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Developing answers and learning in extension for dryland nitrogen management

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Abstract. The complexity of nitrogen management appeared to be stifling farmers' ability to apply advances in scientific understanding of nitrogen processes. Concerns about the impact of traditional 'transfer of technology' approaches led to the development of the Nitrogen in '95/96 workshop series, grounded in the concepts of experiential learning, action learning and adult learning. Nitrogen in '95/96 aimed to help people 'navigate' the available information on nitrogen, and through their personal experiences, transform this information into practical knowledge for use on their own farms. The series of workshops helped small groups of farmers understand the nitrogen cycle, use nitrogen budgets to interpret soil tests from their paddocks and develop recommendations for their own conditions. Planned evaluations demonstrated the impact of the process with 98% of respondents believing Nitrogen in '95/96 helped them better understand nitrogen and 86% believing the process helped them make nutrition decisions. Comparison of participants' initial fertiliser intentions and actual practices confirmed that they put their new learning into practice. Nitrogen in '95/96 presented a transparent simplification of reality, which is needed if any model is to be of any use as a framework for thinking about reality. This simplicity and transparency helped establish useful dialogue between farmers and scientists, and highlighted the potential contribution of learning concepts to agricultural research and extension in Australia.

Additional keywords: decision making, evaluation, experiential learning, extension, nitrogen budgets, nitrogen fertiliser use, model transparency.

Introduction

Nitrogen management

Dryland cereal cropping in northern Australia is based largely on clay soils with plant available water capacities between 120 mm and 250 mm. A dependence on stored soil moisture and unreliable in-crop rainfall creates uncertainty at planting about yield and protein expectations, the crop's subsequent nitrogen requirements, and the most appropriate rates of nitrogen fertiliser. Despite this uncertainty, most nitrogen nutrition decisions are made before, or at, planting because the unreliability of follow-up rain limits opportunities for in-crop applications.

Nitrogen management has been a major focus of research and extension agencies in northern Australia in an effort to enhance on-farm management and productivity of cereal grains industries. Despite this, soil organic carbon and total nitrogen levels in the region have declined (Dalal and Mayer 1986). The Grains Research and Development Corporation was sufficiently concerned about the impact of nitrogen research, development and extension to commission a review of work in the northern grains region (Henzell and Daniels 1995). They reported that: " … while grain growers recognise the problem of declining soil fertility in the region, and scientific understanding of the problems of nitrogen management has advanced rapidly, it may be that the complexity of the processes involved has stifled the ability of growers to use this understanding for farm decision making." (p. 5).

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The traditional transfer of technology paradigm

The Queensland Department of Primary Industries, like others state-based agriculture departments, has traditionally operated its research, development and extension activities within a 'transfer of technology' paradigm. Within this paradigm, Rogers' (1983) 'Diffusion of Innovation' theory suggests extensionists 'transfer' technical information developed by researchers to 'innovative' farmers, through whom the 'innovation' will then 'diffuse' to the wider farming community.

A review of extension theory and practice (Russell *et al.* 1989) concluded that 'transfer of technology' had been successful in some circumstances but that dependence on a too simplistic notion of 'transfer of knowledge' had proved itself to be of limited use. They observed that all significant reviewers of agricultural extension had concluded that 'transfer of technology' alone was no longer an adequate model to deal with increasingly complex agricultural systems.

In their review of the constraints to the adoption of innovations in agricultural research, Guerin and Guerin (1994) confirmed that 'transfer of technology' provided efficient technology adoption in situations with direct financial benefits, minimal complexity, acceptable risk and easy integration into current practices. However, while 'transfer of technology' creates awareness of issues, awareness does not easily translate into understanding or change, nor transcend community barriers when issues are complex (Blacket 1996). Despite its perceived limitations, Guerin and Guerin (1994) concluded that the 'transfer of technology' paradigm remained the basis of research and advisory structures in Australia.

During the 1990s, the Queensland Department of Primary Industries (QDPI) began developing processes that emphasised farmer learning, as evidenced by the publications: 'Learning to Learn with Farmers' (Hamilton 1995); and 'From Teaching to Learning' (Blacket 1996). This emphasis of learning as a process required alternative methodologies and methods to those commonly applied within the 'transfer of technology' paradigm.

Learning and approaches to facilitate learning in research, development and extension

Boyd, Apps and Associates (in Knowles 1990) distinguish between 'education' and 'learning'. For them, education is initiated by one party to effect specific changes in the knowledge, skill and attitudes of others, while learning is a process by which behavioural change, knowledge, skills and attitudes are acquired but which emphasises the person in whom the change occurs. This definition is consistent with Kolb's (1984) experiential learning, the process by which knowledge is created through the transformation of experience, with emphasis on the process of adaptation and learning as opposed to content or outcomes. The simple perception of experience is not sufficient for learning, something must be done with it. Similarly, transformation alone can not represent learning, for there must be something to be transformed, some experience that is being acted on (Kolb 1984).

Action learning. Revans proposed action learning as a philosophical framework for combining people's existing knowledge with their emergent understandings of complex issues. Within this framework, Revans (1997) describes learning (L) as the sum of existing programmed instruction (PI) and questioning insight (Q), that is: $L = PI + Q$. While Revans describes action learning as a social process, he resisted a single definition which preserved it as a philosophy and resulted in a range of activities being described as action learning (Pedler 1997). McGill and Beaty (1995) describe action learning as a continuous process of learning and reflection, supported by colleagues, with an intention of getting things done. Through action learning, individuals learn with and from each other by working on real problems and reflecting on their experiences.

