# Data Standards for Precision Irrigation

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**Abstract.** *Technology has provided many tools to help growers irrigate their land more efficiently. However, these tools rarely work together well, and; growers using them must invest extra effort to bring the information together. Improving interoperability among these tools will reduce users' effort, increase adoption, and lead to greater water use efficiency through improved accuracy and precision of irrigation management.*

*Over the past year, a group of companies began collaborating to develop data standards to enable interoperability of environmental sensors, soil mapping, advanced pump controls, variable rate irrigation, and software applications. The goal is an industry-wide format that will enable the exchange of data currently stored in a variety of proprietary formats, and use of the data by irrigation management systems. This work is currently taking place in the context of AgGateway's Water Management Group and PAIL project. We will present the results of this collaboration and invite future participation.*

**Keywords.** Irrigation, Data Standards, Decision Support Systems, Schema, Use Case, System Integration

## Introduction

Irrigated agriculture in the US accounts for 80-90% of the consumptive water use and approximately 40% of the value of value of agricultural production(USDA, 2009; Schaible and Aillery, 2012). This value, totaling nearly $118 billion, is produced on 57 million acres. Given the increasing challenges in water availability caused by climate change, and the likelihood of increased water conflicts from competing users, irrigated agriculture must increase its efficiency without sacrificing a reduction in the value it produces (Schaible and Aillery, 2012). Much of this efficiency can be derived through application of precision irrigation technologies, and on-farm management systems that facilitate sound agricultural practices. However, less than 10% of irrigated farms use any type of advanced decision support tools or technologies (USDA, 2009). Improving adoption of these technologies is critical to increasing efficiency.

There are a variety of technologies available for precision management of irrigation. Remotely actuated center pivots, drip irrigation systems, soil moisture sensing, on-farm weather stations all enable precise application with precise timing. Numerous software tools exist for deciding when and how much water to apply. However, rarely do these tools interoperate effectively. Data must be moved manually from one application to another and the burden is on the grower to do the data management.

IN 2011 the Northwest Energy Efficiency Alliance (NEEA) convened a group of irrigation expert to discuss issues that will lead to improved energy efficiency of agricultural irrigation. One of the conclusions from that conference was that the irrigation industry needs to support more integration of agricultural technologies. To that end, a group of companies, industry representatives, academics, and interested parties are collaborating to address the integration problem. This project, called Precision Ag Irrigation Leadership (PAIL), has the specific goal of producing a set of data exchange standards[1] that will enable development of more efficient and easier to use solutions for irrigation management.

## An Integrated Solution

Part of the motivation for the PAIL project is the need for an integrated irrigation management system. A great variety of technologies exist for precision irrigation (Smith et al., 2010) and many of these technologies have been available for many years. The nature of irrigation management is such that using all these technologies places and additional burden on the decision maker. The source of this burden is the lack of integration. Nearly all of the information must be moved by the operator.

To provide a conceptual foundation for the data standards development, a fully integrated decision support system in proposed. This system, shown conceptually in Figure 1, will take data from as many sources as is practical, integrate the information using a decision support system, and deliver the irrigation recommendations to the appropriate irrigation system components. The integrated system is a goal as well as a foundation. Today, building a system as shown in Figure 1 would be a significant undertaking. The work and technical expertise required would put this system out of reach of all but the most sophisticated farms. When the data standards have been developed and adopted, constructing such a system would be practical and perhaps even common.

[1] In this document the terms 'data standard' and API (application programming interface) are used interchangeably.

