Internet of Agriculture Network and Services Platform

A New Agricultural Data Platform
For Smart Farming and Resource Conservation

CIG- 69-3A75-17-515

Project Summary

In the past decade significant investment has been made in developing and advancing technologies for farmers to automate activities such as controlling pumps and motors, measuring water use with flow meters, monitoring soil moisture with sensors, tracking water levels, and monitoring, and reporting weather conditions. These activities have included sensors and some have been enhanced with telemetry that provides data to the farmers at near real time to enhance management decisions and support actions from remote locations. These works support conservation efforts associated with water management, water quality protection, nutrient management, and climate change, specifically carbon reductions through improved rice water management requiring water level control data in rice fields. These efforts

and investments have demonstrated the potential for improved management, monitoring and tracking. The technologies utilized have also revealed that current methods are not adequate to address the needs for intense data required for precision farming and agricultural management. The adoption rate remains low for conservation practices, especially when agriculture is compared to other large industries. One common problem is the communication and data transfer system that is either expensive and/or not compatible with other systems making it difficult for farmers or organizations to collect, share, and utilize field data critical to making management decisions and tracking the results for their farming operations.

In 2017, the White River Irrigation District received a Natural Resources Conservation Services (NRCS) Conservation Innovation Grant (CIG) to develop a new data communication platform, the Internet of Agriculture (IoAg), to provide a system that would be low cost, provide site specific on-farm sensor data for farmers to increase agricultural production, monitor resource conditions and increase the adoption of conservative practices. The innovative approach proposed was to utilize the Low Power Wide Area Network (LPWAN) and Cloud Data Management technologies for agricultural data and on-farm implementation.

We have recently completed this project, successfully developed the Internet of Agriculture, and proved that the system can transport real-time on-farm data at high data efficiency rates and at much lower cost than technologies currently being deployed. More importantly, we demonstrated the IoAg platform can be utilized for data collection and reporting the data to the cloud on all resource concerns where data measurement methods have been established and affordable sensors exist. Three working systems were installed in three geographic areas with over a 100,000 data point capability where sensors can be located anywhere under the total 500,000 acre network footprint. This was accomplished utilizing a 1-pound Remote IoAg Controller (RIC) that operated for more than 1 year on 3 AA batteries with real time data collected, transmitted, and stored both in the cloud and in the field. This low cost, easy to install recording and reporting device supports various types of agricultural sensors such as soil moisture sensors, water flow meters, water level sensors, water depth sensors, weather and climate data. Sensor data from single sites can be utilized to track and report resource conditions and make real-time informed management decisions. Recorded data from numerous locations can be accessed by users anytime and anywhere with their computing or mobile devices. Site specific data can be consolidated, analyzed, and reported for whole farm conditions and when participation levels reach a meaningful threshold the results can be utilized to track watershed or regional resource conditions. This only happens if NRCS or others desire to track conservation practice impacts on a watershed scale with focused resources.

The field implementation results have validated the Internet of Agriculture can become a valuable and affordable tool to improve the agricultural processes and conservation practice implementation that can be used to make immediate conservation management decisions, enabling farmers to track performance, monitor resource conditions, and evaluate conservation practice performance. The benefits of combining low cost data, high value resource information, and wide area coverage for multiple users such as farmers, equipment and services providers, and resource managers will help to increase the pace and scale of conservation adoption.

Internet of Agriculture System and Products

The Internet of Agriculture (IoAg) is a wireless network data collection platform that provides low cost, reliable, real-time agricultural data over a broad geographic area. Real-time data from multiple in-field sensors are communicated through Remote IoAg Controllers (RIC) to the IoAg Gateway and Network and to Cloud Data Management servers. Users can access the data and analytical results with their computing or mobile devices to make farm management decisions or track resource conditions. The Internet of Agriculture adopts the advanced Low Power Wide Area (LPWA) wireless technologies specifically for the agricultural environment and the special demands associated with complex climate variables and the generally harsh environment associated with agriculture. The results of this effort is a system that has the following characteristics: low data cost, low device cost, low power consumption, easy to install gateways with high data point capability, easy to install in-field RIC's, and wide coverage area.

Features and System Performance

The highlights of features and system performance is summarized as follows:

- **Long Range Signal Coverage** - The Remote IoAg Controller (RIC) is able to transmit the in-field sensor data over 10 miles to the IoAg network. That means each IoAg Gateway can cover over 200,000 acres of cropland with more than a 50,000 data point capacity with near unlimited capacity when IoAg gateways are repeated across the landscape.