Adult learning. In line with the move from education to learning, Knowles (1990) proposed a new model of adult learning based on adults' readiness to learn things they believe they need in order to cope with their real life situations. Drawing on Knowles and other learning theorists, Malouf (1993) also concluded that mentally and socially safe learning environments, effective 2-way communication, building upon learners' experience, and learners' active participation in the learning process encouraged effective learning.

Nitrogen in '95/96

From within QDPI's emerging 'learning paradigm', a series of nitrogen management workshops for farmers was developed in 1994, tested in 1995 and has continued in various forms ever since. The concept was inspired by a nitrogen budgeting article in the popular press (Marcellos and Felton 1994) and the coherent on-farm approach to nitrogen management developed in the Operation Quality Wheat initiative (Cahill and Strong 1996). It was a time of drought with varying levels of residual soil nitrogen from failed crops (Ridge *et al.*

1996), cash flow difficulties for farmers and several price rises for nitrogen fertiliser. There appeared to be an opportunity to advance beyond creating awareness of the problems and offering prescribed solutions, towards helping people understand how to improve their own on-farm nitrogen management. Understanding nitrogen processes was emphasised because the project team believed the unreliable climate and inconsistent responses to inputs would continue to confuse people if 'recipes' and 'rules of thumb' remained the main extension vehicle for nitrogen management.

Consequently, Nitrogen in '95/96 aimed to help people 'navigate' the available information on nitrogen, and through their personal experiences, transform this information into practical knowledge for use on their farms. The aim was not to ignore scientific understandings of nitrogen, but to help managers integrate scientific insights and their own experiences.

Materials and methods

Nitrogen in '95/96 ran over a full cropping season, but was centred on a 4-h workshop for 6–12 people before sowing. Supporting this central workshop was preworkshop soil sampling, a post-workshop mail-out questionnaire and a postharvest workshop. This paper reports on 44 preplanting workshops conducted across southern Queensland from April 1995 to September 1996. The workshops, which were attended by more than 400 farmers and 50 agronomists, focused on wheat and barley in winter and sorghum in summer.

Nitrogen in '95/96 incorporated the concepts of experiential learning, action learning and adult learning. From an experiential learning perspective, Nitrogen in '95/96 attempted to: (i) incorporate participants' previous experiences with nitrogen (concrete experiences); (ii) encourage discussion of problems and inconsistencies in those experiences (reflective observation); (iii) introduce and refine a framework for thinking about and discussing nitrogen (abstract conceptualisation); and (iv) facilitate the testing of the processes and outcomes 'on-farm' (active experimentation).

From an action learning perspective, Nitrogen in '95/96 attempted to: (i) build on existing farmer and scientific understanding (programmed instruction); (ii) test its assumptions and value to participants' situations (questioning insight); (iii) provide group discussion and interpretation of outcomes (social process of learning from and with each other); and (iv) encourage review of outcomes for future improvement (an emphasis on learning, not just taking of action).

Malouf's (1993) conditions for effective adult learning, were addressed by Nitrogen in '95/96 in the following ways*:* (i) self-selection of participants wanting to understand nitrogen (learners must feel a need to learn); (ii) informal workshops in community halls (a mentally and socially safe environment); (iii) participation in soil sampling and participant's own data and expectations in budget calculations and interpretations (learners must set their own learning goals and participate actively in the learning process); (iv) use of participants' previous crop experiences in discussions (learning must build on and use the learners' experience); (v) review of differences between intentions and workshop recommendations, fertiliser savings and crop performance (learners must see that their learning has been successful); and (vi) active encouragement and use of participants' ideas and insights in future workshops (learning must involve effective 2-way communication).

The Nitrogen in '95/96 process was continually updated, especially early on as inexperience and 'teething problems' with soil sampling, workshop design, worksheets and evaluation methods were overcome. However, the methods of a typical workshop series are described below.

Selection of participants

Participants were producers who had registered interest in learning more about nitrogen management and interpreting soil tests. However, the selection of participants varied greatly between each workshop series in an attempt to expand the program to new locations and use existing networks. For the initial 'pilot series' of 8 workshops, team members contacted producers whom they knew from earlier discussions were interested. Each producer then discussed the concept with his colleagues and formed groups of 6–8 interested people. Participants for the following workshops were self-selected in response to publicity and direct mail promotions. In the final series, participants registered interest with local agribusiness outlets that coordinated the workshops.

Preworkshop soil sampling

Each participant selected a paddock for soil sampling 10–30 days before the preplanting workshops to provide 'real time' soil test information.

Soil cores to 90 cm were obtained from a hydraulically drawn 3-cm-diameter tube with a cutting edge, allowing each person to observe their soil profile *in situ*. Sampling was considered an important part of the learning process. Participants were encouraged to help take the soil samples as few had seen deep soil cores from their paddocks. Also, their knowledge of soil variations in the paddocks could improve the sampling process. Participants were encouraged to inspect and feel the soil cores to assess soil depth, the rooting depth of previous crops and depth of moist soil, which were discussed and documented for each paddock. This interaction during soil sampling aimed to create a relationship between the parties, provide an opportunity to discuss the workshop process and clarify peoples' expectations.

A nominal charge covered the following soil analyses on a subsample of 6 'bulked' cores from across each paddock: (i) (0–10 cm), nitrate nitrogen, Colwell bicarbonate phosphorus, DTPA extractable zinc, pH and electrical conductivity using 1 : 5 water; (ii) (10–60 cm), nitrate nitrogen, pH and electrical conductivity using 1 : 5 water; (iii) (60–90 cm): nitrate nitrogen, pH and electrical conductivity using 1 : 5 water.

