

USING WIRELESS TECHNOLOGY TO REDUCE WATER USE IN RICE PRODUCTION

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ABSTRACT

While rice is produced in some parts of the world in an upland, rainfed culture, almost all US-produced rice is grown with flood irrigation. In the dry-seeding system commonly used in the midsouthern US, the crop is usually flooded at approximately the V-4 (early tillering) growth stage and a continuous flood is maintained until after heading. The total amount of water used in rice production is quite large, and soil, fertilizers, and pesticides can be carried in the runoff from agricultural fields. Flood depth affects most aspects of flooded rice production, and remote monitoring of the flood depth could be quite valuable to many producers. The objective of this research is to develop and test a system for monitoring water depths in rice fields and alerting the producer so that less labor and energy is required to efficiently manage flood-irrigated rice. A prototype monitoring station was designed to measure water depth in a flooded rice field and transmit the information over a wireless link. A similar sensor and circuit performed satisfactorily in a raingage in 2006. In 2007, prototype monitoring stations will be installed in production rice fields. Concurrently with sensor durability testing, tests will be conducted to determine the limits of the wireless communication system. With daily reports of the water status in each paddy, field visits can be reduced. Over-pumping should be minimized by allowing better scheduling of field visits to stop the pump, and future systems should work with automatic pump control systems to stop the pump before runoff occurs.

INTRODUCTION AND BACKGROUND

While rice is produced in some parts of the world in an upland, rainfed culture, almost all US-produced rice is grown with flood irrigation. In the dry-seeding system commonly used in the midsouthern US, the crop is usually flooded at approximately the V-4 (early tillering) growth stage (Counce et al., 2000) and a continuous flood is maintained until after heading. Figure 1 contains an aerial view of a typical midsouthern US rice field. In 2005, more than 1.6 million acres of rice were planted in Arkansas, 49% of the total US crop (NASS, 2005). Vories et al. (2006) reported irrigation amounts applied to 33 Arkansas rice fields during 2003 - 2005 ranged from 18 to 56 inches. The average amount was 31 inches, more than double the amount typically

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applied to other irrigated crops in the state (Hogan et al., 2007). The total amount of water used in rice production is quite large, and currently some rice growing areas of Arkansas, Louisiana, Texas, and California are suffering from serious water problems.