- **Low Power Consumption** - 3 "AA" Alkaline batteries are used to power a RIC which transmits in-field sensor data over long ranges and lasts over 1 year without changing batteries. Solar panels, external batteries or other complex power methods are not required. The low power performance enables easy installation and low maintenance.

- **Easy access to Agriculture Data** - Data from sensors are transported to the IoAg server and stored on the Cloud that can be accessed by computing or mobile devices anytime and anywhere. The IoAg system supports many types of agricultural sensors to provide real-time data for soil conditions, water usage, irrigation canal flows, reservoir water levels, crop conditions, weather and farming conditions, and similar resource information of interest. Such information can be used by farmers to improve their agricultural processes, make real-time management decisions, monitor resource conditions, and evaluate conservation practice performance.

- **Versatile Sensors support** - Various types of commercially available sensors are supported by the IoAg system to provide comprehensive in-field agriculture data. The RIC (Remote IoAg Controller) accommodates a wide range of digital and analog sensors including common soil moisture sensors, multiple types of water flow meters, water level detectors, pressure transducers, wind speed and direction, temperature, rainfall, and water presence or absence. The system will be further expanded to support more sensors such as soil nutrient sensors, soil health monitors and Greenhouse gas monitoring when these sensors become available and affordable.

- **Proper Sensor Location -** Current data with telemetry systems generally require a location near a common in-field data transmission node. IoAg can be located nearly anywhere in the field without node limits where data collection such as soil moisture conditions or water application data is actually needed to make management decisions.

- **Low Device and Data Cost** - Device and data cost of IoAg is commonly 50% of existing commercial systems using cellular, mesh or private communication technology. For soil moisture monitoring, the current cost is as much as $1,500 for each location (device, sensor, communication, and telemetry cost), where IoAg will cost less than $750.

- **Easy to install and maintain** - RIC Installations take less than 5 minutes due to the simplicity of the RIC design without the need for solar panels, chargers or external batteries. On-site setup and validation tests for proper functioning are conducted with a mobile app "Ricster", and a mobile phone with Bluetooth communication. Users are able to use the “Ricster” app and mobile phone in-the-field to read real-time sensor data, trouble shoot, and verify the installation and performance.

System and Product Descriptions

The Internet of Agriculture (IoAg) is a beginning-to-end solution from capturing in-field data, transmitting the data utilizing a wireless network, storing the data on the cloud, processing and presenting data into usable forms, aiding in decision management, and outputting information and results to the end users. The IoAg system is comprised of 3 main products:

- **Remote IoAg Controller (RIC)** - The RIC is a battery operated device which controls and reads sensor data, records data on-site, and communicates data wirelessly to the IoAg network and gateway

- **Wireless IoAg Network (WIN)** - The WIN is a Low Power Wide Area Network (LPWAN) and Gateway which communicates with the RIC and transports data to the IoAg Cloud Data Management and Service Platform

- **IoAg Service Platform (ISP)** - The ISP is a Cloud Data Management (CDM) server, software and data platform that stores, processes, analyzes, and manages the data collected from the RIC located in the site specific field location. Output can be customized according to the needs such as analytical results, field reports, process control, alerts, and decision management.