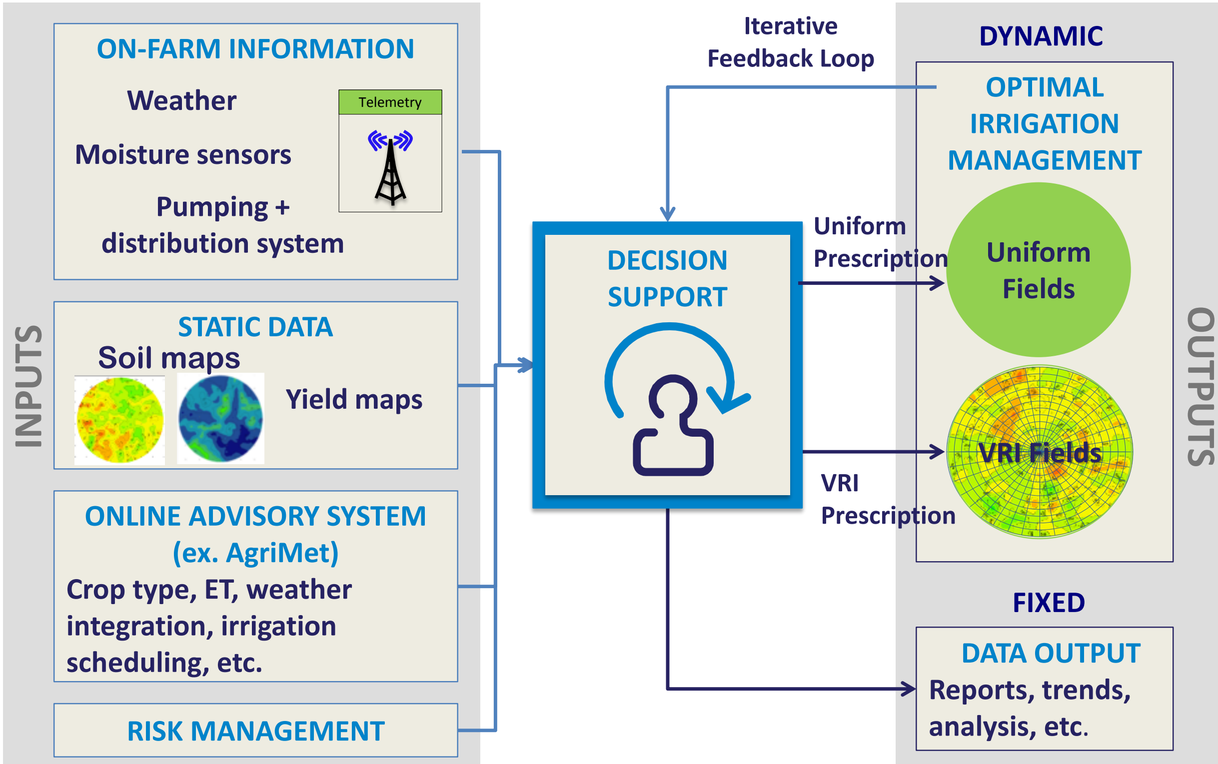


Figure 1 Representation of a fully integrated precision irrigation management system

To give a practical view of how growers will benefit from the API consider the following example. Suppose a grower has 15 quarter mile pivots. This grower is the quintessential modern agriculturalist. The grower uses efficient pivot irrigation systems, remote monitoring and control of the pivots and pumping systems, on-farm weather stations, soil moisture monitoring via remote telemetry, and software to use all these devices. Today, for this grower to implement scientific irrigation scheduling (SIS) he/she must keep records of how much water is applied and when, how much ET has occurred, and any precipitation that occurs. Soil moisture measurements must also be recorded and converted into volumetric water content. To schedule irrigations, the grower must integrate all of this information into a software tool that will calculate a water balance and estimate irrigation dates and amounts. Each of these sources of information is stored in or derived from a separate system. To use the scheduling system, the grower must spend a few minutes entering irrigation amounts, copy-pasting weather data, and evaluating results. This process may only take a few minutes per field but, with 15 fields, that time adds up. If the grower can do each field in 4 minutes then he/she can complete this process in about an hour. In water short or resource constrained conditions irrigation management occurs every day. This means the grower must spend an hour every day moving data around.

When the API is fully adopted a different scenario is possible. The system that monitors and controls the pivots will output irrigation history in a specific file format. Similarly, the weather station, soil moisture monitoring devices, and pumping controls will also use standard formats. The SIS software that calculates the water balance will read these standardized data files automatically. The SIS software can also output irrigation recommendations in a standard format; the same standard format that the pivot control system can read. With all of this integration in place the grower only needs to review, modify, or approve the schedules generated by the system. In this scenario the technologies in use are the same as those from the previous scenario. But now, because of the integration the grower spends less time moving data around and more time benefiting from the technology.

