

Defining precision irrigation: A new approach to irrigation management

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ABSTRACT

Although the term precision irrigation is now quite widely used, often to mean drip irrigation, there is no commonly accepted definition or conceptualisation of the term, and no cohesive framework to guide research, development or adoption. This paper is reporting on a review of precision irrigation funded by NPSI. This review is considering the role of current irrigation application technologies in precision irrigation, variable rate applications, adaptive control, and the sensing and decision support requirements.

Precision irrigation as a concept differs substantially from current practice. In this paper (which is a slightly expanded version of a research bulletin recently published by NPSI) we have defined it using precision agriculture principles. It is well acknowledged that precision irrigation involves the 'differential irrigation' treatment of field variation as opposed to the 'uniform irrigation' treatment that underlies traditional irrigation management. However, we contend that precision irrigation is much more, that it must be holistic in its approach, adaptive and applicable to all irrigation methods.

INTRODUCTION

Despite the widespread promotion and adoption of precision agriculture in dry land cropping systems, the concept of irrigation as a component of precision agricultural systems is still in its infancy, both in Australia and internationally. There is currently no cohesive framework available to guide research, development or adoption of precision irrigation and its associated sensing, control, and decision support technologies.

This project is reviewing research in precision irrigation, existing technologies and the application of precision irrigation. It will assess the role of current irrigation application technologies in precision irrigation, variable rate applications, adaptive control and the sensing and decision support requirements. Opportunities for adoption, future research and extension needs will also be identified. The first stage of the project – conceptualizing and defining precision irrigation - is summarised in this paper. The newness of precision irrigation means there has been very little discussion around the concept—and any research being conducted will certainly benefit from shared knowledge.

WHAT EXACTLY IS PRECISION IRRIGATION?

Drip irrigation is often regarded as epitomizing precise irrigation because of its ability to control application rate and timing. The traditional meaning of precise irrigation is about applying precise amounts of water to crops at precise locations (e.g. within the soil profile) and at precise times – but uniformly across the field. This traditional definition is still widely used, particularly in the commercial sector. An internet search of the term 'precision irrigation' brings up a large number of irrigation installers and equipment sales companies, particularly in the area of turf and drip irrigation installations.

Precision irrigation as a concept differs substantially from this common usage. For this project, we are defining precision irrigation using precision agriculture principles.

A review of the rather sparse literature on precision irrigation brings up a range of definitions, including:

The accurate and precise application of water to meet the specific requirements of individual plants or management units and minimize adverse environmental impact (Raine et al., 2007).

The application of water to a given site in a volume and at a time needed for optimum crop production, profitability or other management objective at the site (Camp et al., 2006).

Applying water in the right place with the right amount (Al-Karadsheh et al., 2002).

Irrigation management (depth, timing) based on crop need to defined sub-areas of a field referred to as management zones (King et al., 2006).

There is a common element to all of these definitions, involving the 'differential irrigation' treatment of field variation as opposed to the 'uniform irrigation' treatment that underlies traditional irrigation management. Precision irrigation focuses on individual plants or small areas within a field, while the traditional practice takes a 'whole-field' approach. However, precision irrigation is much more than the precise application of water:

- precision irrigation involves the optimal management of the spatial and temporal components of irrigation;
- precision irrigation is holistic, it should combine seamlessly the optimal performance of the application system with the crop, water and solute management;
- precision irrigation is not a specific technology, it's a way of thinking, a systems approach.
- precision irrigation is adaptive, it's a learning system; and
- precision irrigation is applicable to all irrigation application methods and for all crops at appropriate spatial and temporal scales.

Other definitions of precision irrigation are informed by the large quantity of international research that has focused on variable rate technologies for pressurized irrigation systems, particularly centre pivots, for example:

Precision irrigation now includes a spatially variable capability. To achieve such capability, an otherwise conventional irrigation machine would need variable-rate sprinklers, position determination, variable-rate water supply, variable-rate nutrient injection (probably), and variable-rate pesticide application (possibly) (Sadler et al., 2005).