Presowing workshops

These workshops began informally by welcoming people on arrival and re-establishing relationships created during soil sampling. The workshops were held in local community halls with an overhead projector, whiteboards and butcher's paper. Participants were seated at tables with workshop folders, pencils, erasers and calculators.

Introduction. The workshops were structured to give the facilitators and participants a clear view of the process and their progress through it. Facilitators reiterated the project's aims and encouraged active discussion and questioning for the benefit of all participants. Each person was then asked to describe their paddock's soil type, age of cultivation, yield and protein outcomes of the last 3 crops, and the current depth of soil moisture. This process was originally designed as an 'ice-breaker' but was soon emphasised and recorded on butcher's paper to help people appreciate each others' situations and provide a focus for discussing the workshop results. The potential to evaluate the impact of the process was recognised after 2 workshops. Subsequently, participants were also asked to nominate their intended crop and fertiliser rates for the season, an attempt to establish benchmarks for assessing the workshops' impact on management.

Discussing and understanding the nitrogen cycle. Issues considered essential to understanding nitrogen processes and the purposeful use of soil testing and nitrogen budgeting were discussed for 60–90 min. Key issues included: organic and inorganic nitrogen; mineralisation processes and the accumulation of inorganic forms of nitrogen; loss mechanisms of nitrogen; processes of nitrogen supply via fertiliser, pasture and grain legumes; relationships between yield and protein; and indicators of fertility decline. This discussion in the early workshops was an informal seminar with questioning from participants. However, interaction was encouraged in later workshops by soliciting participants' ideas and past experiences with issues as they arose. Samples of decaying organic matter and nodulated legume roots were used to make the concepts more tangible. In some cases, facilitation of the group's own experiences and understanding were used to construct and discuss the nitrogen cycle.

Distribution of soil test results. Only after the discussion of nitrogen processes were the soil test results distributed. Personalised test results were provided and the intent of each test clarified. The principles of soil testing and the probability of responses to critical levels of nutrients other than nitrogen were discussed. Each person then compared their soil test results and paddock histories to develop their own management strategies for phosphorus and zinc nutrition. A refreshment break was used to allow people to freshen up and discuss various points of interest. The break was also designed to separate the more passive discussion of general principles from the subsequent application of the interactive nitrogen worksheets.

Interactive nitrogen worksheets. Step-by-step worksheets were used to guide participants through a nitrogen budgeting exercise for their own paddocks. The budgeting process attempted to reconcile each person's yield expectations with cereal crop nitrogen requirements and the available soil nitrogen. Each worksheet presented a key concept of the budgeting process, a summary sentence that encapsulated the concept, background notes and spaces for participants to enter their own yield expectations and paddock details.

Worksheet 1. Expected yield and protein for the season. For example, wheat: 3 t/ha at 13% protein.

Worksheet 2. Expected nitrogen removal in the grain harvested. For example, nitrogen removal in wheat = yield (t/ha) × grain protein (%) × 1.75.

Worksheet 3. Nitrogen needed to grow the expected crop. This calculation assumed a nitrogen use efficiency of 50%. For example, nitrogen needed = 2 × nitrogen removed in the grain.

Worksheet 4. Nitrogen currently available in the soil (from soil tests). This calculation determined the available nitrogen in each depth interval in the soil using soil test results and local soil bulk density estimates. The total nitrogen available to 90 cm was then calculated from these figures. For example:

Available N (0–10 cm) = mg/kg N × bulk density (0–10 cm) × 1
Available N (10–60 cm) = mg/kg N × bulk density (10–60 cm) × 5
Available N (60–90 cm) = mg/kg N × bulk density (60–90 cm) × 3
Total available N = available N (0–10 cm) + available N (10–60 cm) + available N (60–90 cm).

Worksheet 5. Extra nitrogen needed. This calculation reconciled the estimate of nitrogen needed by the expected crop, the available nitrogen and an estimate of in-crop mineralisation from a local reference table. For example, Extra N needed = N needed – N available – expected in-crop mineralisation.

The workshop group completed the worksheets one at a time. The key concepts for each worksheet were reiterated, the assumptions discussed, and an example done before participants completed their own calculations. Only then was this process repeated for the next worksheet.

Participants' worksheet results were recorded on butcher's paper to encourage discussion of the impact of yield expectations and cropping history on crop nitrogen requirements. Supporting reference information, such as safe rates of nitrogen with the seed and concentrations of elements in fertiliser product, was included in workshop binders.

Water and nitrogen interactions were addressed by asking people to consider depth of soil moisture and seasonal forecasts when determining their yield and protein expectations. People were then encouraged to recalculate their nitrogen needs for good and bad seasons to highlight the impact of in-crop rainfall on the actual yield and protein combinations possible in any season. Participants were finally encouraged to apply the paddock recommendations they had developed, but to reassess their strategy if conditions changed.

Postharvest workshop

About half the participants attended a post-harvest workshop which, unlike many one-off extension workshops, aimed to complete the cycle of experiential learning by collectively interpreting and conceptualising the season's results. The workshop was structured to reiterate key soil nitrogen concepts, describe, reconcile and interpret any differences between crop results and preplanting expectations, and review the Nitrogen in '95/96 process and its concepts.