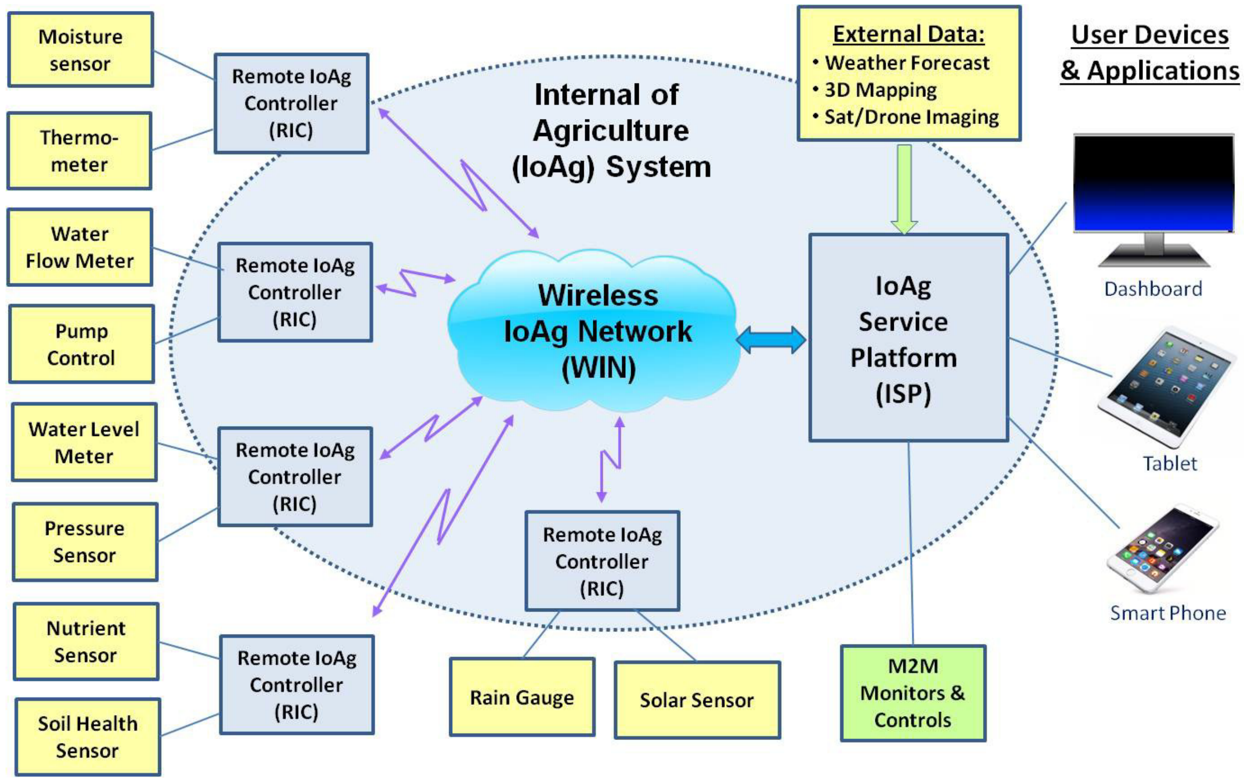


Figure 1: Block Diagram of Internet of Agriculture

The block Diagram of the Internet of Agriculture is shown in figure 1. Multiple sensors are connected and powered by the Remote IoAg Controllers (RIC) that read the sensor data and send the data at real-time to the Wireless IoAg Network and Gateway. The data delivery schedule can be set according to the needs and applications from real time to longer durations. The IoAg Gateway streams the data to the Cloud Data Management server of the IoAg Service Platform where the data are stored, processed and analyzed. The IoAg Platform can provide various service packages according to the demands and applications such as soil condition monitoring, irrigation water management, resource tracking, carbon credit reports, etc. Users can access the data, results, reports and services using their computing or mobile devices.