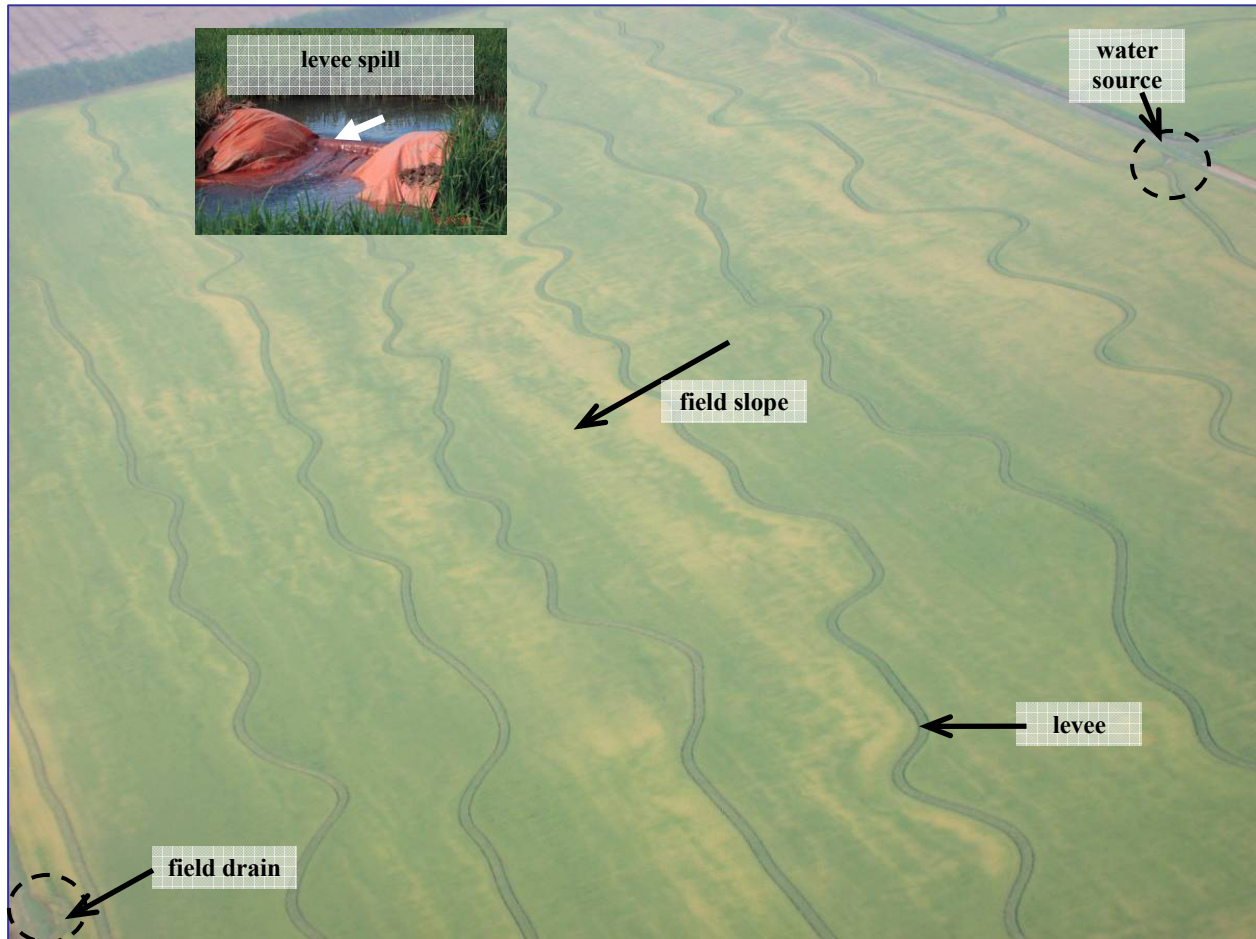


Figure 1. Aerial view of typical rice field in midsouthern US. Gates or spills are placed in the levees to allow water to flow from top to bottom of field.

Insufficient pumping results in dry portions of the fields, leading to increased weed and fertilizer problems and low yields. Excessive pumping wastes water and energy and increases pressure on levees. In addition, soil, fertilizers, and pesticides may be carried in the runoff from agricultural fields. It is essential that production practices be developed and refined that decrease the amount of irrigation water required while simultaneously protecting water quality. With increasing costs for energy and fertilizer, the solutions cannot be prohibitively expensive or they will not be adopted.

Flood depth affects most aspects of flooded rice production. Nutrient availability is highly affected by water management (Seng et al., 2004; Beyrouthy et al., 1994), as is rice water weevil (Stout et al., 2002) and weed control (Masson et al., 2001). Therefore, rice producers commit much time, labor, and energy checking the water status of fields. As farms have grown to

thousands of acres spread over several miles, remote monitoring of flood depth could be quite valuable to many producers.

Smith et al. (2007) looked at water use for different rice production systems in Mississippi and Arkansas and observed large differences. Vories et al. (2005) reported the results from four years of on-farm comparisons in Arkansas, showing 24% less irrigation water applied to multiple inlet rice irrigation fields compared to conventionally flooded fields without reducing yields. Massey et al. (2006) reported potential for additional water savings with multiple inlet plus intermittent irrigation. Intermittent irrigation allows the water levels to fluctuate more than with the conventional practice, which increases rainfall-holding capacity, and reduces over-pumping. Whatever system is used, the producer must have accurate information concerning the water status of each of the paddies in the field.