Participants' preplanting workshop expectations and available soil nitrogen levels were again documented on butcher's paper. Each participant's actual nitrogen strategy and crop results were also described and documented, along with their observations of crop growth, frost damage and other relevant events such as flooding. Following the same facilitation process as the preplanting workshops, each person then used another worksheet to estimate the amount of nitrogen used by their crops that year. These estimates of actual nitrogen use, the expected total nitrogen supply (calculated from preplant soil tests and actual fertiliser rates used), and any differences between them were then clearly documented on butcher's paper for group reference and discussion.

A refreshment break was included at this stage. However, to encourage reflection on the results and to assess participants' understanding of the concepts, each person was asked to take time during the break to consider possible explanations for any discrepancies between the estimates of crop nitrogen use and available soil nitrogen for their paddocks. After the break, possible explanations of both deficiencies and surpluses were listed and used as a focus to explain crop performance, suggest possible changes to the budgeting process and discuss the value of the process to better decision making. Prompts such as 'was this years result good management or good luck?' were used to try to distinguish between the quality of crop results and the quality of the decision making process itself.

Evaluation and process reflection

Evaluation of Nitrogen in '95/96 began with informal market research using discussions with farmers and peers to test the concept. The farmers' enthusiasm affirmed the team's belief in the concept, but vocal criticism from peers who assessed the project on its technological content and believed it offered nothing new (Lawrence and Cawley 1999) created self-doubt about the team's ability to develop the process to its potential. These mixed emotions led to 'evaluation in earnest' with the double-edged motivation of helping the team itself assess and improve the project, while providing propaganda to defend the project against its critics.

Process and impact evaluation was developed to understand emergent issues, make decisions and report to others. The impact evaluation was quasi-experimental (without a control group of farmers) and focused on tracking changes in participants' nitrogen strategies over time. Participants' initial nitrogen management intentions, their workshop recommendations, and the actual nitrogen rates they used were compared for farmers from the Darling Downs (southern Queensland) to provide a case study of the project's impact on decisions. These data were documented in preplanting and post-harvest workshops as described earlier, and a mail questionnaire sent to all participants about 3 months after the preplant workshop.

The questionnaires used 5-point Likert scales to assess participants' attitudes to Nitrogen in '95/96, its processes and impacts on practices, knowledge and skills. These attitudinal questions were supplemented with additional behavioural questions including: (i) have you had any more soil tests done since the workshops? (yes/no), (ii) have you used the nitrogen worksheets since the workshop? (yes/no, please tick what you used them for); (iii) did the workshops influence your decisions for the crop? (yes/no, please tick decisions influenced), (iv) did you spend more/less money on fertilisers as a result of the workshops? (more/the same/less), (v) for the paddock you used at the Nitrogen in'95/96 workshop, what crop did you plant and what rate of fertiliser (if any) did you use?, and (vi) are there any other comments you would like to make?

Additional qualitative process evaluation methods were incorporated into ongoing workshop activities, including; participant observation, discussions with participants, and interviews with agribusiness. These activities aimed to help the project team understand how people used the workshops and to help make decisions as problems or new ideas arose. Workshop reviews with participating farmers were run at some workshops and typically addressed what people learnt, what they liked, and what could be improved.

Team members' observations of participants' ability to use the worksheets and their misunderstandings were discussed after each workshop in the first season. Worksheets and processes were then modified for the next workshop. Full team reviews were also held after each workshop series to reflect upon team members' observations and the questionnaire results. Team members' interpretations of the results were used to develop possible improvements for future workshops. Regular reporting to management and the development of conference papers ensured additional reflection and generalisation of the teams' understanding of the process.

Results

Attitudes to the Nitrogen in '95/96 process

Seventy-five percent of workshop participants returned the mail questionnaire. Their perceptions of Nitrogen in '95/96 were very positive with more than 90% of respondents agreeing the workshops were very useful and very relevant (Table 1).

Table 1. Participants' perceptions of Nitrogen in '95/96 workshops in southern Queensland

Participants' perceptions of the Nitrogen in '95/96 workshops	Percentage of responses				
	Strongly disagree	Disagree	Unsure	Agree	Strongly agree
Overall perceptions and content					
The Nitrogen in '95/96 workshops were very useful	0	0	2	58	40
The workshop was very relevant to my farming system	0	1	8	62	29
Perceptions of the process					
The workshop was a very effective way of looking at nitrogen	0	0	5	67	27
The workshop really helped with nutrition decisions for my (winter and/or summer) crop	1	4	9	65	21
The workshop was too complex	30	64	4	1	0
Perceptions of understanding and skills gained					
I learned a lot at the workshop	0	1	3	75	21
The workshops really helped me better understand soil nitrogen	0	1	2	67	31
I have always found soil tests difficult to interpret	1	18	22	42	17
I can now make much more sense of soil nitrogen tests	0	1	11	68	20
I can now confidently use crop yield and protein to check soil nitrogen status	0	2	21	63	14

Most respondents also believed the workshop process was very effective, with very few finding the process too complex (Table 1). Participants' comments in the survey and workshop debriefs confirmed their perceptions of the effectiveness and simplicity of the process. Some of the comments are listed below:

"It's embarrassingly simple."

"The day was very informative and used a language and a technique that could be understood by those present, without being too detailed to the point of being boring."

"You spoke in our language which made the whole show very worth while."

"(I've) had a lot of soil tests done before but normally had an agronomist to interpret fertiliser/weeds. (It's) good to learn how easy it is to calculate nitrogen requirements. Great idea but felt session was a bit slow although I learnt a lot."

"The demand for this practical, hands-on type of workshops is huge. Get into it."

Use of worksheets and soil testing

Fifty-three percent of questionnaire respondents used the nitrogen worksheets again before planting, a strong indicator of their usefulness. The worksheets were used to redo budget calculations with different yields (35% of respondents), interpret soil tests done after the workshops (16%) and check agronomist's recommendations (18%).

