Helping Senegalese farmers with smart solar

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Credit: Columbia University

By 2050, the world will need to produce 70 percent more food than we did in 2007 to feed a global population expected to reach 9.6 billion, according to the United Nations Food and Agriculture Organization. Increased food production means a greater demand for energy. But many farmers in developing countries do not have access to clean and affordable modern energy. Moreover, they are often unaware of what technology might enable them to farm more efficiently and have no way to finance the up-front costs of new technology.

Powering Agriculture: An Energy Grand Challenge for Development, launched by the United States Agency for International Development and international partners, provides grants to entities exploring clean energy solutions for agriculture that have the potential to be scaled up. In 2013, the Earth Institute at Columbia University received a grant for its pilot Acacia Irrigation project in Senegal.

Senegalese farmers (over 85 percent of agriculture workers are women) typically irrigate their fields by hand, carrying water from wells with buckets, or use diesel pumps, which are expensive to fuel at approximately one dollar a day.

"In some locations, especially the Sahel, the small holder agriculture is based on very small plots," said Vijay Modi, director of the Sustainable Engineering Lab and a professor in the department of mechanical engineering at Columbia. "And when a farmer has a very small plot, it is difficult for them to own their own pump, their own generation system, whether it is a fossil fuel powered pump or a solar pump or a wind turbine, as well as make an investment in the well, and the lifting device."

Credit: Columbia University

The lab wanted to pose the question, "in situations where farmers own very small plots, can a single system provide electricity or water as a service to multiple farmers, as opposed to each farmer having to own their own equipment?" To find out, the Sustainable Engineering Lab set up a battery-less system comprised of three solar photovoltaic (PV) arrays to power irrigation pumps in Gabar, a village in the Niayes zone of Senegal, which produces over half the country's agriculture.

The pilot project involves two solar arrays of 4.8KW that track the sun over the course of the day, and a third stationary array of 6.8KW. Each PV array serves seven farmers or fields (approximately half to two acres in size). Farmers have their own well and submersible 1-horsepower pumps.

The solar panels collect solar energy, which is converted to AC power by an inverter; power is then distributed to the individual pumps through wires laid in trenches in the fields; water pumped from shallow wells is distributed via drip irrigation or feeds storage basins. Farmers pay only for the power they actually use at approximately 60 cents per kWh with prepaid electricity cards issued by a micro-utility and sold by local vendors, who get a commission.

A pump operator uses a smart phone app to turn the pumps on and off as needed. The system software calculates the available solar power and controls the pumps based on light and temperature sensors and smart meter readings, so when it is cloudy, the pumps automatically turn off. The operator waits until the sun returns and turns the pumps back on. He is also responsible for keeping records of the farmers' usage and maintaining the system and the PV array. His salary comes from the fees collected from the farmers.

Credit: Columbia University

Since the systems are battery-less to keep costs down, they are dependent on when the sun shines. Gordon Shaw, project manager for the Acacia Irrigation project, explained that the two solar arrays that track the sun collect more energy.

"They reach their maximum early and it lasts longer," he said. "And since there is no storage, the amount of power available at any given time determines the number of pumps that can be on—the tracking has been very effective, but the disadvantage is that it adds a mechanical system that could fail."

Farmers began using the system in February 2015, and the systems have now run for one or two full seasons. Shaw and his team found very high usage, which shows that the farmers are satisfied with the system and are adjusting to using the pumps when solar power is available. They used 60 to 70 percent of the total energy produced by the tracking solar arrays, and 40 to 50 percent from the stationary array.

One farmer commented, "This ending season I have increase a lot my carrot yield…the solar system help me to irrigate more than before because… it's very easy and I have more time for labor." Another said, "I'm very lucky to be part of this pilot program. During the last campaign before the solar system I had 50 sacks of onions and for this last campaign, I have 97 sacks."

Credit: Columbia University

Early indications are that the farmers using the solar powered pumps for planting carrots have harvested more than similar farmers using diesel pumps, but the results have yet to be confirmed and explained. The team is now analyzing the data on usage of the system and fuel, and harvest.

In a year, the operator was paid approximately $250 per farmer from the farmers' fees for power usage. The farmers made between $2,000 and $1,500 per season from their harvests, significantly more than many other farmers in Sub-Saharan Africa because they're growing higher value crops such as onions and carrots. They also saved money using solar power—it costs approximately $250 a year to use solar vs. $350 to run a gasoline pump. Not using gasoline pumps helped the farmers save time as well as money, because they did not need to get gasoline at a gas station, the nearest of which is a one-hour drive from the village. Each farmer also avoided emitting approximately .24 tons of CO_2 from gas pumps per 100-day season.

"Sharing a system across farmers leads to high utilization," said Modi. "By sharing, they are using it in an optimal way."

The team is currently discussing how to revise the system based on the pilot results. "Instead of a seven-farmer system, which took awhile to arrange, we might go with a three-farmer system," Shaw said. "Then they'd just be sharing with their neighbors, and because the pumps would be closer, you would run less wire," which would cost less. He also noted that the operator would prefer running the system with buttons instead of a smart phone app, so they are figuring out how to make the interface simpler, perhaps with a touch pad.

Credit: Columbia University

One system costs approximately $10,000 to set up. To scale the project up, the team is looking for entrepreneurs in Senegal to finance the systems. Multiple systems could be operated as franchises. Low-interest loans at 1 to 2 percent are becoming available for energy companies. The system collects $10 a day, and with 200 planting days per year, each system could bring in $2,000 per year. Going forward, the farmers' fees could be used to repay the investment or to pay for the operator or perhaps both. Another potential source of revenue, said Shaw, is selling the excess power produced to charge batteries as a community service.

Modi believes the system could work across much of the Sahel. "What is innovative about it," he said, "is the combination of technology, the prepayment system, and the way the architecture allows farmers to share the service."

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