A company in Arkansas (Izon, Inc., Paragould, Ark.⁵) markets a system to notify producers when their well status changes (i.e., flow starts or ceases) or fuel levels are low. FieldSENTRY (Lindsay Manufacturing Co., Lindsay, Neb.) is a similar type of system for remotely monitoring center pivots. A similar type of system could monitor the depth of water in rice paddies and report to the grower when it is time to add water or stop pumping, reducing trips to the field just to check water status. The objective of this research is to develop and test a system for monitoring water depths in rice fields and alerting the producer so that less labor and energy is required to efficiently manage flood-irrigated rice.

PROCEDURES

Inexpensive sensors and wireless technology have advanced to the point that water status in rice fields could be remotely sensed and relayed to the producer at an affordable cost. With such a system (Figure 2), individual monitoring stations would be placed in each paddy; each station would measure the water depth and relay the information to adjacent stations. A central control station would collect the data from each paddy and send status reports to the producer.

Prototype Monitoring Station

A prototype monitoring station was designed to measure water depth in a flooded rice field. The system consists of a pressure sensor and microcontroller circuit housed in a waterproof container. The container is installed in the rice field so that a port in the side of the container is below the water level, allowing the pressure sensor to contact and measure the depth of water in the field (Figure 3). The monitoring station contains circuitry and components for measuring and recording pressure-sensor information at regular intervals, and for transmitting the information over a wireless link.

Table 1 lists the major components used in the prototype station. An inexpensive piezoelectric pressure sensor is used to measure the hydrostatic pressure of the water, which is a function of depth. A circuit was designed to monitor, store, and transmit pressure-sensor measurements. The circuit consists of a programmable microcontroller, real-time clock, memory chip, components to

⁵ Mention of trade names or commercial products is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

power the pressure sensor and amplify the resulting sensor signal, and a radio-frequency (RF) transmitter. The components are inexpensive and commonly available items. A photograph of the prototype sensor components is included in Figure 4. The programmable microcontroller manages the control, logic, measurement, and data storage and transmission functions. The circuit is battery-powered, and capable of continuous, unattended operation for an entire growing season.