Remote IoAg Controller and Implementations

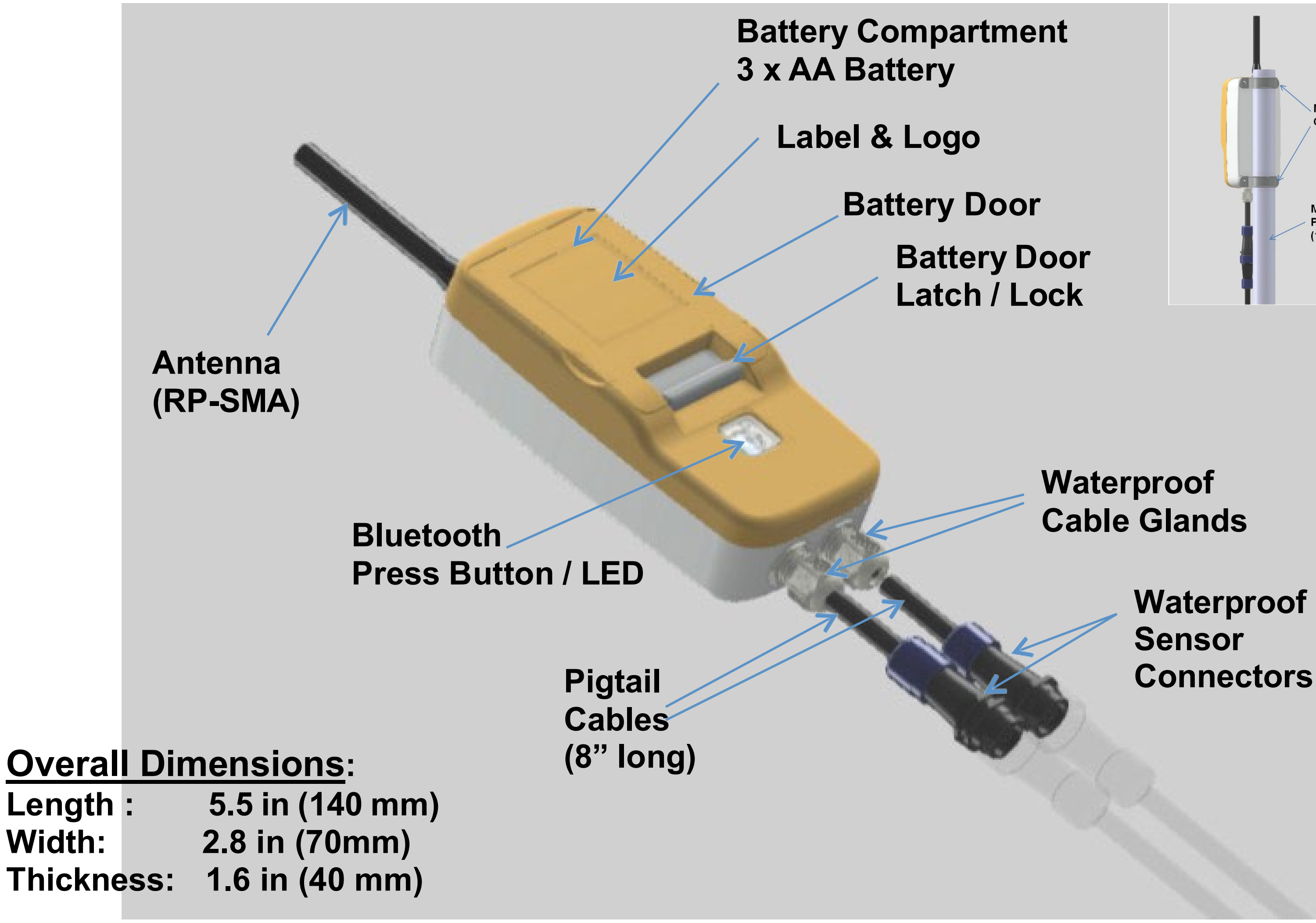
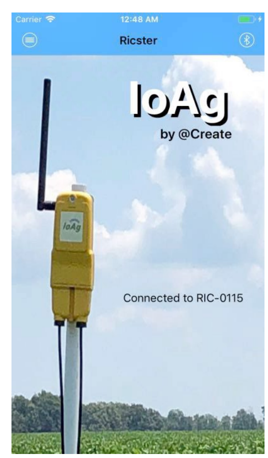


Figure 2: Remote IoAg Controller outline and mounting

The Remote IoAg Controller (RIC) is a key element in the implementation of the IoAg system. Not only will it read and transmit sensor data, the RIC provides power and control for various types of commercially available digital and analog sensors as well as storing the data on-site for redundancy and data safety. The RIC is dust-proof and water-proof to cope with the stringent outdoor environment. The RIC is simple to use, easy to install, with low power requirements and highly reliable for long-term data collection and transmission. This is accomplished with a 1 pound device operated with 3 AA batteries that provide the necessary power for 1 year or more. Figure 2 shows the outline of the Remote IoAg Controller. Each RIC currently supports 2 sensors connected to the RIC with couple-and-lock waterproof connectors.



The RIC is fastened to a commonly available plastic mounting pole inserted over a metal rod driven into the ground. Installations requiring greater heights to reach above the crop canopy utilize longer rods and poles, all of which are inexpensive. The entire RIC installation takes less than 5 minutes without any need for solar panels, chargers or external batteries.

The on-site setup and tests are performed by a mobile phone or tablet that is connected to the RIC via Bluetooth communication. We have developed a mobile app "Ricster" that provides the necessary functions to configure the sensors, data messaging, setting alerts, and scheduling data transmission times and frequencies. The App can conduct tests on sensors and read real-time data to verify the installation as well as routinely check field data during site visits via bluetooth. Users are able to use the Ricster app to access the IoAg cloud data to validate the data communications and settings. They can monitor data from other locations and make necessary adjustment to the configurations and change system set up values.

