RESEARCH BULLETIN

Science and the irrigator: a learning manifesto

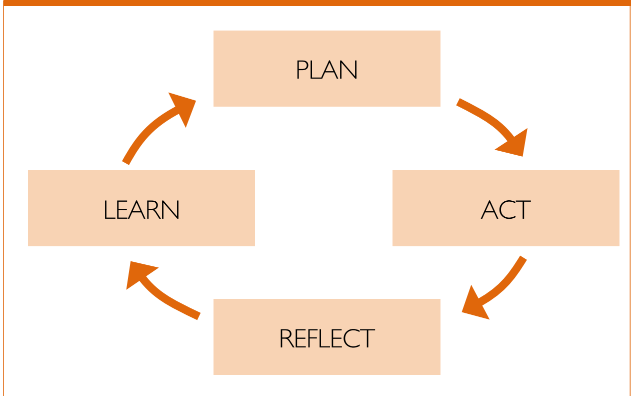
Richard Stirzaker CSIRO Land & Water / CRC Irrigation Futures

Every few years, the Australian Bureau of Statistics asks all irrigators how they make decisions about when and how much water to apply to their crops. Irrigators select the option "Local Knowledge" at the top of their list, way ahead of every other tool, method or model produced by scientists and engineers.

Why is this put at the top of the list? The reason is likely to be the trust people have in knowledge which has local acceptance after being tested and perhaps modified to suit regional soils and climate. It indicates that much that is in the pool of local knowledge is a combination of known facts and information generated from experience.

Figure 1 shows a simple learning cycle.

Figure 1



People are good at the first link from Plan to Act but relatively poor at making the Reflect to Learn link, or continuing the cycle to make improvements. For instance, an irrigator may plan to fine-tune water applications so acts by purchasing an automatic measuring system. Observations of variations in crop performance, however, suggest some tweaking is needed. And further reflection leads to the discovery of saline patches or nutrient imbalances which affect production. The irrigator decides to keep the new technology but learns how to use it more effectively and not in isolation All along there is a background to decisions which are made. Often research agencies will take the first step of planning for outcomes from a project, with these outcomes being incorporated in the "known domain" as reports and fact sheets. Current extension methods are also fairly predictable and usually undertaken without an understanding of the requirement for primary producers to deal with the unknown as well the known, and without enough appreciation of knowledge they already have and can develop while applying the results of a research project or using a new piece of technology.

Stronger conceptualisation, completion of the learning cycle and faster and more appropriate application of knowledge, will result from acceptance that several sources of information and different managerial considerations exist. The author of this bulletin, Richard Stirzaker, is pictured with a FullStop device which he helped develop, but he advocates a process that goes beyond a piece of equipment or a research project to find answers.

Completing the learning cycle and understanding adaptive learning are therefore vital for continuing to improve irrigation efficiency and crop performance.The following short history of working out crop water requirements shows how adaptive learning evolves.

Fifty years ago crop water requirements were estimated using an evaporation pan to set the upper limit for transpiration. It worked well, apart from the problem that the crop factors relating plant water use to pan evaporation vary with sites, crop varieties and irrigation methods. Later the neutron probe allowed us to directly measure plant water extraction from the soil – a very accurate method but ultimately too slow and cumbersome for all but the motivated minority.

The revolution in electronics and communication ushered in the golden age of soil water monitoring. Scientists saw these new tools as less accurate than their predecessors, but the ease of getting data collected, plotted and even delivered to the desktop computer was more than an acceptable trade-off for busy irrigation managers.

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The same electronics revolution invigorated the evaporation method, with networked weather stations replacing the pan, and satellites able to determine the evaporating surface area of the crops. Meanwhile the aspiration to produce the ultimate sensor that measured the plant itself, rather than the soil or air, continues on.

All this technological development is exciting and necessary, but it has failed to hear the voice of the irrigators recorded in tens of thousands of census forms. Their primary source of information is their own knowledge and experience. This experience may have been shaped by any one of the science-based tools or methods. But the message is clear. From the perspective of the person operating the taps, science on its own does not solve the irrigation dilemma.