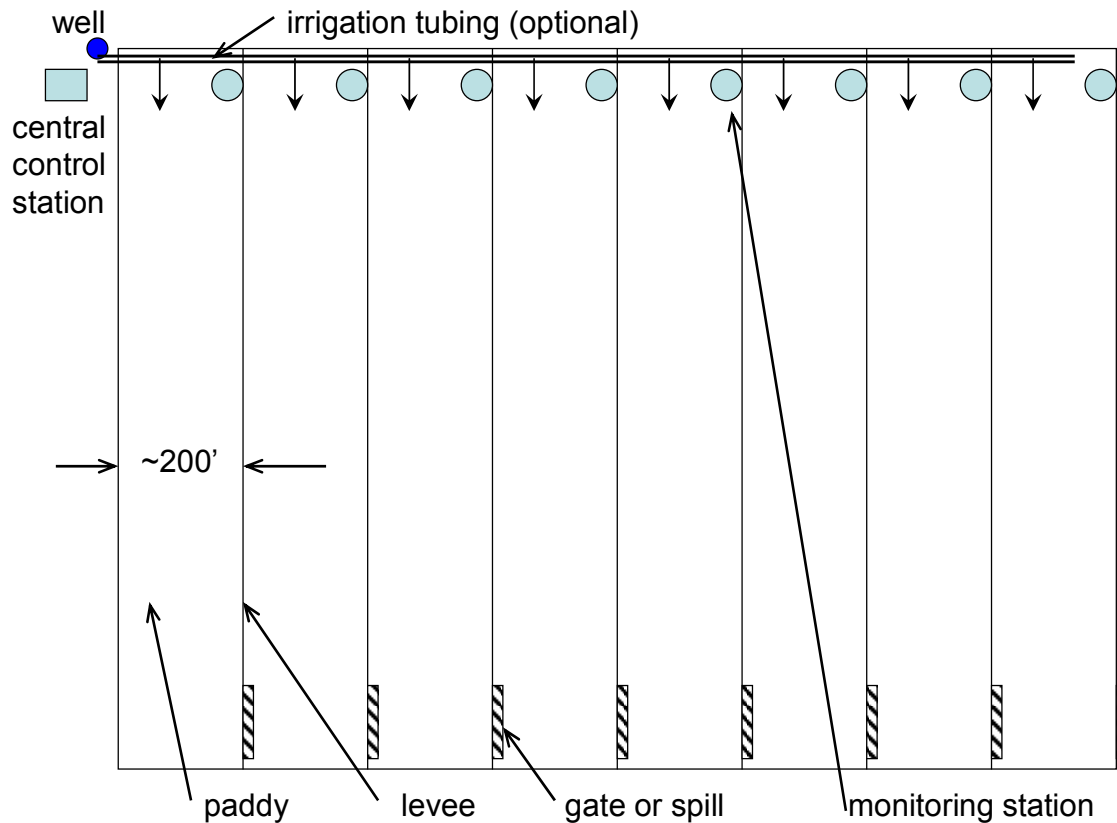


Figure 2. Diagram of monitoring system in rice field.

The microcontroller continuously monitors the real-time clock, which maintains time and date information, and maintains the circuitry in a low-power mode until it is time to take a measurement. At the beginning of each hour, the microcontroller activates the circuitry, turning on power to the other components. A depth measurement is made by providing power to the pressure sensor and measuring the output voltage signal. An operational amplifier is configured as a constant-current source, which powers the pressure sensor. The output voltage signal is input to an instrumentation amplifier, which increases the voltage level. The signal is then input to an analog-to-digital (A-D) converter built into the microcontroller, which measures the signal. The temperature of the pressure sensor is measured with an adjacent temperature sensor inside the PVC container for use in compensating for temperature effects on the pressure sensor. A

calibration equation programmed into the microcontroller then calculates the water depth based on the pressure-sensor output voltage signal and the sensor temperature. Data are stored in a non-volatile memory chip and transmitted via a wireless transmitter. At each measurement interval, date and time, water depth, and temperature information are stored. This information, along with an identification number unique for each circuit board (i.e., monitoring station), is transmitted via the RF transmitter. The microcontroller then returns the circuit to low-power mode until the next measurement interval.

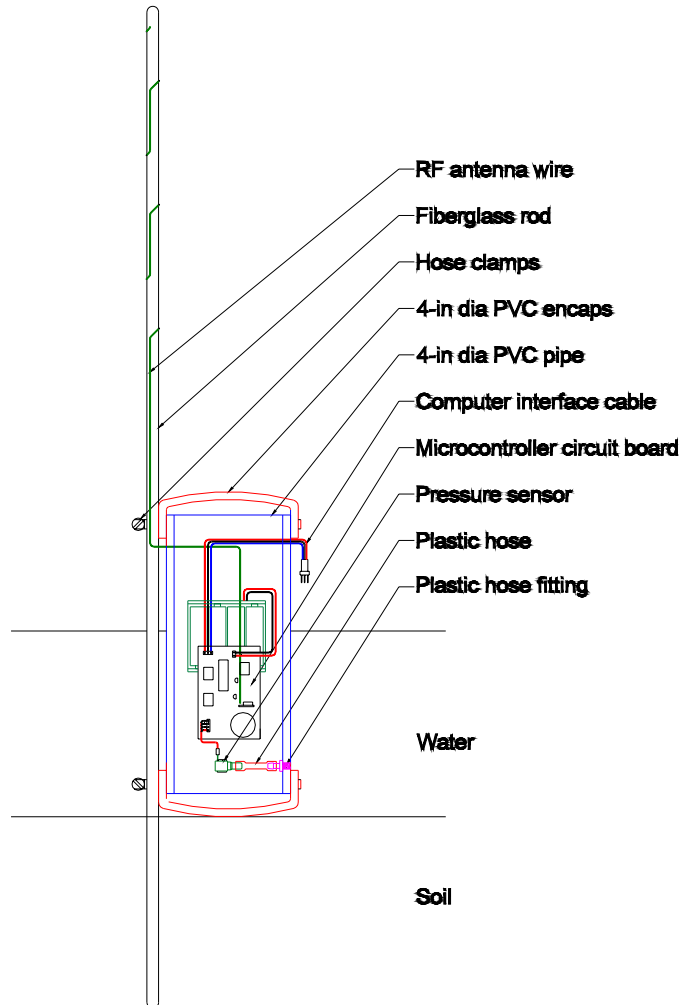


Figure 3. Sketch of monitoring station.