Multiple RICs with multiple sensors can be installed nearly anywhere within the coverage footprint (200,000 acres or more per Gateway) of the IoAg Network to provide not only spot data but aggregated long-term data from multiple locations with differing site conditions. This data can be utilized to make value added information available and enable farmers to make adjustment to their operations and to monitor conservation practice performance.

Pilot Implementation Results

During the pilot runs in 2018 and 2019, we conducted extensive testing and evaluation on the IoAg system in real-life on-farm installations. We have accomplished our primary goals to develop, implement and validate the performance of the IoAg system. Based on the pilot test results, we have proven that the Internet of Agriculture is fully capable of providing high capacity data, reliably, at a lower cost when compared to currently deployed methods, over a wide coverage area. These test results will be the performance benchmark and reference for future expansions of the Internet of Agriculture. NRCS can use the IoAg system and the test results for new practice standard adoption and other conservation programs. The pilot test results are summarized in the following.

IoAg Network Test Results

Over the course of the project, 3 IoAg networks were installed in the following locations:

a) Hazen, AR - located at the office of White River Irrigation District ("WRID")

b) Stuttgart, AR - located at the campus of Arkansas Rice Research Center ("ARRC")

c) Judd Hill, AR - located at the Judd Hill Research Foundation Farm ("JHRF")

Network performance including the communication range, quality of signal and it's usability were tested with Remote IoAg Controllers (RIC) as the reference remote device. Multiple Test messages were sent from the RIC at locations of varying distances relative to the IoAg Network Gateways. The received messages at the IoAg Network and Gateway were evaluated to determine the signal quality, data link reliability, and the communication range.

The test results verified that the communication range of the WRID and ARRC networks to be consistently over a 10 mile radius. The effective coverage is approximately 200,000 acres for each network gateway. The distance between WRID and ARRC network stations is about 23 miles. We were able to send data messages from the RIC continuously across the WRID and ARRC networks in excess of 40 miles long and 20 miles wide resulting in a footprint of about 500,000 acres.

The range of the Judd Hill network was about an 8 mile radius that was less than the WRID and ARRC locations. The Judd Hill installation was surrounded by trees in close proximity to the Gateway that might cause attenuation and reception of signal reduction. Future plans will include moving the Gateway to a more accessible location with less canopy.

Despite the relatively flat terrain of the network coverage area, there were obstacles like trees, buildings, and rolling fields that might cause attenuation of the signal. We found certain spots, mostly with trees in close proximity to the RIC, reduced the effective range due to such obstacles. The issue could be resolved by positioning the RIC away from those obstacles.

The performance of the IoAg network was further evaluated with the field installed RICs and sensors. Sensor data were transmitted by the RIC at pre-set intervals to the networks. Each data message was tagged with a sequence number. The quality of the network (QoN) was evaluated by examining the received messages and sequence numbers to identify any missing messages. For the past 15 months, over 20,000 messages were sent from each installed RIC and sensors. The QoN results have demonstrated the network consistency and reliability to transport and process massive amounts of data under the network footprint.

RIC and Sensors Field Implementation Results

We started the pilot deployment of Remote IoAg Controllers and sensors in July 2018. During the pilot implementations, we have installed and tested 9 different commonly available types of sensors in field conditions. These were commercially available sensors including 2 types of soil moisture sensors, 3 types of water flow meters, water flow switches, ultrasonic distance sensors, pressure transducers, and temperature sensors. Specific data interface and protocols were developed for the RICs to ensure the system compatibility and power consumption of each type of sensor and the accuracy of the sensor readings. Based on the test results, we have validated the usability and accuracy of the sensors, the interface with RICs, and data conversion protocols of the IoAg Cloud Data Management. RICs and sensors were installed at selected locations on 3 farms - Larkin, Sabbatini and Hooks Farms providing data for temperatures, soil conditions, irrigation processes and water levels. In-field data were collected and delivered in scheduled intervals (typically every 15 to 20 minutes) throughout the growing season in 2018 and 2019. Soil moisture sensors installed at different depths of soil and different locations provide valuable data of the soil conditions. The irrigation process, water consumption and distributions were monitored and controlled with respect to the soil conditions. Water level sensors in tail-water systems and reservoirs tracked water levels and the status of storage and surface water use. All these data were collected from sensors and were transported and stored at the cloud server of the IoAg Service Platform (ISP). The data were then processed and analyzed to demonstrate the output and comprehensive results and decision management information that farmers could utilize to track resource conditions. Figure 3 shows the test results of the IoAg implementation at the Larkin Farms. They demonstrate the viability of the IoAg system to provide long term irrigation data such as pump operation and flow rates and water volume consumed in the irrigation operations. More importantly, the effect of the irrigation process could be revealed by the soil moisture pattern of the soybean field. The combined data and results could be utilized to improve the water management and soil health management.