Twenty-two percent of respondents undertook more soil tests before planting, with most (73%) using the worksheets to interpret the results. Commercial agronomists helped run Nitrogen in '96 and the proportion of people taking more soil tests increased to 30%. INCITEC Fertilizers confirmed that nitrogen budgeting in cereals had contributed to increased demand for soil testing and increased the pressure on commercial service agents to provide facilities capable of sampling to depths of 60–90 cm (Chris Dowling INCITEC pers. comm.).

Understanding, learning and skills

Questionnaire respondents clearly believed that they had learnt a lot at the workshops and developed their nitrogen management skills (Table 1). More than 90% of respondents believed the workshops helped them better understand nitrogen in the soil, and a majority believed they could make more sense of nitrogen soil tests. Many respondents who had not previously found soil tests difficult to interpret still believed they could now make more sense of nitrogen soil tests.

Facilitators' observations and anecdotal evidence at project team meetings confirmed participants' increased understanding of nitrogen. Facilitators observed open discussion of nitrogen processes and some participants' decisions to either ignore in-crop mineralisation in future budgets, or try to refine in-crop mineralisation and soil bulk density estimates for their districts. However, the best illustration of participants' growing understanding of nitrogen was their ability at post-harvest workshops to provide explanations for any discrepancies between estimates of actual crop nitrogen use and the expected nitrogen supply. Seasonal variations in nitrogen mineralisation rates, efficiencies of nitrogen uptake (nitrogen use efficiency), sampling errors, root development and access to nitrogen below the sampled depth were typically suggested by people in each postharvest workshop.

While postharvest workshop discussions identified likely causes of nitrogen budget discrepancies, they could not provide definitive answers. These discussions raised many questions about the workshops' general assumptions for each district, namely: rates of mineralisation between sampling and sowing, rates of in-crop mineralisation, the efficiency of nitrogen uptake by crops, the accuracy of soil nitrogen testing, and the precision needed in nitrogen decisions.

Decision making and nitrogen management practices

Questionnaire responses also indicated that participants believed they had put their new learning into action. Only 5% of respondents did not agree that the workshops had helped their nutrition decisions for the crop (Table 1). Sixty-seven percent of respondents believed the workshops had directly influenced their decisions. The decisions influenced included crop choice (15%), fertiliser type (42%), nitrogen fertiliser rates (52%), and whether to use pasture rotations such as lucerne (6%).

Participants in Nitrogen in '95/96 were willing to adjust fertiliser rates to match seasonal conditions and soil nitrogen reserves. Thirty-one percent of respondents in 1996 reported saving money on nitrogen fertilisers, while 40% reported using more fertiliser than they would have otherwise. Participants' comments from the questionnaire included:

"I am 100% behind these workshops. Just one paddock which was tested and from the result we saved $A4000."

"I think the workshop was worth many thousands of dollars to us. It shocked us into using much more nitrogen than normal and with the change in seasons the crops look great."

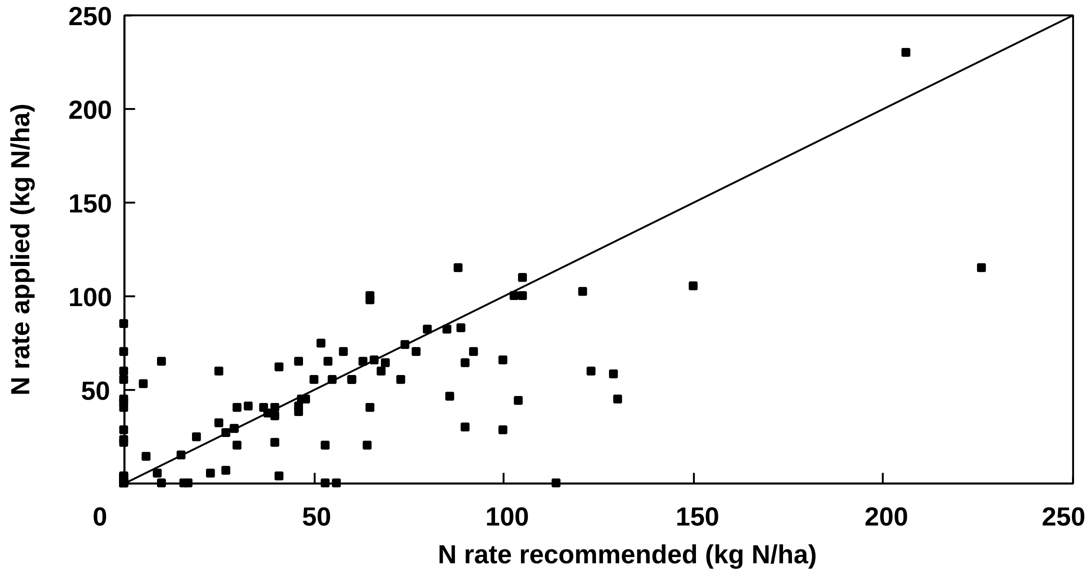

Figure 1. A comparison of participants' nitrogen rate recommendations from the Nitrogen in '95/96 workshops on the Darling Downs (southern Queensland) and the actual nitrogen rates they applied.

Comparisons of individuals' intended nitrogen strategies before the workshops, their own recommendations developed during the workshops and their actual practices after the workshops provided further evidence of the impact of Nitrogen in '95/96s on participants' decisions and management.

