BSES Limited

FINAL REPORT – SRDC PROJECT BSS268

ACCELERATING THE ADOPTION OF BEST-PRACTICE NUTRIENT MANAGEMENT IN THE AUSTRALIAN SUGAR INDUSTRY

by

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SD10009

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SUMMARY

Nutrient inputs in the Australian sugarcane industry have traditionally been based on a set of general guidelines with little recognition of regional and/or soil differences. During the early 1990s, it was realised that profitable sugarcane production needed to be achieved in combination with environmental responsibility. Rising to the challenge to remedy this incongruous situation, we developed an integrated approach to nutrient management within project BSS232: *Improved nutrient management in the Australian sugar industry*. Systematic roll-out of the integrated nutrient management approach was made possible by our development of a delivery mechanism badged as the 'BSES SIX EASY STEPS Nutrient Management Program'. This comprehensive nutrient management system, based on principles of best-practice management, is intended as a cyclical learning experience for growers and their advisers. It consists of the following steps:

- Knowing and understanding our soils
- Understanding and managing nutrient processes and losses
- Soil testing regularly
- Adopting soil-specific nutrient management guidelines
- Checking on the adequacy of nutrient inputs
- Keeping good records to help interpret trends and modify nutrient inputs when and where necessary

Project BSS268 offered a unique opportunity to develop the SIX EASY STEPS program further and to include additional components to this integrated package. It, therefore, aimed to accelerate the adoption of sustainable nutrient management by:

1. Improving knowledge of the constraints to the adoption of best-practice nutrient management using grower surveys.
2. Developing a Soil Constraints and Management Package (SCAMP) for improving on-farm management decision making.
3. Facilitating the use of nutrient management plans at block and farm scales and the implementation of soil/site-specific fertiliser applications using a participative approach.
4. Assessing the risk of on- and off-site impacts of land management practices using vulnerability maps at catchment scales.
5. Demonstrating the benefits of best nutrient management practices with on-farm strip trials.
6. Reviewing the N-use efficiency factors associated with relevant trials.
7. Developing a computer-based decision support system for the SIX EASY STEPS nutrient management package.

Attitudes of industry stakeholders to nutrient management were assessed by collating examples of inefficient nutrient use, seeking answers to specific questions about 'best-practice nutrient management', aspects of nutrient management and the level of actual implementation on-farm. Although symptoms of inefficient nutrient management were identified, sustainable nutrient management is considered to be an integral part of the sugarcane production system in Australia. Growers generally identified with the principles and main 'steps' of the SIX EASY STEPS program. They agreed that sustainability means the adoption of best-practice options in order to achieve profitability in combination with environmental responsibility. The SIX EASY STEPS program, which is based on a logical set of principles, is aimed at facilitating the adoption of appropriate nutrient management

practices on-farm. It encourages growers to make informed decisions about their nutrient inputs.

In line with the above philosophy, the Soil Constraints And Management Package (SCAMP) was developed as a decision support framework to assist with the systematic development of sustainable soil management guidelines at block scale. Examples given in this report indicate the usefulness of SCAMP for identifying inherent soil constraints and systematically arriving at appropriate management options to deal with these constraints. With this knowledge, fertiliser practices such as timing and placement can be adjusted to reduce losses in productivity and environmental consequences. SCAMP has been particularly useful when developing nutrient and soil management practices that will assist in minimising off-site losses.

Due to changing economic and environmental pressures, growers needed to gain confidence in applying principles of sustainable nutrient management on-farm and receive appropriate training in the use of the SIX EASY STEPS program to develop nutrient management plans at farm and block scales. The effectiveness of the SIX EASY STEPS approach was assessed by reviewing the short-course format, considering the results of surveys and ensuring that articles relating to the SIX EASY STEPS program were published in an appropriate manner. The roll-out of the SIX EASY STEPS short course program has been extremely successful in facilitating the use of nutrient management plans on-farm. The importance of this initiative increased substantially with the introduction of the Australian Government's Reef Rescue Program and the Queensland Government's Reef Regulations. In both instances, the SIX EASY STEPS package enabled the industry to be better prepared to meet the challenges set by environmentally-focused government agendas. The one-day SIX EASY STEPS short-course format has proved to be popular and has enough technical detail to empower growers to make informed decisions about their nutrient inputs. The range and scale of scientific papers and grower-orientated articles associated with this project has ensured that the SIX EASY STEPS program has had wide coverage. This 'publicity' has contributed markedly to industry awareness and ownership of the SIX EASY STEPS program.