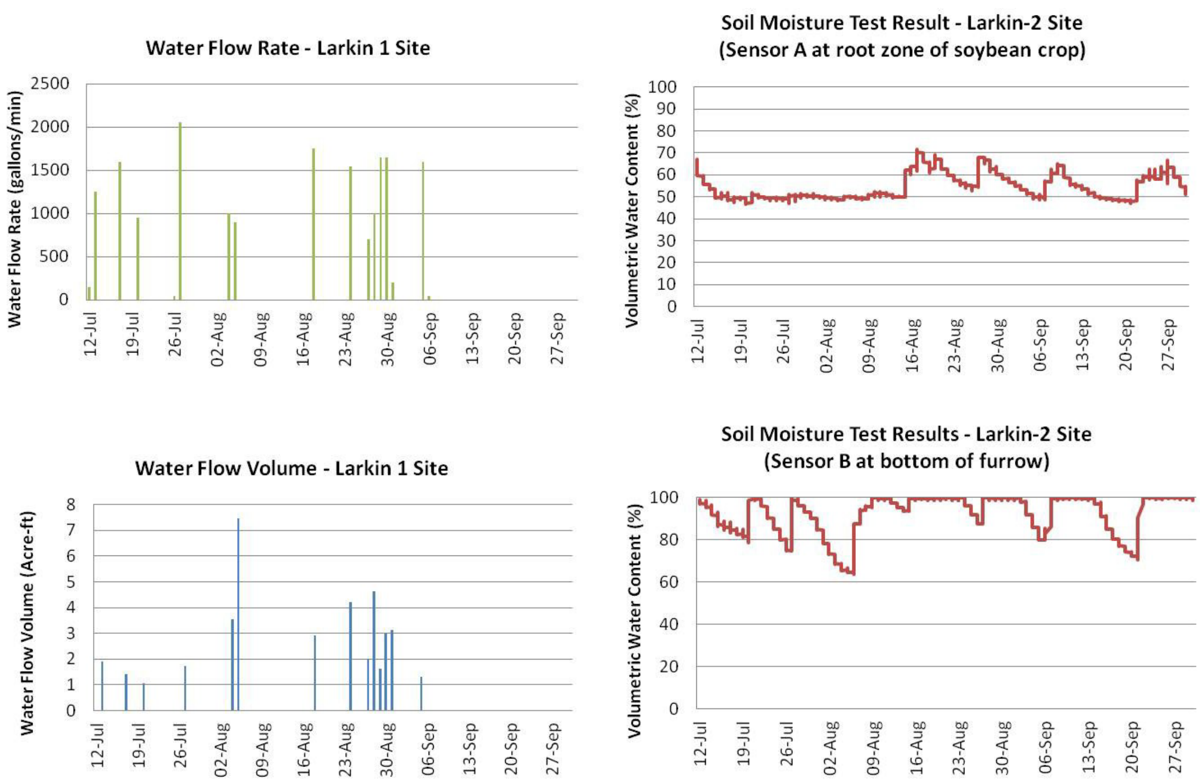


Figure 3: Test results of IoAg implementation at Larkin Farms

During the past 24 months, we have proven that the cost of data collection can be reduced, the usability and availability of that data can be improved significantly, and "the last mile" issue has been eliminated or at least increased to 8 or 10 miles. The IoAg is a valuable tool to reduce the cost of conservation practice implementation, and provide a meaningful avenue for farmers and NRCS to track conservation practice effectiveness.

Challenges

In the course of this project, we have not encountered any serious problems or difficulties in the development and implementation of the Internet of Agriculture. Most of our limitations are associated with funding that limits network expansion and accelerated data collection. The installation of the network, Gateways, cloud server, RICs and sensors were conducted according to our plan, on time and within budget. The operation and performance of the IoAg system has exceeded our initial expectations. There were some software issues discovered during testing and field implementation. These issues were resolved by firmware and software changes. Based on the field results and user feedback, we have made several design modifications to the RIC and Ricster app to improve the user interface and robustness of the system. Two significant modifications were made during the implementation process. 1) Bluetooth functions were added to the RIC and Ricster app to improve the on-site installation, testing, verification, and making on-site sensor readings and 2) sensor “plug connections” were modified to make field RIC to sensor connections easier and more reliable.