In an attempt to get more irrigators to use the products of science, agencies have deployed a lot of the carrot and a little of the stick. The carrot involves the roll out of free extension and training programs, and subsidies on purchases of equipment and services. The stick involves a future of less water and in some jurisdictions, more regulation as to how it is used.

Between the carrot and the stick lies the field of adaptive learning, where both the formal knowledge of science mingles with the practical knowledge on the farm. Extension and the related areas of technology transfer focus on the one-way passage of knowledge from science to practice. Adaptive learning sees scientists, extension workers and farmers as co-creators of knowledge. Scientific and farmer knowledge are different, but they can be linked together to form a powerful combination.

Figure 2 gives us one example of an attempt to combine scientific and farmer knowledge. Farmers and scientists contribute to defining the problem that needs to be addressed. After that, scientists use their special knowledge to look for a solution to the problem. The new knowledge is transferred back to the farmers.

In this model, the science and farmer knowledge meet at the point of problem definition. Once the problem is clear, scientific method goes to work on unraveling the cause and effect relationships among bits of the pieces of the puzzle using the classical methodology of:

- Stating testable hypothesis
- Removing variables extraneous to hypothesis
- Control and replication
- Statistical analysis
- Peer review

The new knowledge is transferred to the clients usually by:

- Guidelines / factsheets
- Workshops / conferences
- Journal publication / reports / decision support tools

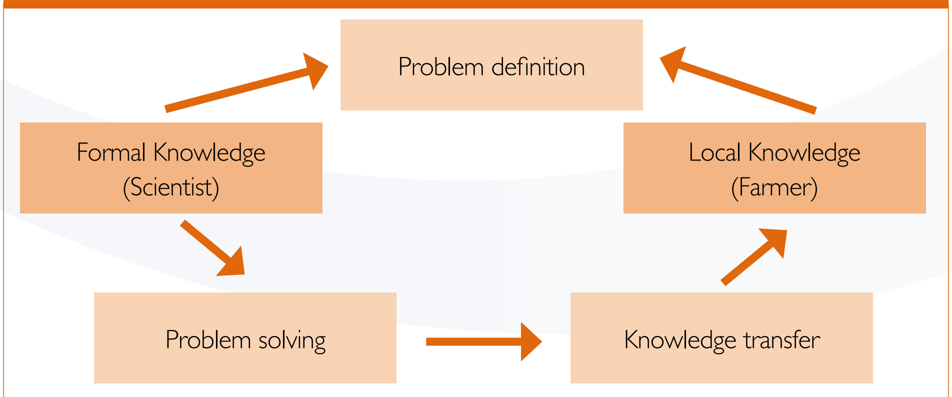
To stay in business, farmers have to manage the whole system. Understanding one part in great detail does not help when profitability is sensitive to the weakest link in the production chain. The deficiency with the model in figure 2 is that it implicitly assumes that certain aspects of the farm can be removed and replaced like defective components of a machine. In a biological system involving people, there are always constraints in applying new knowledge or the new can be a bad fit with existing structure of the business. In many cases the new scientific knowledge turns out to be, at best, a partial solution to the problem.

Figure 3 shows a second model for combining scientific and farmer knowledge. In this case both parties contribute their understanding of the problem at hand, but in this case it goes well beyond just problem definition. Scientist and farmer construct a conceptual plan about how they will go about solving the problem in the real world – the management options and the things that will be measured to see if they are on track.

The scientist will draw primarily on formal specialist knowledge e.g. theory / academic texts while a farmer would draw primarily on local knowledge e.g. their own experience and locally generated knowledge. Together they produce a description of what they expect to happen. Then they draw up the simplest monitoring protocol that allows them to monitor the key variables of interest. The farmer makes decisions based on experience, but informed by the monitored data.

Reality (the actual data) will often not concur with the expectation (the conceptualisation), giving both parties and opportunity to learn something new. The new knowledge is fed back into step 1 in Figure 3 above.