The recent government-initiated programs mentioned above are aimed at improving water quality in the Great Barrier Reef lagoon. Developments within this project have contributed in two ways towards attaining this goal: (a) the capacity for assessing the risk of on- and off-site impacts of land management practices has been advanced through the production of vulnerability maps at catchment scale, and (b) the development of *SafeGauge for Nutrients* for use at a block by growers and their advisors. While landscape and soil attributes affect the pathway of water movement, soil attributes determine productivity constraints such as susceptibility to compaction, tendency to acidify, and ability to supply and retain nutrients. Spatially referenced soil surveys were used to produce examples of maps of various hazards e.g. acidification, nutrient loss, and primary pathways of water movement (by attributing each soil with a permeability class, drainage class, and erosion hazard). The development of *SafeGauge for Nutrients* (and its eventual linkage to BSES SIX EASY STEPS NutriCalc) is an important step towards raising the awareness of growers and their advisors to the risk of nutrient losses (run-off and/or leaching) associated with particular nutrient management practices (choice of fertilisers, timing, application rates, etc). This is especially the case when seasonal weather conditions favour the chance of heavy or persistent rainfall events.

The SIX EASY STEPS program is aimed at promoting the adoption of sustainable nutrient management on-farm through the use of best-practice guidelines. Persuading growers to move away from the traditional and grower-developed nutrient management strategies required a series of replicated strip trials that could be used to compare grower practices to inputs based on the SIX EASY STEPS guidelines and to demonstrate that the use of soil-specific guidelines for achieving sustainable sugarcane production. This was achieved using a combination of participative replicated strip-trials and some key small-plot experiments in various districts across the Queensland industry. The strip-trials have been most successful in demonstrating the benefits of nutrient inputs based on the SIX EASY STEPS guidelines. In most instances the SIX EASY STEPS inputs resulted in yields comparable to the grower-determined nutrient applications. However, partial net returns were often in favour of the SIX EASY STEPS based strategies. Data from small-plot experiments also confirmed this trend and provided important data that showed that the SIX EASY STEPS approach was superior to other available strategies (grower-developed, traditional and N-Replacement). These types of trials also contributed to fine-tuning of the SIX EASY STEPS guidelines.

Best-practice management aims to improve nutrient use efficiency. In particular, the N fertiliser utilisation index should be as low as possible, with the reciprocal fertiliser N-use efficiency being as high as possible, without affecting productivity and profitability. The calculation of target N-use efficiency factors associated with the SIX EASY STEPS guidelines and actual N-use-efficiency factors derived from trial data, indicate that the targets are appropriate. Results from the demonstration strip trials and small-plot experiments indicated that improvement in N fertiliser-use efficiency cannot be seen in isolation from productivity and profitability on farm. The SIX EASY STEPS approach that considers both these aspects is more appropriate than systems aimed at either maximum production (grower-developed inputs) or being overly environmentally focused (N Replacement strategy). In overall terms the SIX EASY STEPS is aimed at sustainable sugarcane production that encompasses best practice management by considering a combination of agronomic, economic, environmental and social benefits.