The previous example makes the benefits to the grower apparent but there are also important benefits to the irrigation industry. Barriers to grower's adoption of new technology includes both the time/effort required to use the technology and the cost of acquiring it. Use of the API by industry will address both of these issues. The scenario described previously shows how the time/effort will be reduced. If we assume that growers have different levels of effort that prevents them from adopting and that this level varies between individuals, then by reducing the effort required there will be more potential adopters. Thus, adoption of the API increases the size of the market for advanced irrigation technologies

The API can address the cost issue also. The following example describes an integration effort that actually occurred between two companies in 2008. A significant amount of time and effort was invested by both companies. The collaboration was successful and both companies benefited from the project however, the costs were not trivial. If an API had been available both companies could have achieved the same goal with lest time investment required. This is how the API reduces costs for the grower: by reducing cost of development of new interoperability between existing systems, those savings can be passed on to the customer.

**Summary:** In 2009, CropMetrics and AgSense worked jointly to develop the industry's first wireless Variable Rate Irrigation solution.

**Issue/Problem**: CropMetrics developed a VRI speed control prescription program but did not have any way to implement or load the prescription file effectively on the center pivot. At the same time, all center pivots were limited on the number of application adjustments they could make.

**Solution**: Working collectively with AgSense, they developed a prescription data format to upload wirelessly to AgSense's pivot monitoring and control website via a new API protocol developed by AgSense. AgSense then controls the speed of the pivot to adjust water application based on the CropMetrics variable rate prescription file. This was the first full integration of variable rate speed control irrigation.

**Collaboration**: Without the close working collaboration of both companies, the success of this technology would have been delayed or halted. Working together to develop a data standard, made wireless data transfer possible with greatly improves the efficiency, effectiveness and overall simplicity of the technology today.

**Business Success**: The development of this VRI technology introduced new development by pivot manufacturers to improve hardware to accept similar capabilities as well as introduced business opportunity for agronomic service providers. Most importantly, this joint effort delivers a solution to improve water use efficiency and conserve our most valuable natural resource.

## Target Market for an Integrated Ag Irrigation Solution

The USDA Economic Research Service (ERS) categorizes farms primarily on the basis of Gross Cash Farm Income (GCFI)[2]. Previous versions only used annual sales income. ERS recently updated the typology to reflect three important trends: commodity price increases, a shift in production to larger farms, and the rapid growth of the use of production contracts among livestock producers

For PAIL's purposes the relevant categories are derived from (Hoppe and MacDonald, 2013):

1. Small Family Farms, GFCI less than $350,000
2. Mid-size Family Farms, GFCI between $350,00 and $900,00
3. Large Scale Family Farms, GFCI greater than $1,000,000
4. Large Family Farms, GFCI of $1M - $499,999
5. Very Large Farms, GFCI of $5M or More
6. Non-Family Farms (includes Corporate Farms and Cooperatives). GFCI level is not specified. Defined as any farm where the operator and persons related to the operator do not own a majority of the business.

The previous version (2001) of the typology included large farms, with sales between $250,000 and $499,999, and very large family farms, with sales of $500,000 or more. However, farm production is shifting to much larger farms, thus the additional category of Mid-size family farms and the much higher levels of GCFI. Farms that annually generate $250,000 plus in sales represent just 10% of the nation's farms, but account for 82% of U.S. food production (CNN Money, Nov 2012).

Due to the size of investment (both time and money) to deploy an integrated solution, the *ideal* target customer for a level 2 or 3 Integrated Ag Irrigation solution is the Large Scale Family Farm or the Non-Family Farm. Mid-size Family Farms who are early adopters may also be targets, but would likely need large incentives as part of purchase. Small Family Farms are more likely to adopt the Level 1 solution, if they are to make a change.

In addition to the definitions above, the ideal target customers have one or more of the following characteristics:

1. They have a requirement or compelling need (either through natural causes or government regulations) to reduce irrigation water use.
2. They must manage multiple brands of equipment, especially center pivots.
3. They already have a level of data management on their farm and employ one or more employees who are dedicated to data management and integration.
4. Their overall attitude toward farming technology is forward thinking.
5. They are required by their local government, utility or crop insurance provider to report applied irrigation and/or chemigation.
6. They are already ready to purchase new irrigation capital equipment.