Figure 2



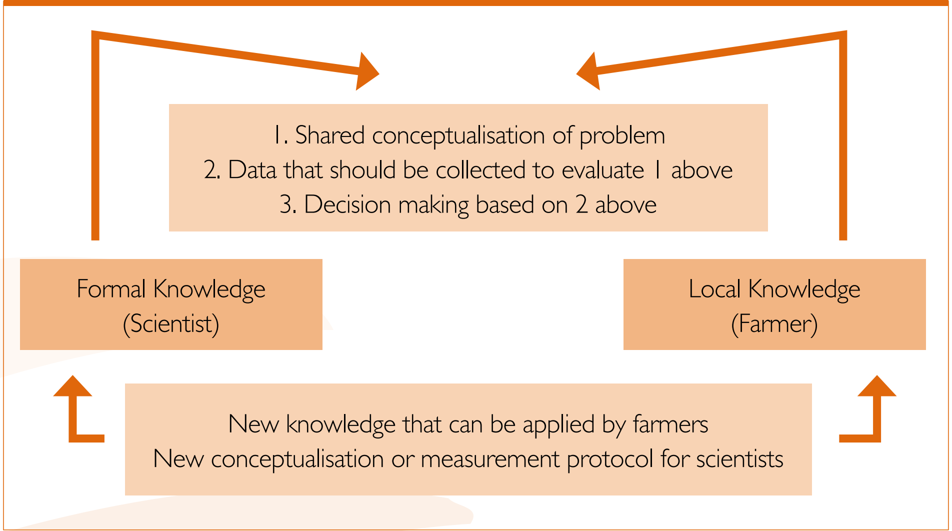
An example

We need to get highest possible yield of sweet corn using waste water with an Electrical Conductivity (EC) of 900 ppm. We need to i) keep the soil wet ii) prevent salt build up iii) minimise nitrate leaching and iv) demonstrate responsible use of water.

The particular example is not important here – rather it is the methodology for learning-by-doing.

The knowledge domain of the grower is based largely on local experience of growing sweet corn in the region. The crop needs between 500 and 700 mm of irrigation and 200 kg of N fertiliser (50 kg at planting and two side

Figure 3



dressings). The expected yield is 15-22 t/ha. The relatively poor quality of water means it is advisable to err towards higher applications of water to flush out the salt.

The knowledge domain of the scientist is more formal, as follows:

1. Water: keep the soil wetter than 25 kPa suction during establishment and flowering. At other times the soil can dry to 50 kPa.
2. Salt: apply extra irrigation when the EC of the top soil rises above 2500 ppm.
3. Nitrate: reduce irrigation when the nitrate level of the subsoil rises to 100 ppm
4. Responsible management: generate a weekly 'irrigation ratio' which is the amount of water applied divided by potential water use.

The first clash between the two world views is how much data to collect. The scientist can never get enough. For the farmer there is considerable cost and time investment in monitoring which has to pay off. In this context less is better.

It is a task for the scientist to find the minimum data set that can realistically inform decision making. We use prior knowledge to determine this.

The terms topsoil and subsoil above mean:

Topsoil – where most of the water and nutrient uptake occurs; and

Subsoil – fewer roots are present so we can leach salt to this layer but not nitrate.

Whereas it might be good to measure water extraction at ten depths down a profile, we may be able to glean 80% of the information by targeting just two depths.

Scientists are in the business of advancing knowledge within a speciality. For example there are experts in ET measurement, or one particular soil or plant sensor and these experts are searching for incremental improvements. Most of the tools are useful to a point, but there are often diminishing returns (from the perspective of the user), as the scientists strive for more accuracy. In other words the additional accuracy is usually outweighed by the additional cost and complexity involved (see Figure 4).