With the acceptance of the SIX EASY STEPS program as the basis for best-practice nutrient management by the Australian sugarcane industry, we decided to develop a computer-based nutrient management system for growers and their advisors. This would enable access to an automated facility for determining nutrient inputs for specific blocks from soil test values and a record keeping facility. The importance of determining appropriate nutrient inputs, keeping good records and having the ability to provide records in summary form became more urgent with the introduction of the Queensland Governments Reef Regulations. The web-based nutrient management tool, badged as BSES SIX EASY STEPS NutriCalc (NutriCalc), was developed by combining the technical nutrient, soil and industry information and guidelines (based on the SIX EASY STEPS program) with an appropriate computer-based framework provided by NCEA. It is a user-friendly system that will be available to all growers via the BSES web-site. NutriCalc was launched at the BSES Field Day held in Mackay in May 2011. It will be accessible to users by mid-June 2011. The versatility of the system will enable further developments and add-on improvements when and where necessary.

Several future research needs are identified. The three most important of these (in terms of a priority rating) are: (a) the need to adjust DYP for seasonal climatic conditions, (b) the development of mitigation strategies for denitrification losses, and (c) undertaking glasshouse screening of commercial varieties for N-use efficiency. Importantly it is also recognised that any changes to the sugarcane production system, the method of planting cane and/or use of sugarcane for biomass production will necessitate investigations to determine whether modifications to current SIX EASY STEPS nutrient management guidelines are warranted.

In summary, this project has enabled further development and validation of the SIX EASY STEPS package. It has resulted in a number of important outputs and outcomes consistent with the philosophy of sustainable sugarcane production. It also provided an opportunity to promote and accelerate the adoption of best-practice nutrient management across the Australian sugarcane industry.

1.0 BACKGROUND

Nutrient inputs in the Australian sugarcane industry have traditionally been based on a set of general guidelines (Calcino, 1994) that were used across regions and soils (Wood *et al.*, 1997). These guidelines were obtained from the averaged results of a large number of calibration trials conducted in different regions of the industry over many decades (Chapman 1971a,b; 1994). Despite the simplicity of these guidelines, they were primarily aimed at maximum cane productivity with little recognition of regional and/or soil differences (Schroeder *et al.*, 1998; 2006a). During the early 1990s, it was realised that profitable cane production needed to be achieved in combination with environmental responsibility (Kingston and Lawn, 2003) i.e. maintenance of soil fertility on-farm with minimal off-site effects.

Rising to the challenge to remedy this situation, we developed an integrated approach to nutrient management within project BSS232: *Improved nutrient management in the Australian sugar industry* (which received funding from the Sugar Research and Development Corporation (SRDC), BSES Limited, CSR Sugar Ltd and the then Queensland Department of Natural Resources and Mines). This approach was based on our earlier work within the Cooperative Research Centre for Sustainable Sugar Production (Schroeder *et al.*, 1998; Schroeder and Wood 2001; 2002). It was achieved using a systems-based framework to establish appropriate nutrient management guidelines to suit local conditions and requirements within the various districts of the industry. The basic premise of this approach was to link nutrient management to intrinsic soil properties, the processes that occur within soils, and the interaction of applied nutrients with soils. It also recognised that the concept of integrated nutrient management inherently includes use of soil/site-specific nutrient management guidelines and regular soil testing, with some mechanism to check on the adequacy of nutrient inputs (e.g. leaf analysis).

The framework was originally developed and tested in the Herbert and Bundaberg regions. It was used in the development of a reference booklet “Soil Specific Management Guidelines for Sugarcane Production” for the Herbert district (Wood *et al.*, 2003) within a separately funded SRDC project (CSR026). Systematic extrapolation of the integrated nutrient management approach to other cane-growing areas then commenced using a delivery mechanism we badged as the “BSES SIX EASY STEPS nutrient management program” (Schroeder *et al.*, 2006b). This comprehensive nutrient management system is based on principles of best-practice management and is intended to function as a cyclical learning experience for growers and their advisers. It consists of the following steps:

- Knowing and understanding our soils
- Understanding and managing nutrient processes and losses
- Soil testing regularly
- Adopting soil-specific nutrient management guidelines
- Checking on the adequacy of nutrient inputs (e.g. leaf analyses, on-farm strip trials, etc)
- Keeping good records to help interpret trends and modify nutrient inputs when and where necessary