Like most new game changing technologies, the major challenges facing the Internet of Agriculture are the adoption difficulties, crossing the chasm to main-stream, and clear resource limitations for a national technology roll out.

Adoption Difficulties

The Internet of Agriculture is new. It was not the intent of this CIG to perform a full-scale deployment. That effort is planned to start in the 2020 growing season. However, during this proof-of-concept work we found it difficult to communicate the value of data, especially environmental and resource data. Farmers are familiar with soil moisture sensors, flow meters, rain gauges and such, but they sparingly use these data points as a key resource within their operations. In most cases, such data is not in a meaningful format with recommendations, the timing is wrong to meet their needs, or the value is limited for their purposes. They see data from a station (e.g. pump flow rate) as one piece of data to be used at that specific time and discarded. What they don't see is a system that can collect and record long term data at the same station under different conditions, and combine data from other locations, to provide a data base that can be utilized to make extraordinary value added information and decision points for their farm. Why? Because that process has not been developed or available until now with the IoAg system and even now, implementation is an unknown because of the lack of committed resources for network deployment. These value added components can enable the farmers to make adjustments to their operations, to automatically generate year-end reports, make their own irrigation water management decisions, and to monitor conservation practice performance. That, we believe, is the value of data and is yet to be proven to farmers by anyone. We all need to do a better job of communicating the value and benefits of data but only after we can demonstrate the value with reliable economic or resource protection benefits. We need to make the data less expensive and more valuable.

Crossing the Chasm

Related to the adoption difficulties is the challenge to cross the chasm from early adoption to main-stream majority. In the early adoption stage, volume of usage is relatively low despite the effort in promoting the benefits of this new tool and value of data. On the other hand, significant resources are needed to deploy the initial network to provide reasonable coverage for identified farming regions. During 2020 we are anticipating raising the necessary capital to implement a regional network. This is a catch 22 issue. We have to convince the investors and stakeholders on prospective growth and market acceptance of this innovative technology. We also recognize the limitations of a small organization like the White River Irrigation District to implement a nationwide system that meets the diverse and varied technical, conservation and farming needs. It is crucial to obtain support from NRCS and agricultural communities to generate necessary drive and momentum to move forward with this game changing technology.

Potential Next Steps

The Internet of Agriculture project has completed the "proof-of-concept" phase where we have demonstrated and documented the components, system performance characteristics, cost, and identified the vast potential for this technology. The next phase is to roll out the networks and on-farm implementations in Arkansas and Lower Mississippi River Valley region. Our goal is to eventually provide national coverage for 350 million acres of US cropland.

In addition to the current 3 operating networks, we plan to install 4 more networks, resources permitting, in the Grand Prairie region of Arkansas providing coverage for nearly 1 million acres of intensely irrigated cropland. We expect to initially engage 15 to 30 farms to implement advanced irrigation water management and other conservation practices, and to measure watershed ground water and surface water impacts. This will serve as the model for future expansion and replication. Our initial focus will be on commonly accepted and utilized technologies including flow meters, soil moisture sensors, weather stations, and water table monitoring.

To accelerate the rate of adoption, assuming funding resources are available, we plan to migrate the IoAg network to an open-platform that can be accessed and utilized by developers, service providers, public and private companies. New data products, applications and services can hence be developed cheaper and faster for farmers and agricultural communities. The open-platform can be replicated at nearly any location within the US and thus greatly speed up the national roll out of the IoAg networks. If raising the necessary capital from the private sector to implement a regional network is required, the open-platform decision must be revisited.

We will continue to promote and market the IoAg network, platform and services. These valuable tools will improve the agricultural process and conservation practices for immediate conservation management decisions, tracking performance and provide data for long term monitoring and evaluation of conservation practices. The benefits of low cost data, with high value for both the farmers and the public, combined with wide coverage will help to increase the pace and scale of conservation adoption.

Additional Document and Reports Available but Not Included in this final report as per instructions/suggestions for final report submittal

- Internet of Agriculture System and Products
- Internet of Agriculture Marketing Fact Sheet
- Internet of Agriculture Data Sheet documentation sheets
- Internet of Agriculture Implementation Test Reports
- Internet of Agriculture Presentation Materials
- Internet of Agriculture Installation and User Manual