However, it is our view that variable rate technology, applied at the scale implied by this definition, is not an essential component of precision irrigation, rather it is one of the many tools that may be applicable in implementing a precision irrigation system. The concept of precision irrigation can be applied to all forms of irrigation application, with and without variable rate technology and such definitions significantly limit the scope and potential of precision irrigation.

AIMS / GOALS OF A PRECISION IRRIGATION SYSTEM

Spatial variability in crop production (for example Figure 1) occurs as a result of spatial and temporal variations in soil structure and fertility; soil physical, chemical and hydraulic properties; irrigation applications; pests and diseases; and plant genetics. It is argued that this variability can be managed and economic benefit from irrigation maximized by meeting the specific irrigation needs of individual management zones through a precision irrigation approach.

Precision irrigation will potentially alter on-farm decision-making, and simultaneously achieve the multiple objectives of enhancing input use efficiency, reducing environmental impacts, and increasing farm profits and product quality.

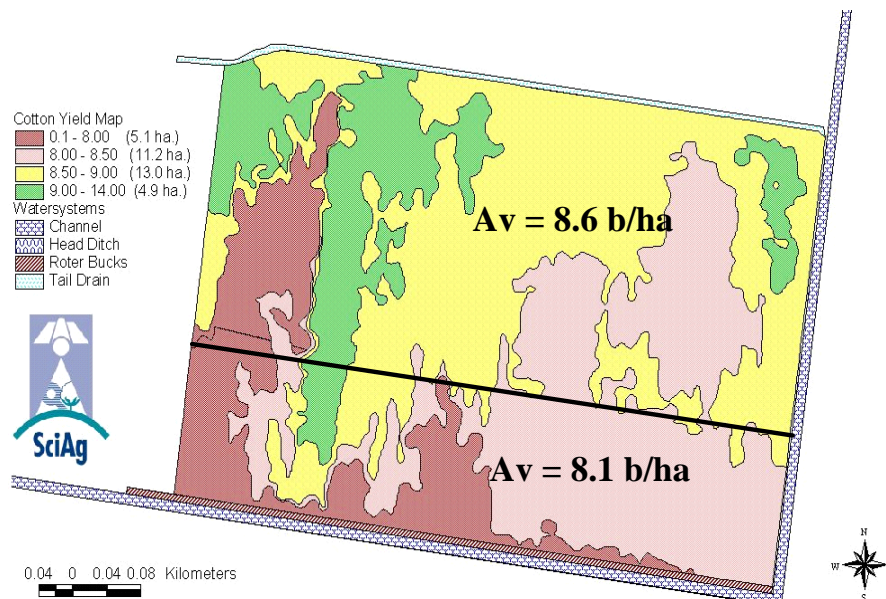


Figure 1 Example of the spatial variability of cotton yields under surface irrigation

The key to a successful precision irrigation system will be defining site specific goals or objectives, which might include:

- saving water and reducing costs by applying only the optimum amount of irrigation;
- minimising adverse environmental impact, and better management of the resource base;
- optimizing the economic value of the water applied through irrigation; or
- optimizing crop production (yield quantity and/or quality).

While conditions might exist for which the optimum input for a field is greater than the amount usually applied in a conventional, whole-field mode, most researchers expect a reduction in input use on at least parts of fields, and a reduction in the input aggregated over entire fields (Sadler *et al.*, 2005). The potential for conservation accrues from not irrigating non-cropped areas, reducing irrigation amounts to adapt to specific problems, or fully optimizing the economic value of the water applied through irrigation.

FOUR ESSENTIAL STEPS OF A PRECISION IRRIGATION SYSTEM

Precision irrigation is best viewed as a management approach defined by the precision farming cycle. There are four essential steps in the process: data acquisition, interpretation, control, and evaluation (Figure 2).

Data acquisition

Precision irrigation systems need clear evidence of significant spatial and/or temporal variability in soil and crop conditions within a field and between fields, and the ability to identify and quantify such variability. Existing technology can measure the various components of the soil-crop-atmosphere continuum (soil based monitoring, weather based monitoring, plant sensing), many in real-time and at sub-metre scales, and can provide precise and/or real-time control of irrigation applications. The practical limitation will be the density of measurement required.