The SIX EASY STEPS program promotes the concept of best-practice nutrient management and consists of several mutually supportive components. The original program consisted of:

- The overall SIX EASY STEPS framework
- Sets of district specific nutrient management guidelines
- Grower-orientated district specific short-courses entitled “Accelerating the adoption of best-practice nutrient management”
- Soil reference booklets for various districts containing information on soil-specific nutrient management guidelines for sugarcane production

Our paper entitled “Delivering nutrient management guidelines to growers in the Central Region of the Australian sugar industry” summarises this overall approach (Schroeder *et al.*, 2006b). It is included in this report as Appendix 1.

Apart from optimising sugarcane productivity, sustainable nutrient management needs to ensure that profitable production can be achieved, and that environmental conditions (especially rainfall) and fertiliser management strategies (timing, placement and/or form) are assessed in terms of the risk of on-site and off-site losses. It was therefore recognised that the SIX EASY STEPS program needed to be further enhanced by:

- Gaining a better understanding of growers’ attitudes to nutrient management
- Developing mechanisms to illustrate the benefits of the integrated nutrient management package
- Developing decision support packages that would assist with the establishment of sustainable nutrient management options for specific circumstances and provide a means of incorporating temporal risk probability into the consequences of various land management procedures

It was also recognised that the SIX EASY STEPS nutrient management package needed to be promoted throughout the industry using a series of participative demonstration strip-trials. It was envisaged that this would lead to a movement away from the ‘one-fits-all’ approach that was historically used in the Australian sugar industry. Project BSS268 therefore offered a unique opportunity to further develop the SIX EASY STEPS program and to include further components in this integrated package.

2.0 OBJECTIVES

This project aimed to accelerate the adoption of sustainable nutrient management in the Australian sugarcane industry by focusing on profitability in combination with environmental responsibility.

The specific objectives were to improve on-farm profitability (reduce fertiliser costs by $60/ha or $0.65/tonne of cane) and ensure greater environmental awareness, accountability and responsibility by:

1. Improving knowledge of the constraints to the adoption of best-practice nutrient management using grower surveys.
2. Developing a Soil Constraints and Management Package (SCAMP) for improving on-farm management decision making

3. Facilitating the use of nutrient management plans at block and farm scales and the implementation of soil/site-specific fertiliser applications using a participative approach.
4. Assessing the risk of on- and off-site impacts of land management practices using vulnerability maps at catchment scales.
5. Demonstrating the benefits of best nutrient management practices with on-farm strip trials.

In June 2008, SRDC agreed to a variation in the project with two additional objectives:

6. Reviewing the N-use efficiency factors associated with relevant trials.
7. Developing a computer-based decision support system for the SIX EASY STEPS nutrient management package.

3.0 ACHIEVEMENT OF OBJECTIVE 1

Improving knowledge of the constraints to the adoption of best-practice nutrient management using grower surveys

3.1 Introduction

Despite about 30% of the average annual on-farm budget being allocated to fertiliser inputs, little effort was made by growers in the past to determine whether their actual nutrient inputs were appropriate for their specific circumstances. This lack of understanding of soil / site specific nutrient inputs suggested that inefficient nutrient management was occurring, at least to some extent, in parts of the industry. This project provided the opportunity to identify possible symptoms of inefficient nutrient management and to understand more fully the constraints to the adoption of so-called best-practice management on-farm.

3.2 Method

Attitudes of industry stakeholders (growers, miller representatives and industry advisers) to nutrient management were assessed by:

- Collating examples of inefficient nutrient use in the sugar industry.
- Seeking answers to specific questions at the initial project consultative group meetings:
  a. What is meant by the phrase ‘best practice nutrient management’?
  b. What constrains the adoption of ‘best practice nutrient management’ on-farm?
- Getting groups of growers to complete custom-designed survey forms that covered attitudes to various aspects of nutrient management (soils and nutrition, sampling, nutrient / fertiliser applications, nutrient losses, nitrogen, phosphorus and potassium) and actual implementation on-farm.
- Asking attendees at the SIX EASY STEPS nutrient management short-course to complete self-assessment forms to determine attitudes to nutrient management prior to the course.