Impact on decisions – Darling Downs (southern Queensland) case study

Twenty-six percent of the case study's 114 participants developed workshop recommendations within 10 kg N/ha of their preworkshop intentions; 40% developed recommendations at least 10 kg N/ha above

Table 2. The impact of Nitrogen in '95/96 on participants' nitrogen fertiliser management on the Darling Downs

Classification of participating farmers based on their preworkshop intentions, workshop recommendations and actual fertiliser rates used	Proportion of people in each group (%)
Group 1. Recommendation to maintain intended nitrogen rate (30 people) (workshop recommendation within 10 kg N/ha of the preworkshop fertiliser intention)[A]	
Actual nitrogen rate within 10 kg N/ha of participants' workshop recommendation	87
Actual nitrogen rate not within 10 kg N/ha of participants' workshop recommendation	13
Group 2. Recommendation to increase intended nitrogen rate (46 people) (workshop recommendation >10 kg N/ha above the preworkshop fertiliser intention)[A]	
Actual nitrogen rate within 10 kg N/ha of participants' workshop recommendation	50
Actual nitrogen rate above participants' preworkshop intention, but not within 10 kg N/ha of the workshop recommendation	26
Actual nitrogen rate the same or lower than participants' preworkshop intention	24
Group 3. Recommendation to reduce intended nitrogen rate (38 people) (workshop recommendation >10 kg N/ha below the preworkshop fertiliser intention)[A]	
Actual nitrogen rate within 10 kg N/ha of participants' workshop recommendation	53
Actual nitrogen rate below participants' preworkshop intention, but not within 10 kg N/ha of the workshop recommendation	18
Actual nitrogen rate the same or above workshop recommendation	29

[A]A 10 kg N/ha increment was used to account for the rounding of recommendations in workshops to the nearest 5 kg N/ha, the accuracy of the budgeting approach, the need for a significant difference before people would change their intentions, and the practicalities of applying precise fertiliser rates.

Table 3. The impact of Nitrogen in'95/96 on the nitrogen rates initially intended, recommended and actually used for participants in southern Queensland

Classification of participating farmers	Mean nitrogen rates (kg N/ha) Preworkshop intention	Workshop recommendation	Actual application
Group 1. Recommendation to maintain intended nitrogen rate	22	20	21
Group 2. Recommendation to increase intended nitrogen rate	37	81	59
Group 3. Recommendation to reduce intended nitrogen rate	49	9	24
Total of all participating farmers (114 people)	37	40	37

their intended rates; and 33% developed workshop recommendations at least 10 kg N/ha below their intended rates. Participants' actual nitrogen rates ranged from well below, to well above the recommendations they developed at the workshops (Fig. 1). The 1 : 1 line shows many participants applied nitrogen rates similar to their workshop recommendations, however some individuals with workshop recommendations of up to 115 kg N/ha applied no nitrogen, and others with workshop recommendations of nil nitrogen applied up to 85 kg N/ha.

The context of nitrogen decisions. The impact of the workshops was clearer when the context of participants' decisions and their preworkshop intentions were taken into account. A majority of people applied fertiliser rates within 10 kg N/ha of their recommendations, ranging from 87% of participants where workshop recommendations and preworkshop intentions were similar, to 50% where workshop recommendations and preworkshop intentions differed by over 10 kg N/ha (Table 2). Additionally, many of the remaining participants did alter their actual nitrogen rates in the direction of the workshop recommendations.

The mean nitrogen rate across all case study participants did not alter (Table 3). However, taking into account the context of their decisions again showed that participants with workshop recommendations that differed by more than 10 kg N/ha from their intended rates, typically adjusted their intended rates towards the recommendations developed at the workshop (Table 3). The mean of participants' nitrogen rates: (i) remained unchanged where workshop recommendations suggested no change, (ii) increased from a mean intended rate of 37 kg N/ha to a mean actual rate of 59 kg N/ha where workshop recommendations suggested an increase of more than 10 kg N/ha, and (iii) decreased from a mean intended rate of 49 kg N/ha to a mean actual rate of 24 kg N/ha where workshop recommendations suggested a decrease of more than 10 kg N/ha.

Discussion

Nitrogen in'95/96 has clearly affected participants' understanding of nitrogen, their decision making process and their practices. Evidence of improved understanding of nitrogen comes from participant's own perceptions of their learning and team members' observations of participants' ability to discuss key concepts and develop explanations of unexpected results. Agribusiness observations have confirmed farmers growing understanding of nitrogen processes (C. Dowling pers. comm.). Evidence of the impact of Nitrogen in '95/96 on decision making processes and skills again comes from participants' perceptions of this impact, their nomination of decisions influenced and participants' continued use of worksheets. Finally, the evaluation process has documented differences between participants' nitrogen intentions and actual practices. Participants' practices typically matched or moved towards their workshop recommendations, and are reflected in increased mean nitrogen rates where higher rates were recommended, and lower nitrogen rates where lower rates were recommended.

The impact of the Nitrogen in '95/96 workshops is perhaps the best evidence of their value. However, participants in Nitrogen in '95/96 have confirmed the value of the process by their agreement that it was useful, relevant, an effective way to look at nitrogen, and not too complex. Final confirmation of the value of Nitrogen in '95/96 comes from its extensive use by farmers, government extension officers and agribusiness. State Agriculture Departments and commercial industry had conducted about 100 similar workshops across Australia's eastern seaboard by the end of 1996, and workshops have continued in Queensland as Nitrogen in '97/98/99 (Lawrence and Cawley 1999).