For the grower, the opportunity is to increase profitability through lower energy use and reduced costs with the availability of an integrated, easy-to-use decision support solution that uses a flexible approach combining optimal irrigation techniques with well-integrated soil, moisture, and weather data. The AG IRR initiative offers opportunities for cost reduction in energy, fertilizer and the

[2] GCFI includes the farm's sales of crops and livestock, receipts of Government payments, and other farm-related income. Gross farm sales, in contrast, exclude other farm-related income and include items than are not revenue to the farm: the value of sales accruing to share-landlords and production contractors and Government payments accruing to landlords.

associated labor expenditures. In-stream water requirements limit the amount of irrigated land development and water efficiency may drive more acreage development.

The irrigation data standards can also be seen as part of a larger set of data standard requirements. Growers are seeing an increasing need to integrate distinct sets of farm data. Merging precision farming technologies offer advantages in identifying, managing and tracking their products. However, given the lack of data standards and interoperability between manufacturers and suppliers, they also create significant challenges as dissimilar products and platforms multiply.

Allan Fetters, Director of Technology at J.R. Simplot Company and a PAIL team member, agreed with McDowell. "Growers are inundated with data. We have diagnostic and performance data coming in from each piece of equipment we use, on each and every field of the farm, let alone what and where all the crop inputs are being applied. This is compounded especially if you are running a mixed fleet of equipment," he explained. "Each source of data received on the farm is displayed in its own configuration, on its own site, so a lot of extra time is being spent trying to analyze this data and interpret it into useful information that is going to make the farmer more productive. We need a free flow of data to enable us to farm with the best real-time data available. Ideally I would have all of my key farm data and digital decision making accessible through one common, easy to use dashboard, so I can control, manage, troubleshoot, view, and analyze my farm data."

## Complex Systems Market Model

Developing and aligning to a set of data standards is a critical component of a larger system that must be configured before an integrated solution actually reaches the market. Unlike individual soil sensors or field weather stations, which are high volume sales, the AG|IRR solution is a complex systems market model.

Figure 2 below shows an adaptation of Geoffrey Moore's model for complex systems (Moore, 2005), as applied to an agricultural irrigation system.