3.3 Results and discussion

3.3.1 Examples of inefficient nutrient use

Examples of inefficient nutrient management practices that were identified in the sugarcane industry are shown in Table 1. Although not all of these symptoms necessarily occur on every farm, some of these may be applicable on specific farms. We suggested that if growers recognise some of these in their own farming enterprises, they should consider seeking advice and implementing more efficient alternatives. These symptoms of inefficient nutrient management were included in a publication entitled "Sustainable nutrient management – delivering the message to the Australian sugar industry" (Schroeder *et al.*, 2006a). The paper is included in this report as Appendix 2.

Table 1 – Symptoms of inefficient nutrient management

- A perception that soils are all very similar (basically dirt).
- Nutrients are applied to feed the crop – don't need to consider the soil.
- An assumption that all nutrients react with soil in a similar way once they are applied.
- A belief that 'more fertiliser is better than less, and any excess is not doing much harm anyway'.
- Lack of understanding of nutrient losses and their effects.
- Use of generalised fertiliser recommendations across districts and soils.
- Application of generalised fertiliser inputs on the farm by targeting the worst soil and fertilising the whole farm according to those requirements.
- Infrequent use of soil testing and leaf analysis.
- Over-application of some nutrients (especially N and P).
- Under-application of some nutrients (possibly K, S, or others).
- No check on the adequacy of fertiliser inputs.
- Few or poorly kept records.
- Little modification of nutrient inputs: year to year, crop cycle to crop cycle.
- No adjustment of fertiliser application rates after mill by-products have been applied.
- Nitrogen applications that are not reduced after a good legume fallow.

3.3.2 Best-practice nutrient management

Responses to the question "what is meant by the phrase best-practice nutrient management" showed that the term meant different things to different people. A range of answers is shown in Table 2. Although some replies gave the impression that adoption of best-practice on-farm could result from the simple adoption of a single concept, others were more complex and showed a greater understanding of the need for a multi-faceted / integrated approach to nutrient management on-farm. It is encouraging that aspects of sustainability relatively often formed part of the various 'definitions' that were supplied. However, it also became apparent that a 'universally' accepted definition of best-practice management was needed in the Australian sugarcane industry.

Although best-practice agriculture is generally considered to be a continuous improvement process, the large number of associated terms and standards, and different perceptions (as indicated in Table 2), often leads to a confused understanding of the overall concept. In describing best practice management, Williams and Walcott (1998) suggested that best-practice management encompasses an underlying process, appropriate changes that may (or may not) have to be sought externally, and an agreed framework for successful implementation. In recognising these components, a contemporary definition of 'best management practice' (BMP) states that it is "an economically viable management practice that has been determined to be the most cost effective and practical means of preventing or reducing pollution and thus environmental harm" (Smith, 2008). *We suggest that best-practice nutrient management is linked directly to the concept of 'risk'. It should be thought of as an overall combination of input strategies and processes that enables the risk of losses in productivity (loss of yield), profitability (loss of income), nutrients (leaching, run-off and/or gaseous losses), and soil resources (erosion and fertility losses) to be minimised.* Despite the apparent focus on losses, this definition also covers over-application of nutrients, or nutrients that are applied when not needed, because they could ultimately cause losses of nutrients and profitability. Our description of 'best-practice nutrient management was included in a paper entitled "Concepts and value of the nitrogen guidelines contained in the Australian sugar industry's 'SIX EASY STEPS' nutrient management program" (Schroeder *et al.*, 2010)'. The publication is included in this report as Appendix 3.