Interpretation

The data acquired has to be interpreted and analysed at an appropriate scale and frequency. The inadequate development of control and decision support systems for making precision agriculture decisions is one major stumbling block to adopting a precision agriculture

approach. Appropriate multi-dimensional simulation tools (incorporating crop response, system constraints etc) are essential for optimizing irrigation.

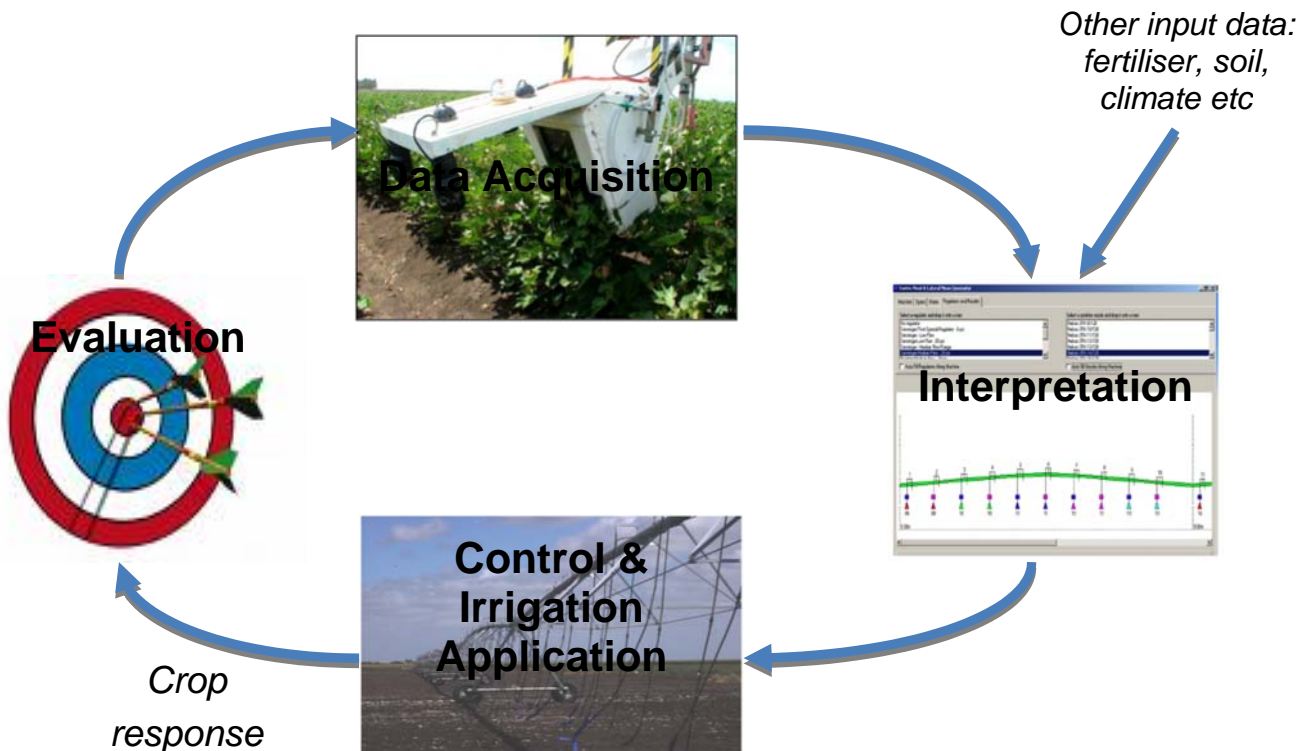


Figure 2 Precision Irrigation Cycle: (i) Data acquisition, (ii) Interpretation, (iii) Control and (iv) Evaluation

Control

The ability to reallocate inputs and adjust irrigation management at appropriate temporal and spatial scales is an essential component of a precision irrigation system. Applying different depths of water over a field will depend on the irrigation system, but can be achieved in two ways: by varying the application rate or by varying the application duration. Automatic controllers with real time data from on-the-go sensors should provide the most reliable and potentially accurate means of controlling irrigation applications.