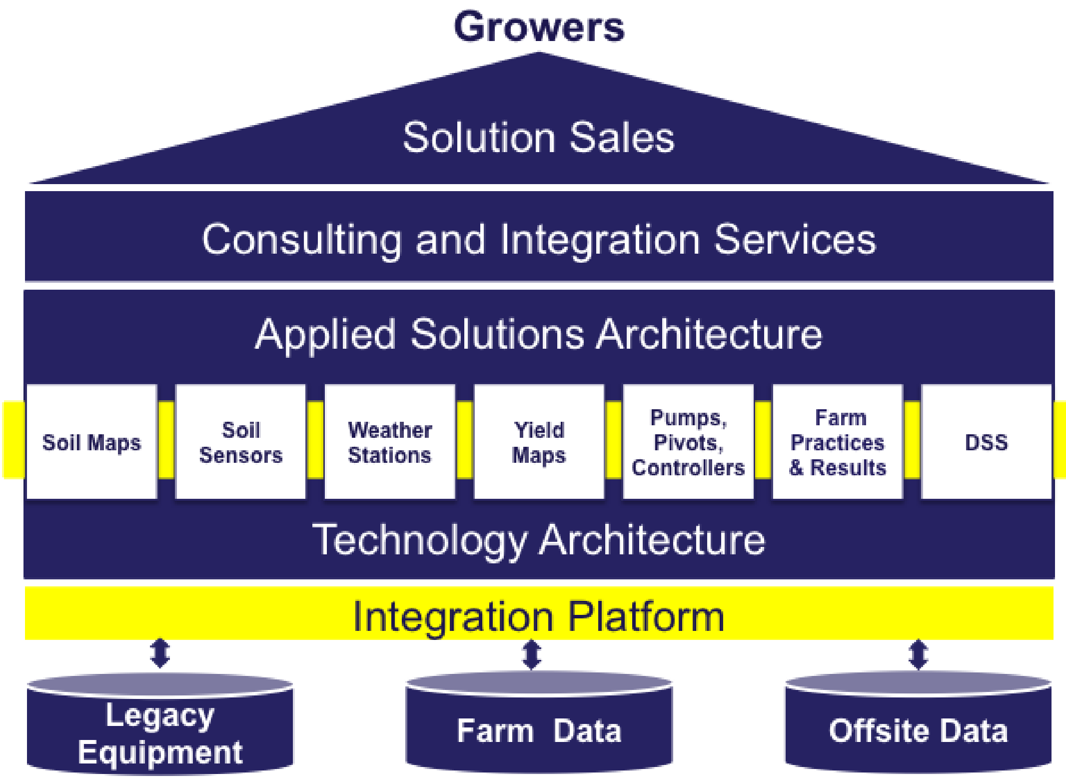


Figure 2 Complex Systems Market Model

The model is organized around the grower because market success is dependent upon a relatively small set of customers making relatively large purchase commitments. Qualified customers are the scarcest resource in the system. They typically have the power in sales negotiations, and solutions must be customized to fit within their existing farm management processes and equipment infrastructure. No two solutions are identical. Lead times are long.

Solution Sales can be driven from a local sales source, such as an irrigation equipment retailer, or in conjunction with a consulting service. Irrigation consultants can either work directly with growers or vendors. In some cases, they may be tied directly with a particular pivot or irrigation services provider. Their role is to bridge the specific needs and requirements of the grower and the core capabilities of the Ag Irrigation solution.

Two sub-architectures surround a set of multiple, disparate elements. These elements are modules that can be used to provide the system's ability to generate irrigation prescriptions and to monitor and report the results. Different vendors often supply them. The system is extensible: new modules can be added. And the system can integrate with other FMIS systems if necessary or desired.

The technology architecture unifies the system on the systems-facing side. It includes common facilities and protocols, such as the PAIL data standards and data transfer mechanisms. It would also include the business rules for those data standards. The technology architecture enables disparate elements to be swapped in and out to create different solution sets, without having to reconstruct everything from the ground up.

The solution architecture unifies these elements in a way that is clear and actionable by the grower. It consists of application specific templates that align the generic Ag Irrigation solution with the specific grower's needs. It embodies business and farm processes that are specific to that grower, and communicates the business results of the applied application. It is also understandable and sellable by the consultants and system integrators, as well as the solution sales force. It includes the user interface, as well as instructions and training.

The bottom layer indicates what the grower already has in place: pivots and other equipment, a local database, as well as offsite data, such as SSURGO soil maps or Agrimet weather forecasts. Above that, the Integration Platform provides a buffer that is familiar to the current generation of farm managers, has proven reliability, probable longevity, and is predictable in its interactions with the equipment and systems with which it interfaces.

No one member of the value chain can deliver all the products and services end-to-end. Typically this requires a company that has a reputation in the solution space that gives it permission to lead, bringing in value-added partners who can complete the solution model.

## The PAIL Project

The goal of the Precision Agriculture Irrigation Leadership (PAIL) Project is to improve agriculture irrigation by developing a common set of data standards and formats to convert data for use in irrigation data analysis and prescription programs.

"Ultimately, the objective of this project is have a common set of data standards and protocols used across the agriculture industry," says Terry Schlitz, AgSense President and Chair of AgGateway's Water Management Council. "With those in place, industry can deliver much more efficient, easy-to-use solutions for producers, which in turn will help them use available water and energy more effectively."

Producers and manufacturers currently report that it is difficult and time-consuming to make decisions on how much water to apply when and where. That's because weather, soil moisture and other relevant data are stored in a variety of Original Equipment Manufacturer (OEM) formats and data sources.

"Growers have many more options now to irrigate their fields more effectively," said Andres Ferreyra, AgGateway Precision Agriculture Council Chair, and AgConnections research and development coordinator. "For example, they can invest in soil maps, install different types of pumps or flow meters, use soil moisture sensors, and put variable rate irrigation systems on their center pivots. There are a few software applications that tie them together. However, these tools don't actually talk to each other effectively or efficiently."

## Project Plan and Progress

The PAIL group officially began work in early 2013. A summary of the planned steps are shown in Figure 3. The project to have two parts. The first will focus on specifying the standard. The second phase will focus on testing and implementation, expansion of the standard to include other uses of irrigation technology, and inclusion of emerging issues. Specific deliverables of the first phase are:

- Use Cases - These will describe most (or all) of the likely scenarios where systems will use the data standards. The use cases also help to define the scope of the data standard.
- Glossary - a robust dictionary of terms and definitions as they are used within the context of specifying the data standard.
- Ontology - a technical specification of each of the quantities and variable referenced in the standard. The ontology uniquely identifies each of the variables referenced in the project.
- Schema - a technical document that unambiguously specifies all of the potential information, its structure, and interrelationships. This document is the basis for creating, verifying, and using documents and messages that conform to the data standard.
- A test of the standards wherein the standard's function and completeness are verified within the context of an integrated irrigation management system
- A proposed standard submitted to the American Society of Agricultural and Biological Engineering