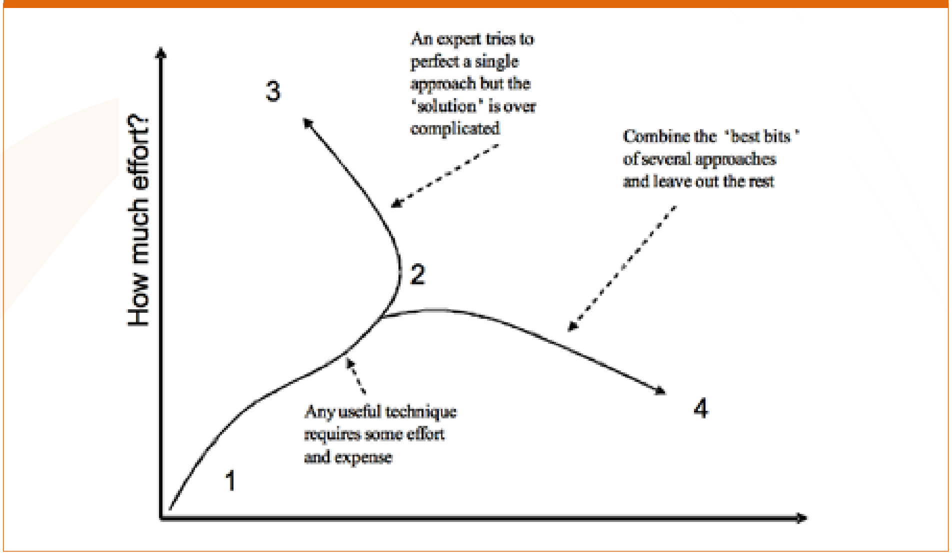
In learning mode it is better to employ several different methods side by side rather than try to perfect a single method. This is like travelling from position 2 to 4 in the above diagram, rather than going from 2 to 3.

For example in our sweet corn example, a combination of simple monitoring of soil water potential, ET, wetting front depth and soil solution monitoring can give us a much fuller picture than monitoring just one or two of these in great detail.

In the sweet corn example we placed one watermark sensor at 30 cm depth and wetting front detectors at 20 and 40 cm depths. Irrigation was carried out once per week and prior to this the change in soil tension was plotted. The irrigation amount was based on soil dryness and the salt and nitrate values from the previous week.

Let's say the soil water suction was 30 kPa and the crop was pre-silking. The salt in the shallow WFD was low but the nitrate was high. In this case the irrigation decision is quite easy. The soil is not too dry, we do not want to leach nitrate and we do not need to leach salt. So we apply a relatively small irrigation – say enough to activate the shallow WFD.

Figure 4



Sometimes there are conflicting requirements. If the soil is dry, there is high salt in the shallow detector and high nitrate at depth, then we have to compromise.

The advantage of collecting different 'strands' of information is they complement each other. Where they don't, they alert us to potential problems in our conceptualisation or our data collection.

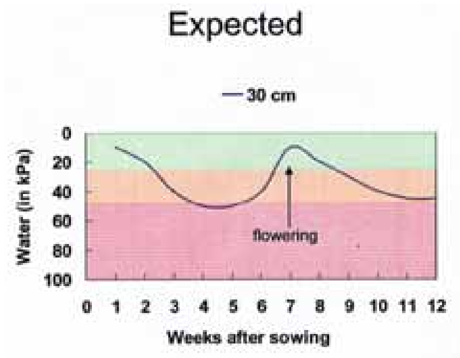
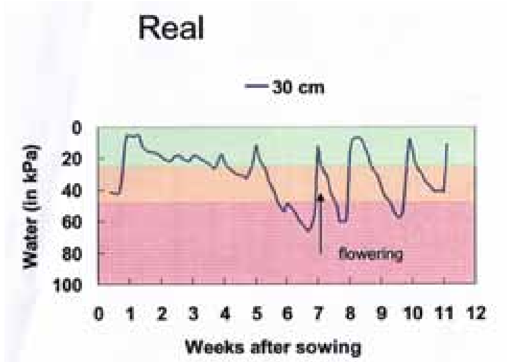
In our case there are five strands of information which are independent of each other. Strand 1 is what the crop looks like, based on the experience of the manager. Strand 2 is the soil water tension. Strands 3 and 4 relate to the depth that the water penetrates to and the concentration of the solutes (salt and nitrate). Strand 5 is the thermodynamic limit to transpiration i.e. the amount of water applied divided by the potential that could be lost to evapotranspiration.