The waterproof container is constructed mainly of common PVC pipe and fittings. The bottom endcap is glued to one end of a short length of pipe. A small hole is drilled and tapped through the pipe wall just above the top lip of the endcap. A plastic hose barb is inserted and glued into the hole so that the barb extends into the inside of the pipe. A short length of plastic tubing is secured to the barb to allow attachment of the pressure sensor. A second hole is drilled through the pipe near the top of the container to allow the antenna wire and a computer-interface cable to pass through. A second endcap is placed on top of the pipe to secure and protect the electronic

components. A fiberglass rod is used to install and secure the container in the field. The rod is driven into the soil, and the container is attached to the rod with hose clamps. The container is positioned on the rod so that the pressure sensor port is below the water surface at all times. The rod is also used to secure the antenna wire for the RF transmitter.

Table 1. Major components used in the prototype monitoring station circuit.

Component	Manufacturer
Microcontroller	Microchip Technologies
Pressure sensor	Honeywell
Real-time clock	Dallas Semiconductor
Memory	Microchip Technologies
Voltage regulator	Linear
Current source	Linear
Instrumentation amplifier	Analog Devices
RF transmitter	Laipac
Clock crystal	Seiko

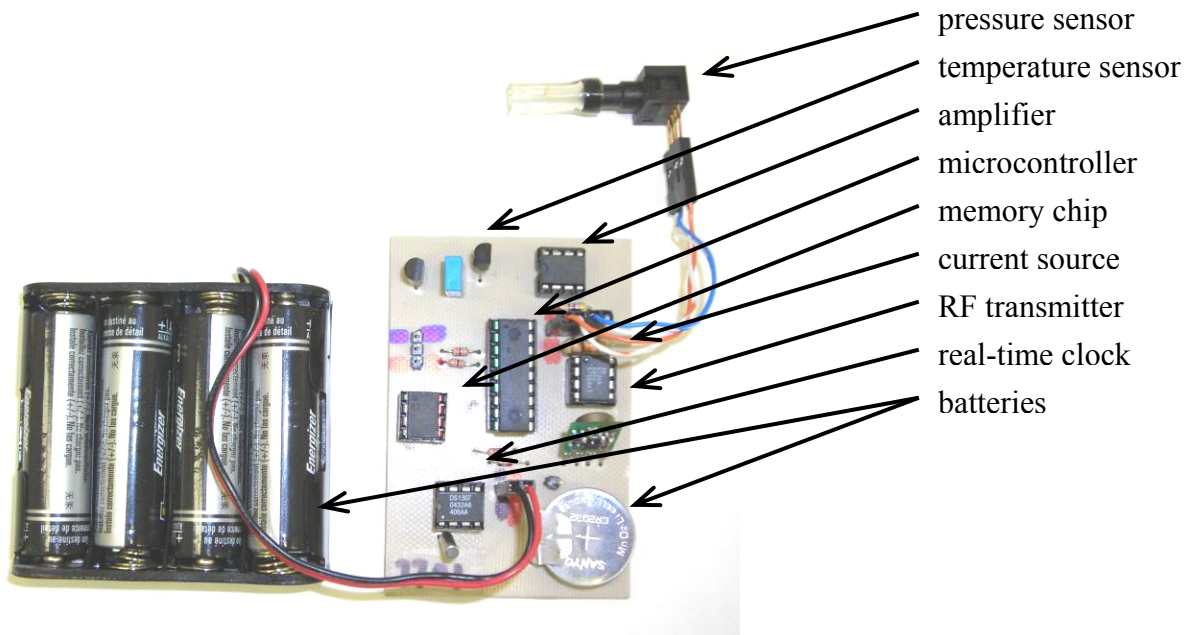


Figure 4. Photograph of prototype monitoring station components.