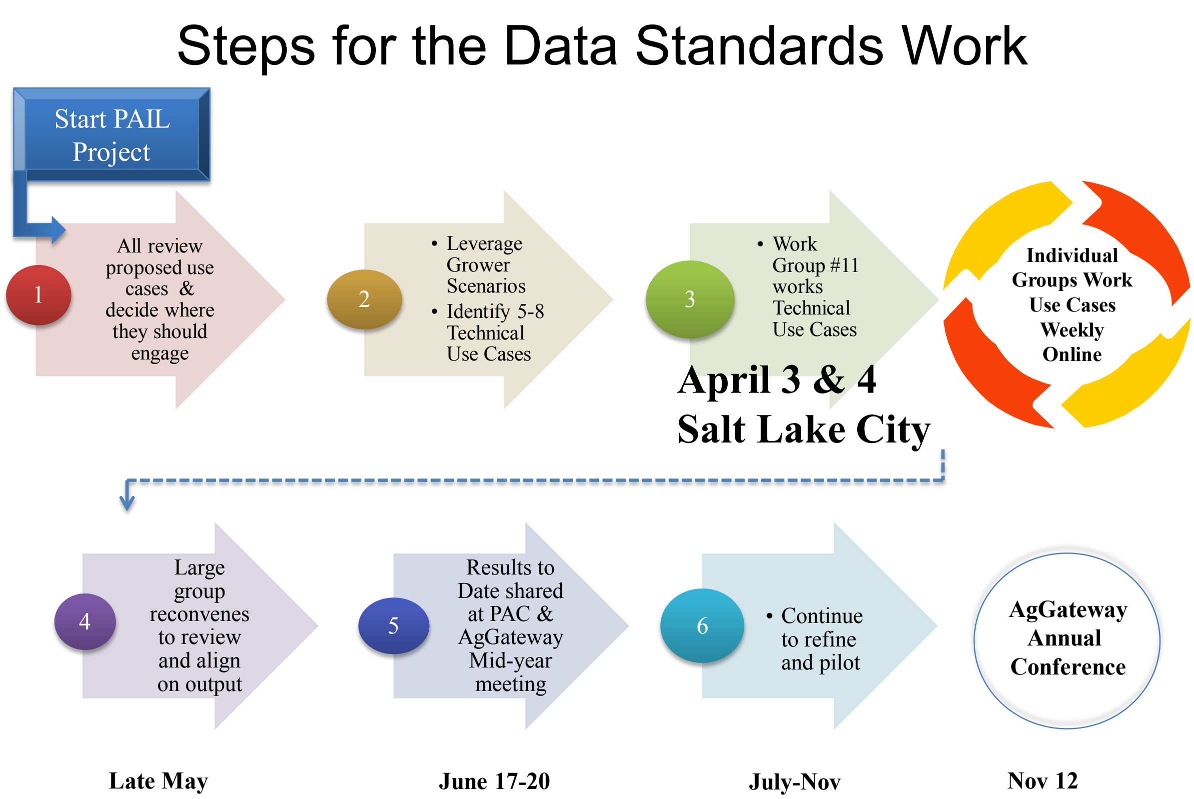


Figure 3 The PAIL Data Standards process

Significant progress has been made on the Use Cases that will fully define the scope of the data standard. A broad definition of the PAIL scope is included in the PAIL project charter. The scope is included below.