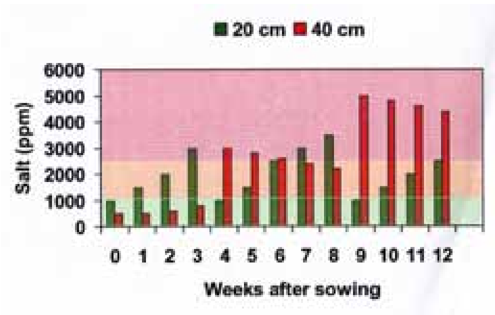
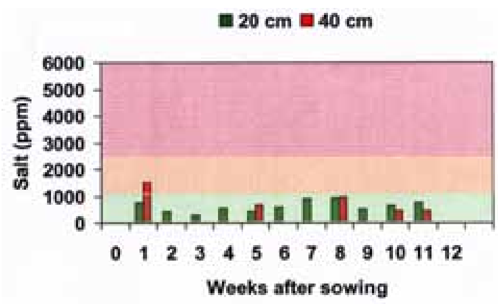
These strands (experience, soil dryness, infiltration depth, solute changes and thermodynamics) should be in agreement. It would be strange if we applied more water than the crop could use but did not leach salt. Yet it is precisely where these stands do not agree that there is something to investigate and something new to learn.

The site www.thescientistsgarden.com (blog) gives a week-by-week account of how the season unfolded.

A summary is given on the following pages

<table>
<tr><th>Issue 1: Water Stress</th><th>Conceptualisation</th><th>Reality</th></tr>
<tr><td>Monitoring soil water tension using a Watermark sensor</td><td>Soil water tension must be below 25 kPa at establishment and flowering, with minimum falling to 50 kPa.)</td><td>Stressed the crop pre-flowering to try and reduced nitrate leaching

Weekly irrigation not sufficient to stop topsoil drying below 50 kPa</td></tr>
<tr><td></td><td>
</td><td>
</td></tr>
<tr><th>Issue 2: Salt</th><th>Conceptualisation</th><th>Reality</th></tr>
<tr><td>The change in EC of the soil solution at two depths in the root zone</td><td>The is salt in the irrigation water which will build up in the root zone.

This salt will be pushed into the subsoil by leaching in week 4 and 9</td><td>The salt did not build up as expected, probably because water conditioners in the washing powder reacted with soil cations</td></tr>
<tr><td></td><td>
</td><td>
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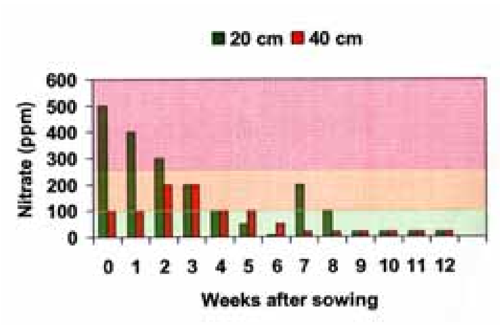
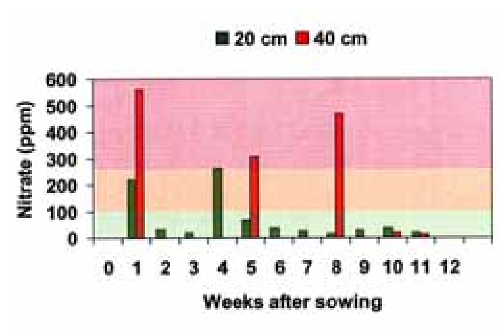
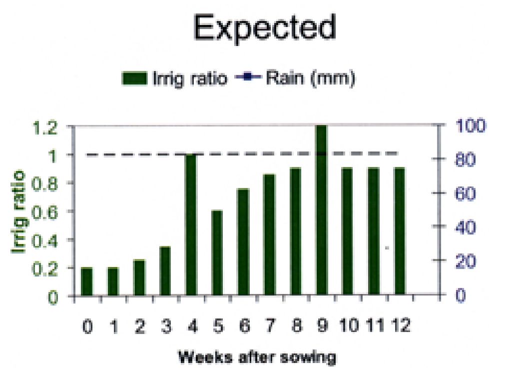
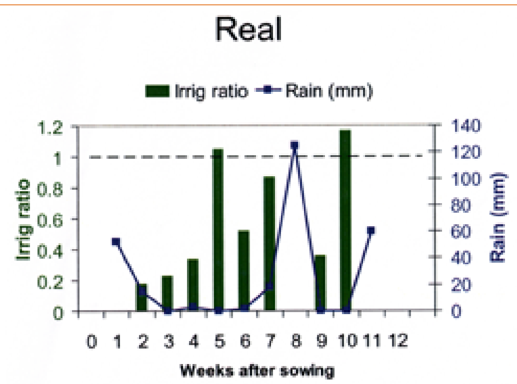
Issue 3: Nitrate leaching	Conceptualisation	Reality
The change in nitrate at two depths in the root zone	Nitrate is usually high early in the season due to mineralisation. Side dress when nitrate falls below 50 ppm	A huge amount of nitrate was at 40 cm depth. Irrigation schedule modified to try and use this nitrate. Side dressing applied at weeks 4 and 7.
		
