasons, including solar availability and water scarcity, and because all were great candidate markets for eventual adoption of the technology.

"People usually understand their own problems really well, and they're very good at coming up with solutions to them," says Fiona Grant '17, SM '19, also a Ph.D. candidate with the GEAR Lab Drip Irrigation team. "As designers, our role really is to provide a different set of expertise and another avenue for them to get the tools or the resources that they need."

The controller, for example, takes in weather information, like relative humidity, temperature, wind speed values, and precipitation. Then, using artificial intelligence, it calculates and predicts the area's solar exposure for the day and the exact irrigation needs for the farmer, and sends information to their smartphone. How much, or how little, automation an individual site uses remains up to the farmer. In its first season of operation on a Moroccan test site, GEAR Lab technology reduced water consumption by 44% and energy by 38% when compared to a neighboring farm using traditional drip irrigation practice.

"The way you're going to operate a system is going to have a big impact on the way you design it," says Grant. "We gained a sense of what farmers would be willing to change, or not, regarding interactions with the system. We found that what we might change, and what would be acceptable to change, were not necessarily the same thing."

GEAR Lab alumna Georgia Van de Zande '15, SM '18, Ph.D. '23, concurs. "It's about more than just delivering a lower-cost system, it's also about creating something they're going to want to use and want to trust."

In Jordan, researchers at a full-scale test farm are operating a solar-powered drip system with a prototype of the controller and are receiving smartphone commands on when to open and close the manual valves. In Morocco, the controller is operating at a research farm with a fully automated hydraulic system; researchers are monitoring the irrigation and conducting additional agronomic tasks. In Kenya, where precision agriculture and smart irrigation haven't yet seen very much adoption, a simpler version of the controller serves to provide educational and training information in addition to offering scheduling and control capabilities.

Knowledge is power for the farmers, and for designers and engineers, too. If an engineer can know a user's requirements, Winter says, they're much more likely to create a successful solution.

"The most powerful tool a designer can have is perspective. I have one perspective—the math and science and tech innovation side—but I don't know a thing about what it's like to live every day as a farmer in Jordan or Morocco," says Winter. "I don't know what clogs the filters, or who shuts off the water. If you can see the world through the eyes of stakeholders, you're going to spot requirements and constraints that you wouldn't have picked up on otherwise."

Winter says the technology his team is building is exciting for a lot of reasons.

"To be in a situation where the world is saying, 'we need to deal with water stress, we need to deal with climate adaptation, and we need to particularly do this in resource-constrained countries,' and to be in a position where we can do something about it and produce something of tremendous value and efficacy is incredible," says Winter. "Solving the right problem at the right time, on a massive scale, is thrilling."

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