The use and impact of Nitrogen in '95/96 indicate that it provided a mechanism to help people understand, integrate and use nitrogen information on their own farms. However, Nitrogen in '95/96 was based on nitrogen technology and information that was widely available. Consequently, nitrogen management may have been limited, not by a lack of technical information, but rather a lack of processes to help people 'navigate' the available information and transform it into useable knowledge.

While the impact and appeal of the Nitrogen in '95/96 approach is clear, the lessons for research and extension agencies are open to debate. The workshops evolved and were continuously 'improved' by observing participants' reactions and use of Nitrogen in '95/96 concepts, reflecting on possible explanations for their behaviour and developing new ideas for future workshops. However, while the project team reached consensus on what they considered to be the key lessons from the approach, these generalised understandings arose from experiences in the northern grains region only, and are typically grounded in trial-and-error and qualitative assessments. Consequently, the following 'contentions' are the Nitrogen in '95/96 team's learnings. They may be supported by theory, but may also require further testing.

The value of learning-based approaches

The initial nitrogen budgeting approach arose from traditional research and extension activities but was not widely used by farmers. The impact of Nitrogen in '95/96 and its grounding in experiential learning and action learning concepts, and the inclusion of adult learning principles appears to demonstrate Bruner's assertion (in Kolb 1984), that any subject can be respectably taught at any level. Nitrogen in '95/96 also highlights the potential impact of helping people understand complicated concepts like nitrogen. This is in direct contrast to the transfer of technology paradigm and the assumption that communication of information as an 'activity' will lead to behaviour change in the recipient of the information (Timms and Clark 1999).

Answers and learning

Nitrogen in '95/96 was not 'learning for learning's sake', but helped participants use their learning to make more informed nitrogen decisions for their farms, a tangible benefit from the workshops. The workshops facilitated learning by helping participants discuss nitrogen principles, use their own paddock results, practise budget calculations to develop 'real-time answers' and apply their learning. The National Training Laboratories' (Maine USA) average retention rates of 5% for lectures, 10% for reading, 50% for discussion groups, 75% for practise by doing and 90% for teaching others or immediate use of the learning (Clark *et al*. 1996) confirm the impact of high involvement processes on participants' learning. Using participants' own expectations and soil test results appeared to bring the whole process to life and provides a contrast to workshops based on hypothetical examples only.

Frameworks for dialogue and learning

Like French and Shultzs' (1984) model of water use efficiency, Nitrogen in '95/96 has established a framework for benchmarking and understanding management options. Variable results to similar inputs each season can be investigated and possible explanations developed by farmers and agronomists. By establishing frameworks for dialogue, and revealing the underlying assumptions, learning based approaches should help people interpret others' experiences and better integrate them with their own knowledge. While farmers reported using the workshop processes to check agronomists' recommendations, agronomists have also recognised farmers increased ability to discuss nitrogen options and challenge recommendations (C. Dowling pers. comm.).

Scientific learning

The transition from education to learning has since provided opportunities for both scientists and farmers to learn. For example, the difficulty in reconciling some nitrogen budgets at postharvest meetings raised questions about the accuracy of soil nitrogen testing. From subsequent analysis, Schwenke and Manning (1998) concluded that at least 10 samples were required to be 90% sure that the result was within ± 20 kg N/ha. This is sobering when the nitrogen removal for a tonne of wheat is 20 kg/ha and the average yield is about 2.5 t/ha. The finding was challenging to extension officers and highlighted the need for careful soil testing and the potential of alternatives such as yield and protein histories from the paddock. Not only did the nitrogen workshop provide the research question for this study, it also provided most of the data for their analysis which explained the trade-off between number of samples and accuracy. Post-harvest discrepancies between estimated nitrogen use and estimated nitrogen supply have also led to further on-farm trials and discussion between farmers and scientists in western Queensland (Christodoulou 2000).

The precision of nitrogen decisions

Nitrogen in '95/96 helped farmers get their nitrogen rate roughly right and raised the question of how precise nitrogen decisions needed to be. However, this precision issue was not exclusive to the nitrogen workshops. Appropriate precision has long been an issue for agricultural economists (e.g. Anderson 1975), and Malcolm (1994) suggested it is better to be roughly right than precisely wrong. Indeed, Henzell and Daniels (1995) observed that farmers had much less interest in fine-tuning their nitrogen rates than researchers and extension specialists. However, the nitrogen workshops provided a focus for this debate. In northern New South Wales this debate precipitated a mail survey to 400 farmers which found that although they had dramatically increased their nitrogen rates over the last 5 years, they had rejected or been slow to adopt more complex approaches to determining nitrogen requirements (Hayman and Alston 1999). This behaviour is consistent with analyses by Hayman and Turpin (1998) and Turpin *et al.* (1998) that examined the impact of fixed and variable rates of nitrogen based on assessments of available nitrogen, available water and seasonal forecasts. These analyses concluded there was less to be gained from being 'precisely right' than first imagined. The widespread use of the nitrogen budgeting approach precipitated these research questions, and the findings of these simulation studies in turn provided feedback to the robustness of the nitrogen budgeting approach.