**In Scope**

1. Irrigation system (not restricted to pivots) setup, configuration, performance specification
    1. Location and geometry of the irrigation system
        1. Opportunity to discuss end gun, corner arm specification
    2. Flows and pressure
2. Irrigation system operation, control, and status
    1. Schedules (how much and when) and Prescriptions (where)
        1. Data representation for establishing a schedule / prescription's scope in space and time
    2. Error reporting, Alerts
    3. As-applied / resource use accounting (non-economic)
3. Pumping Plants
    1. Setup & Configuration
    2. Monitoring & Control
4. Data acquisition systems (Observations. Source is on-farm)
    1. Setup & Configuration
    2. General environmental monitoring
    3. Soil monitoring
    4. Atmospheric monitoring
    5. Plant-based monitoring
5. External Data Inputs (Offsite, weather networks, etc.)
    1. Weather Forecast, aggregated weather / climate info, weather networks
    2. Soil (SSURGO and other soil maps, EC maps, holding capacity maps, etc.)
    3. Energy
    4. DEM
    5. Historical Yield Data (Explore cooperation w SPADE)
    6. Manual Soil Sampling
    7. Crop Performance, Crop coefficients
6. Data Outputs
    1. Historical Weather summary
    2. Yield analysis
    3. Water balance (e.g., NRCS IWM reporting)

**Out-of-Scope**

1. Data exchange below the OSI (Open Systems Interconnection) Transport Layer, corresponding to the International Standards Organization (ISO) 7498 standard.
2. Crop simulation details
3. Biotic factor scouting details.
4. Considerations / recommendations about sampling rates.
5. Crop performance: Yield modeling
6. Human-mediated data acquisition (e.g. scouting)
    1. Stand density, quality, growth stages
    2. Abiotic stress factors, such as water and flooding
    3. Biotic stress factors, such as insects and diseases
7. Economics (energy use, energy cost, water costs, revenue forecast (estimated yield & price), estimated costs of other production practices (fertilizers, crop protection).

## Organization

The preceding scope statement includes a broad variety of information sources and types. Accordingly, the PAIL participants also represent a diverse group of technologies. Companies producing Farm Management Information Systems, Pivot Irrigation Systems, weather and environmental monitoring equipment, soil moisture monitoring equipment, and a few large growers are participating in the PAIL project.

### AgGateway

AgGateway (www.aggateway.org) is a non-profit consortium of approximately 200 companies of the agriculture industry. Its mission is to promote, enable, and expand eBusiness in agriculture. AgGateway member companies work on projects within nine industry segments, including Ag retail, crop protection, crop nutrition, seed, grain and precision agriculture.

The irrigation data standards work is happening within the Water Management Working Group, part of AgGateway's Precision Ag Council. In November 2012 the companies that had previously been working on data standards development with NEAA agreed to move the standards development effort into the AgGateway environment, to benefit from AgGateway's anti-trust umbrella, to benefit from AgGateway's existing infrastructure and standards development and maintenance services, and to benefit from the synergies that could arise from exposure to a larger group of businesses committed to data exchange standards. As a result, AgGateway's Precision Ag Council chartered the PAIL (Precision Ag Irrigation leadership) Project in early 2013.

### Northwest Energy Efficiency Alliance

The Northwest Energy Efficiency Alliance (NEEA) is a non-profit organization working to increase energy efficiency to meet our future energy needs. NEEA is supported by and works in collaboration with the Bonneville Power Administration, Energy Trust of Oregon and more than 100 Northwest utilities on behalf of more than 12 million energy consumers. NEEA uses the market power of the region to accelerate the innovation and adoption of energy-efficient products, services and practices. Since 1997, NEEA and its partners have saved enough energy to power more than 600,000 homes each year.

### Workgroups

Given the breadth of information covered by PAIL's scope, it is impractical to have the entire group address the entire scope simultaneously. Instead three sub groups have been formed: Inbound data sources, Field Operations, Setup & Configuration. A conceptual representation of these groups is shown in Figure 4. The scope of the different groups illustrates the collaborative development process used in PAIL. The work groups were not defined *a priori*. The groups evolved out of several of the PAIL group meetings. The different company representatives whose products interacted or performed similar functions gravitated together to focus on data exchanges that their products were likely to perform. Not only does this partitioning provide a practical decomposition of the scope, it also provides a convenient way for new participants to find the right workgroup for their participation.