Responses to the question about impediments to the adoption of best-practice nutrient management were divided into five major categories: social, products, equipment, on-farm management and knowledge/advice (Table 3). The identified constraints indicated that this issue is complex and that there is no one single factor that will enable easy adoption across farms and districts. Perceptions appeared to be as important as tangible factors. The identified constraints also confirmed that an integrated solution or 'whole of system' approach is necessary to enable acceptance and adoption by growers.

Table 2 – Consultative group responses to the question: What is meant by 'best practice nutrient management'?

Category	Response
Simplistic	▪ Knowing your soil type. ▪ Appropriate placement strategies. ▪ Taking consideration of environmental issues. ▪ Balanced nutrition. ▪ Keeping good records. ▪ Supply what the crop needs. ▪ Ability to maximise best possible returns according to inputs. ▪ Basing applications on results of soil and leaf tests. ▪ Using the appropriate guidelines at the time. ▪ Eliminating nutrient losses. ▪ Variable rate nutrient applications. ▪ Taking account of nutrients in by-products. ▪ Identifying nutrient limitations and interpretation of soil tests.

Category	Response
Integrated	▪ Optimising timing of nutrients to achieve most efficient nutrient use and minimise losses to the environment. ▪ Integrating soil analysis and crop requirements according to soil type and crop type. ▪ Optimising profitability but minimising nutrient losses. ▪ Right nutrient recommendation for the right variety and soil type. ▪ Right nutrient recommendation for the right variety at the right time to get the right result. ▪ Nutrient requirement to grow an optimum crop on a particular soil type with minimal off-farm impacts but with maintenance of soil health (physical, chemical and biological). ▪ Right fertiliser at the right rate in the right place at the right time to get the right result (right will mean different things to different growers – in terms of results it can mean cane yield, sugar yield, profit, minimal off-site impacts, maintaining health and sustainability of soil). ▪ Nutrient requirement to maximise profitability with minimal off-site effects. ▪ Most efficient use of nutrients to maximise returns whilst ensuring soil health for sustainable production. ▪ Matching varieties, soil types and nutrient regimes – varying rate to suit different soils. ▪ Timely preparation, planting and application. Get fertiliser application timing right for soil and landscape – has to fit the 'window of opportunity' (taking climatic factors into consideration).

Table 3 – Consultative group responses to the question: What constrains the adoption of 'best practice nutrient management' on-farm?

Categories of constraints	Responses
Social	▪ Fear of the unknown / crop loss. ▪ Risk – fertilisers traditionally a cheap form of insurance. ▪ Time constraints. ▪ Reluctance to change – doing something different is a risk. ▪ Age of growers – lack of inertia to change
Products	▪ Cost of products. ▪ Lack of appropriate mixtures and granular versus liquid fertilisers. ▪ Quality of fertiliser products.

Categories of constraints	Responses
Equipment	▪ Inability to apply variable rates. ▪ Lack of technology to meter fertiliser outputs. ▪ Availability and type of equipment.
On-farm management	▪ Ease / convenience of using a single product over multiple blocks. ▪ Ease / convenience of using a single application rate over multiple blocks. ▪ Time constraints. ▪ Reluctance to change something that has worked well in the past. ▪ Good soil and leaf sampling is very time consuming. ▪ The application of fertiliser on-farm is a major task that needs to be undertaken in a relatively short period. ▪ Weather conditions.
Knowledge / advice	▪ Lack of recognition of best practice management. ▪ Reliance on generic recommendations. ▪ Lack of knowledge about soils and fertilisers. ▪ Conflicting information and advice ▪ Recommendations not provided in 'grower language'. ▪ Making decisions about inputs – should you apply more or less fertiliser on weak / poor soils. ▪ Lack of definite soil-specific guidelines. ▪ False claims by 'snake-oil merchants'. ▪ Inability to translate nutrient best-practice into monetary benefits.