Issue 4: Irrigation ratio	**Conceptualisation**	**Reality**
The proportion of water applied relative to potential water use by a well watered crop (estimated from pan or weather station data)	Water requirement increases with leaf area development. From time to time extra irrigation will be required to remove salt from the root zone (weeks 4 and 9, hatched)	Ideal case was impacted by rain and the reduce nitrate leaching. Salt was not a factor.
		



So what did we learn?

The problem

We needed to get the highest possible yield of sweet corn using waste water with an Electrical Conductivity (EC) of 900 ppm. We needed to i) keep the soil wet , ii) prevent salt build up, iii) minimise nitrate leaching and iv) demonstrate responsible use of water.

The expectation

The crop needs between 500 and 700 mm of irrigation and 200 kg of N fertiliser (50 kg at planting and two side dressings). The expected yield is 15-22 t/ha. The relatively poor quality of water means it is advisable to err towards higher applications of water to flush out the salt.

The experience

Eleven weekly irrigation events were planned. Rainfall obviated the need for three. The shallow WFDs collected samples 11 times (8 from irrigation 3 from rain) and the deep WFDs collected samples 5 times (3 from irrigation 2 from rain).

No basal N dressing was applied. Rain in week 1 revealed very high nitrate, particularly in the deeper WFD. Small N side dressings were applied at weeks 4 and 7.

The salt did not build up as expected. The wastewater containing 900 ppm salt was from washing powder. We hypothesise that the water softeners in the powder cause complex cations in the soil, presumably forming insoluble precipitates.

Total water applied was 454 mm comprising 172 mm of waste water and 282 mm of rain (120 mm coming in just 2 days)

Total N applied was 20 kg/ha

Marketable yield 20 t/ha

Learning:

The irrigation schedule was influenced more by nitrate dynamics, resulting in very low fertiliser usage with no loss in yield. Less irrigation was applied than expected, without compromising yield.

Salt accumulation did not proceed according to our original conceptualisation

Soil phosphate increased 10-fold at 30 cm depth and ph rose near 1 unit in three months. These variables need to be measured.

Cooperative Research Centre for IRRIGATION FUTURES

CSIRO

About the Program

The National Program for Sustainable Irrigation defines and invests in research on the development and adoption of sustainable irrigation practices in Australian agriculture. The aim is to address critical emerging environmental management issues, while generating long-term economic and social benefits that ensure irrigation has a viable future.

ISBN: 1921025 24 7

Product Code: NPSI-3-10

The National Program for Sustainable Irrigation is managed by Cotton R&D Corporation on behalf of the partners. The partners include irrigators, water authorities, research agencies, state and Commonwealth departments.
For information about the Program, please contact:

Guy Roth, Program Coordinator
0417 223 179
guyroth@roth.net.au