Complexity and transparency of models

Henzell and Daniels (1995) concluded that there had been 'excellent research' on nitrogen in the northern grains region but were concerned that farmers had not adopted much of this research. They argued that the complexity of the scientific understanding may have stifled growers' ability to use this understanding in their decision making. Considerable effort has been applied to providing scientific information to growers through modelling, most recently as simulations based on a biophysical representation of the soil and plant with a daily time step (Woodruff 1992; McCown *et al.* 1996). HOWWET? (Freebairn *et al.* 1994) uses simpler computerised mathematical modelling to communicate scientific understanding, that is, communicate scientific information along with the key processes, mathematics and assumptions. Nitrogen in '95/96 also provided a simpler mathematical model for farmers and advisers in their nitrogen management decisions. Its apparent impact on both learning and practice suggests simple mathematical models such as Nitrogen in '95/96, HOWWET? and others based on the concept of water use efficiency (WUE) (Freebairn *et al.* 1998; Robinson and Freebairn 1999) should not be dismissed as 'rules of thumb' that provide answers with little understanding.

Ridge and Cox (1996) used the concept of explanatory power proposed by Casti (1992) to compare the simple mathematical model of WUE and simulation modelling. Explanatory power can be measured statistically as the degree to which the regression equations account for the variations. Alternatively, explanatory power can refer to the extent that a model reveals the important components and their inter-relations. Ridge and Cox (1996) noted that there was often a trade-off between explanatory power in the statistical sense and transparency. They argued that a model that was transparent was more powerful for creating change because the logic could be introduced as part of the case for change. In Nitrogen in '95/96, this transparency was provided by the worksheets and discussion of the underlying assumption of the budgeting approach used.

The debate on appropriate levels of complexity for models continues. McCown *et al.* (1998) argued for the potential of simulation-aided discussion on a range of crop and crop-land management issues in their FARMSCAPE approach. However, the complexity of simulations may make them less transparent and require users to develop their own simpler models and schema to understand and interpret the output. The biggest difficulties may be expected where designers and users apply the models for different decisions and include different variables, especially if these differences are not recognised.

For some farmers the transparent framework of the nitrogen workshops may be a stepping stone to more complex models, but for others it may be the appropriate level of complexity or already be too complex. District guidelines and other 'rules of thumb' are available to simplify nitrogen decisions for this latter group. For example, the notion of achieving high protein wheat by matching the kilograms of nitrogen available to the millimetres of plant available water at planting (Dalal *et al.* 1997) may provide a useful guide for people trying to guarantee prime hard wheat quality. However, these 'rules of thumb' provide little understanding of nitrogen to their users and do not provide insights into discrepancies when they occur. Without this understanding of nitrogen, it is questionable whether many farmers will follow any unusually high nitrogen rate recommendations proposed for their districts.

Espoused theories and actual practice

Nitrogen in'95/96 highlighted differences between people's espoused theories and their actual practices, their theories-in-use (Argyris and Schon 1996) with regards to prime hard (13% grain protein) wheat. Participants typically calculated their nitrogen requirements for prime hard wheat at their yield expectations. However, when very high nitrogen rates were needed, facilitators commonly observed participants reducing their yield expectations to levels that reduced fertiliser costs back to what their cash flow would allow, reducing their chances of achieving prime hard quality. Participants were not conforming to the commonly espoused theory of having to produce Prime Hard quality wheat to survive economically. Processes that do not allow flexibility and review may only provide potential users with a choice of accepting or rejecting them on 'face value'. Similarly, 'rules of thumb' will be most useful where their underlying assumptions are clear to potential users and match users' real values and practices, not their espoused theories. By providing a transparent framework, Nitrogen in '95/96 may inevitably provide a process for individuals to understand alternative nitrogen strategies and develop 'rules of thumb' for their own values and conditions.

Evaluation as a planned activity

Purposeful evaluation was critical to the existence and progress of the Nitrogen in '95/96 process. Management support may have been difficult to maintain without the encouraging evaluation results that could not be ignored with the extremely high response rate of 75%. These results were equally important in gaining the interest and support of agribusiness to run the later workshop series and make papers such as this possible.

The 'before and after' analysis of participants' decisions has shown that learning approaches can directly affect farm management. However, participants' self-assessment and facilitators' qualitative observations were used to assess participants' knowledge and understanding. We believe this approach helped develop and improve Nitrogen in '95/96 however, if learning based approaches become more widely used, funders are likely to demand quantitative evidence of any changes in participants knowledge.

However, the most valuable forms of evaluation to the project team may not be so apparent. Consistent with the philosophy of action learning, the project team reviewed all aspects of the process from worksheets and facilitation processes, to partnerships with agribusiness and the projects focus on learning. This action learning approach and the continual assessment of progress during workshops, matching activities to participants' needs and reactions, may have been the evaluation with most impact. We are in agreement with Dick (1993) who asserts that in people-oriented activities where work is a 'performing art', short-cycle evaluation is a frame of mind and may make the greatest contribution to performance.

Conclusions

Nitrogen in '95/96 aimed to help people 'navigate' the available information on nitrogen and, through integration with their own experiences, transform this information into practical knowledge for use on their farms. The process was grounded in learning concepts and principles and this paper has demonstrated its impact on participants' understandings of nitrogen, their decision making processes and actual nitrogen practices. As such, the concepts of experiential learning, action learning and adult learning demand continuing attention from agricultural research and extension agencies. As we enter the information age, processes that help people create knowledge from information may become increasingly important.

Like all models, Nitrogen in '95/96 presented a simplification of reality. This is necessary if a model is to be any use as a framework for thinking about reality. However, the simple and transparent framework of the nitrogen budget appears to have helped establish useful dialogue between farmers and scientists managing and studying the system. Indeed, the fact that it did not include everything may have been a major strength because that encouraged further discussion and learning.

Finally, we contend that any decision making process must make its assumptions clear to avoid a mis-match between its designers' and users' intentions. If the assumptions of 'rules of thumb' or complex simulation models are not transparent, informed selection by potential users is difficult.

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