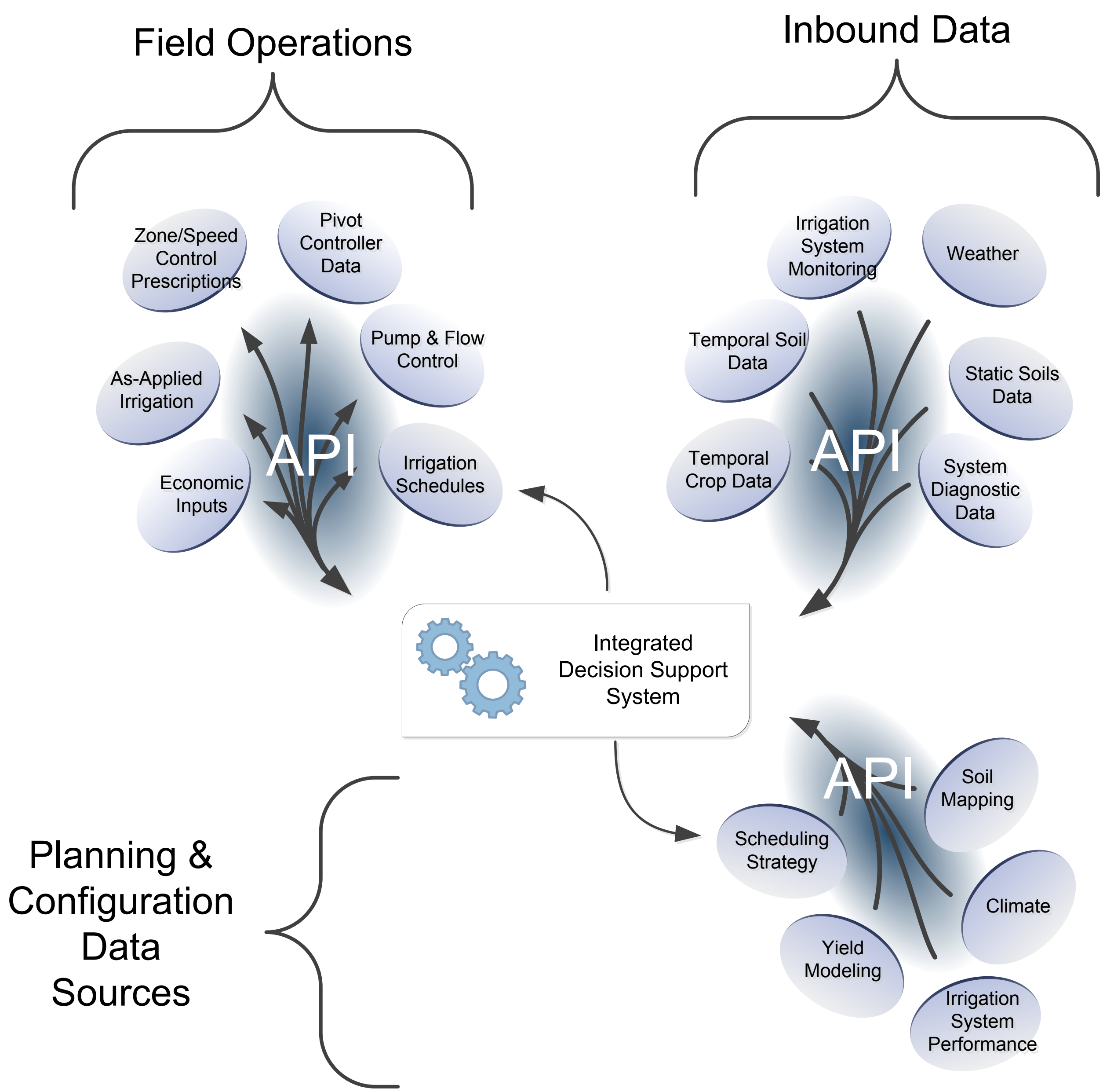


Figure 4 Conceptual representation of PAIL work groups

## Conclusion

System integration is a significant factor in ease of use of advanced technologies. Adoption of new irrigation technology is limited by the effort required to use the technology. The Precision Ag Irrigation Leadership project is expected to have a lasting beneficial impact on the agricultural irrigation industry. PAIL will improve interoperability of irrigation technologies and, consequently, increase adoption of more efficient irrigation practices. This paper has described the goals, structure, and progress of the Precision Ag Irrigation Leadership project. The PAIL project is ongoing and the workgroups expect to complete their goals in 2014. Plans for the second phase, PAIL 2, are already underway. Companies, institutions, and organizations interested in participating should contact the authors for instructions on how to join AgGateway and how they can contribute to this effort. As of November 2013, membership in the PAIL project is still open to new participants; it requires membership in AgGateway, and membership in the PAIL project. Interested parties should contact AgGateway Member Services (member.services@aggateway.org) for more information.

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