Evaluation

Evaluation or ‘closing the loop’ is an important step in the precision irrigation process. Measuring the engineering, agronomic and economic performance of the irrigation system is essential for feedback and improving the next cycle in the system.

HIGH TECHNOLOGIES?

In its ultimate form, precision irrigation represents a convergence of advanced irrigation management and application technology with sensing, modelling and control technologies. This implies automation and real-time adaptive control, an example of which is the VARIwise system being developed by McCarthy *et al.*, (2009). Similarly, spatially varied irrigation has to a large degree, been driven by the advent of various high technologies, for example, real time positioning using GPS, proximal soil and crop sensors, remote sensing, variable rate technology and GIS. This might lead to the perception that precision irrigation is about the use of high technology. However is not universally true. Precision irrigation is a systems approach to optimise crop yields through systematic gathering and handling of information about the crop and the field. In its most basic form a human being (the irrigator) may provide the data gathering and handling, the learning and adaptation, the control response and the

evaluation. In this form it is akin to the five strands of learning proposed by Stirzaker (2009) for salinity management.

TEMPORAL AND SPATIAL SCALES

Precision irrigation can be viewed from the "tactical" or day-to-day management level to the "strategic" or seasonal management level. Strategic precision irrigation is the result of longer term decision making processes involving the use of broad scale field or farm level data over long time frames using seasonal or yearly data) It should be used to identify broad scale strategies in relation to irrigation management based on variations in a range of operating variables including crop/variety selection, planting area, planting dates, expected weather conditions, field layout, equipment constraints and expected economic returns.

However, tactical precision irrigation requires a much smaller areal and temporal focus and, in its most precise form, an ability to alter irrigation management in real-time and at the sub-metre scale. Where sensor, decision-making or control capability is limited in either temporal or spatial scale, the level of precision achievable is a function of the most limiting component in the process.

In either case the responses can be: automatic – in which a real time response follows immediately that some variable quantity is measured; or temporally separate – in which the appropriate action occurs some time (possible next season) after the measurement and recording.

The spatial resolution of a precision irrigation system will be influenced by:

- spatial scales inherent in the irrigation application system used (Table 1);
- spatial limitations associated with data acquisition, decision support simulation capabilities etc; and
- the spatial scale associated with the variability in the crop water requirements.

The spatial and temporal yield variability within the whole field can be controlled by variable rate applications or by dividing the field into homogenous management zones, ie., areas within a field or irrigation system where the crop response to irrigation is somewhat uniform (for example, Goodwin et al., 2008).

Table 1. Spatial scales of common irrigation systems (from Smith *et al.*, 2009)

System	Spatial Unit	Order of magnitude of spatial scale (m ²)
Surface - furrow	single furrow	1000
Surface - furrow	set of furrows	50000
Surface - bay	bay	10000 to 50000
Sprinkler - solid set	wetted area of single sprinkler	100
Centre pivot, lateral move	wetted area of single sprinkler	50
LEPA - bubbler	furrow dyke	1
Travelling irrigator	wetted area of sprinkler	5000
Drip	wetted area of an emitter	0.1 to 1
Micro-spray	wetted area of single spray	20

CONCLUSION

The review of precision irrigation is being undertaken to provide a framework for future development and implementation of the concept. The final report will:

- conceptualise how precision irrigation might be used for a range of irrigation systems (sprinkler, surface and micro), including the appropriate sensing, control and decision support requirements;
- identify opportunities for and potential benefits from precision irrigation;
- identify research opportunities and needs; and
- present a series of case studies illustrating examples of tools, technologies and practices that might form part of a precision irrigation system.

We are seeking feedback from irrigators, researchers and extension officers with experience in precision irrigation or its associated technologies. Do your irrigations vary across your fields and/or between irrigations? What tools and technologies do you use to measure and manage the variation in irrigation demand in space and/or time? What were the issues in implementing your system? What were the benefits / negatives in adopting your system? Your assistance in identifying case studies, examples, gaps, or opportunities related to the concept of precision irrigation would be very welcome.

ACKNOWLEDGEMENTS

The authors acknowledge the National Program for Sustainable Irrigation (NPSI) for funding this review project.

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