A similar sensor and circuit were installed in a raingage in 2006. Figure 5 shows a series of water-depth measurements from the raingage for a 10-day period in July. Automated measurements were taken at one-hour intervals, with periodic manual measurements of the water depth for comparison. A rain event occurred during which the raingage registered 0.61 inches of rainfall, compared with 0.63 inches from the “official” experiment station value.

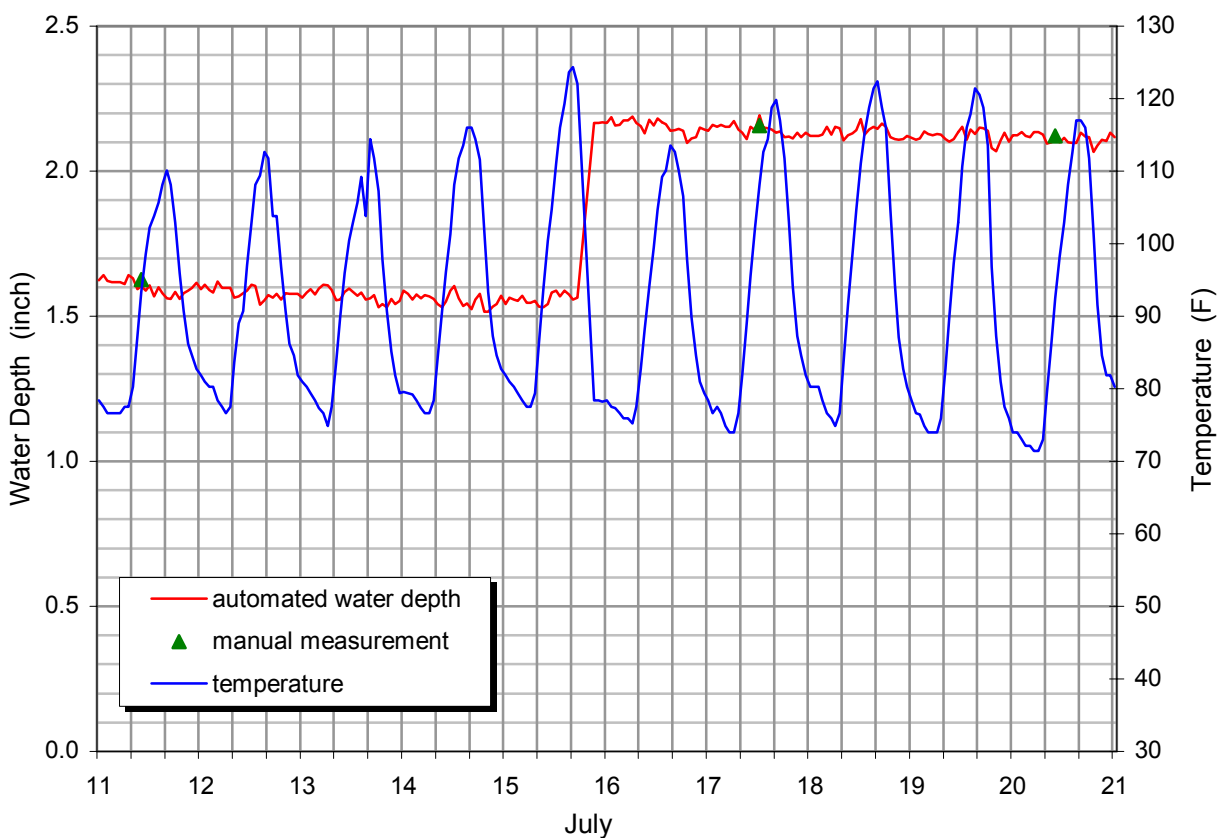


Figure 5. Graph showing a series of water-depth measurements from a raingage with a sensor and circuit similar to the prototype monitoring station.