3.3.3 Attitudes to various aspects of nutrient management and actual implementation on-farm

Completed survey forms were received from 90 Queensland sugarcane growers. The survey aimed to assess attitudes to, and adoption of, aspects of best-practice nutrient management on-farm. The survey included the choice of "agree", "disagree" and 'unsure" to statements that were designed to gauge perceptions / knowledge of growers, and "yes", "no" and "no, but I intend to" to statements that were designed to gauge actual adoption of the specified practice on-farm.

'Average' percentage responses to statements about aspects of nutrient management (soils and nutrition, sampling and nutrient / fertiliser applications), nutrient losses, and the major nutrients (N, P and K) are included in Tables 4, 5 and 6 respectively. About 80% of the growers (average of 93, 83 and 74% relating respectively to aspects of soil knowledge, appreciation of the need for sampling and recognition of the need for appropriate fertiliser applications) recognised the need for using best management practices. Only about 60% of respondents (average of 63, 58 and 63% relating respectively to adoption of good nutrient management, adequate sampling and appropriate application practices) indicated that they actually applied appropriate practices on-farm (Table 4).

It is interesting to note that in terms of nutrient losses, 63% of the growers indicated that the were aware of losses and that certain practices could reduce these losses (Table 5), about 74% were already adopting practices that were reducing the potential for such losses. However, only about 14% of respondents realised that greenhouse gas emissions and N losses were linked.

Table 4 – Survey responses from 90 growers in relation to some general aspects of nutrient management

Topic	**Response (%)**					
	Agree	Disagree	Unsure	Yes	No	No, but I intend to
Soils and nutrition						
Recognise that growers should: ▪ Attend soils/nutrition workshops. ▪ Have a good knowledge and understand nutrient / soil interactions ▪ Practice balanced nutrition on-farm.	92	2	6			
Actually: ▪ Attended a soils/nutrition workshop. ▪ Adjust fertiliser rates to match soil types and soil/nutrient interactions. ▪ Use soil and leaf testing for determining nutrient inputs.				63	24	14
Sampling						
Recognise that growers should: ▪ Soil sample all blocks prior to planting, discuss soil test results with advisers. ▪ Be aware of potential nutrient losses. ▪ Leaf sample to check the adequacy of nutrient inputs ▪ Keep good records to enable informed decisions	83	2	15			
Actually: ▪ Soil sample all blocks prior to planting, get advice to interpret soil test results. ▪ Take account of potential nutrient losses. ▪ Leaf sample to check the adequacy of nutrient inputs. ▪ Keep good records to enable informed decisions.				58	29	13
Nutrient / fertiliser applications						
Recognise that : ▪ Cane land should be limed to bring soil pH to 5.5. ▪ Fertiliser application rates should take account of other sources of nutrients. ▪ Fertiliser box settings need to be adjusted for different blocks. ▪ Mill mud is an important sources of nutrients,	74	9	17			
Actually: ▪ Monitor soil pH and apply lime when required. ▪ Reduce fertiliser rates following legume fallows or mill mud applications. ▪ Change the settings according to the required rate for a particular block. ▪ Use mill mud as an alternative source of nutrients. ▪ Reduce fertiliser inputs in poor-producing blocks during difficult times.				63	31	6

Table 5 – Survey responses from growers in relation to loss pathways associated with nutrient management

Topic	Response (%)					
	Agree	Disagree	Unsure	Yes	No	No, but I intend to
Nutrient losses						
Recognise that : ▪ Nutrients such as N, P and K can be lost from blocks of cane. ▪ Volatilisation and run-off are some ways that nutrients may be lost. ▪ If possible losses are decreased, then fertiliser applications can be reduced. ▪ Greenhouse gas emissions and N losses from farms are linked. ▪ Best-practice nutrient management can reduce nutrient losses.	63	9	28			
Actually: ▪ Aware of possible nutrient losses and take these into account. ▪ Change fertiliser management if known gaseous or run-off losses may occur. ▪ Alter farm practices to minimise off-farm nutrient losses. ▪ Tried to reduce N losses to reduce the contribution to greenhouse gases. ▪ Adopted practices that are perceived as best-practice management options.				74	20	6