System Testing

Initial tests conducted during summer 2007 will address the suitability of the inexpensive sensors under agricultural environments. Prototype monitoring stations (Figure 3) will be fabricated and installed in each paddy of two production rice fields (a target of at least ten stations). Logging flowmeters (McCrometer MD-308 with pulse output) and a logging tailwater depth sensor (INW PT2X, 5psig) will be installed in each field. Periodic visits will be made to the fields for manual depth measurements. Records will be kept regarding sensor-system failure rate and causes. The research team will meet after the season to discuss the results and how to address the failures. In the cases of water or farm equipment damage, better methods of protecting the units will be developed. If the first pressure sensors are deemed unsuitable, a different type of sensor will be identified the following year. Concurrently with the sensor durability testing, tests will be conducted to determine the limits of the low-cost wireless communication system within production rice fields, to determine antenna requirements and maximum communication distances. Once reliable sensors have been identified and communication requirements determined, additional complete systems will be assembled for field testing. Communication from the field to the producer (and researchers) will probably use an existing system (e.g., Izon, Inc.). The system will send daily status reports and additional alerts by text message and/or e-

mail when problems are suspected. Follow-up efforts will use the findings from the field testing to make inferences concerning potential water/energy/labor savings with the systems.

Potential Value

To get an idea of the potential value of a remote monitoring system, the situation of one northeast Arkansas producer was considered. The producer had 24 rice fields in 2006 for a total of 2,000 acres of rice (in this case, adjacent fields were counted as one since they would be visited at the same time). Each field was visited every day, and the average distance from the farm headquarters to the fields was approximately 10 miles. Typically on a large rice farm, one reliable, experienced worker, a "water man," is assigned to be in charge of maintaining the floodwater on all of the rice fields and during the approximately 70-day flood duration, that worker has little time for any other duties. With daily reports of the water status in each paddy, the field visits should be easily reduced to every third day, allowing the "water man" time for other work. In addition to the labor cost, significant savings should result from fuel costs spent driving to the fields and vehicle maintenance. Over-pumping should be reduced by allowing the worker to better schedule his visits to stop the pump, and future systems should work with the pump control system to automatically stop the pump before runoff occurred. Furthermore, by knowing the water status at all times, the producer would be more comfortable with intermittent irrigation (Massey et al., 2006) or some other approach that allowed more efficient use of rain.

SUMMARY

Insufficient pumping in rice production results in dry portions of the fields, leading to increased weed and fertilizer problems and low yields. Excessive pumping wastes water and energy and increases pressure on levees. In addition, soil, fertilizers, and pesticides may be carried in the runoff from agricultural fields. Flood depth affects most aspects of flooded rice production, including nutrient availability, rice water weevil, and weed control. Therefore, rice producers commit much time, labor, and energy checking the water status of fields. As farms have grown to thousands of acres spread over several miles, remote monitoring of flood depth could be quite valuable to many producers.

A prototype monitoring station was designed to measure water depth in a flooded rice field using an inexpensive piezoelectric pressure sensor, and transmit the information over a wireless link. A similar sensor and circuit were installed in a raingage in 2006 and performed satisfactorily. Initial efforts in summer 2007 will test the suitability of the inexpensive sensors under agricultural environments. Prototype monitoring stations will be fabricated and installed in each paddy of two production rice fields. Periodic visits will be made to the fields for manual depth measurements. Concurrently with sensor durability testing, tests will be conducted to determine the limits of the low-cost wireless communication system within production rice fields. Once reliable sensors have been identified and communication requirements determined, additional complete systems will be assembled for field testing. Follow-up efforts will use the findings from the field testing to make inferences concerning potential water/energy/labor savings with the systems.

Typically on a large rice farm, one worker is assigned to be in charge of maintaining the floodwater on all of the rice fields and that worker has little time for any other duties. With daily reports of the water status in each paddy, field visits should be easily reduced from daily to every third day, allowing the "water man" time for other work. In addition to the labor cost, significant savings should result from fuel costs spent driving to the fields and vehicle maintenance. Over-pumping should be reduced, and future systems should work with the pump control system to automatically stop the pump before runoff occurs. Furthermore, by knowing the water status at all times, the producer would be more comfortable employing an approach that allowed more efficient use of rain.

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