Table 6 – Survey responses from growers in relation to nitrogen, phosphorus and potassium

<table>
<tr><th rowspan="2">Topic</th><th colspan="6">Response (%)</th></tr>
<tr><th>Agree</th><th>Disagree</th><th>Unsure</th><th>Yes</th><th>No</th><th>No, but I intend to</th></tr>
<tr><td colspan="7">Nitrogen</td></tr>
<tr><td>Recognise that:
▪ Soil organic C determinations assist in knowing how much N to apply.
▪ Leaf testing can be used to check on the adequacy of N inputs.
▪ Fertiliser N needs to be adjusts to for N from legume crops / mill by-products.
▪ Potential N losses and likely weather can impact on N fertiliser strategies.</td><td>74</td><td>3</td><td>23</td><td colspan="3"></td></tr>
<tr><td>Actually:
▪ Use N guidelines based on district yield potential and N mineralisation index.
▪ Regularly use leaf testing to check the adequacy of N inputs.
▪ Reduce N rates following legume fallows or use of mill mud.
▪ Take weather conditions into account when planning fertiliser applications.</td><td colspan="3"></td><td>81</td><td>15</td><td>4</td></tr>
<tr><td colspan="7">Phosphorus</td></tr>
<tr><td>Recognise that:
▪ Soil tests (BSES & PBI) indicate P availability and how much to add.
▪ P in mill mud needs to be taken into account when planning fertiliser inputs.
▪ Blocks of cane with high BSES P may not need P for at least a crop cycle.
▪ Leaf tests can be used to check the adequacy of P inputs.</td><td>64</td><td>6</td><td>30</td><td colspan="3"></td></tr>
<tr><td>Actually:
▪ Adjusted P application rates based on soil tests.
▪ Taken P in mill mud into account when planning fertiliser P inputs.
▪ Only apply P at planting when a need is indicated by soils testing.
▪ Used leaf analyses to check on the adequacy of P inputs.</td><td colspan="3"></td><td>55</td><td>35</td><td>10</td></tr>
<tr><td colspan="7">Potassium</td></tr>
<tr><td>Recognise that :
▪ Soils tests determine how much K fertiliser is needed.
▪ Applications of mill by-products enable reducing K fertiliser inputs.
▪ Should neither 'mine' soil of K nor apply excessive amounts.</td><td>62</td><td>5</td><td>33</td><td colspan="3"></td></tr>
<tr><td>Actually:
▪ Use soil tests to determine fertiliser K inputs.
▪ Reduced normal K application rate when mill by-products have been used.
▪ Use current K guidelines that ensure neither over- nor under-application..</td><td colspan="3"></td><td>60</td><td>31</td><td>10</td></tr>
</table>

3.3.4 Results of self-assessments to determine attitudes to nutrient management prior to attendance at SIX EASY STEPS short-courses

Responses to statements (Table 7) covering three broad categories: soils and nutrition (Figure 1), sampling (Figure 2), and nutrient / fertiliser applications (Figure 3) were obtained from 192 attendees prior to SIX EASY STEPS short-courses. These attendees were asked to rate each of the statements according to a scale of 1 to 5, with 1 = strongly disagree / non-compliance and 5 = strongly agree / full compliance.

Table 7 – Statements used within a survey to determine attitudes to nutrient management prior to attendance of SIX EASY STEPS short-courses

Soils and nutrition ▪ Attendance of soil nutrient management workshops has been beneficial in the past. ▪ Knowledge of soils is important for determining appropriate nutrient management. ▪ Understanding nutrient / soil processes allows more efficient use of nutrients. ▪ Balanced nutrition is a key to maintaining productivity on-farm. ▪ Fertiliser applications need to be tailored to different soils / varieties.
Sampling ▪ Soil samples should be collected from all blocks prior to planting to determine nutrient requirements. ▪ Discussion of soil test results with local extension staff / industry advisers ensures appropriate nutrient inputs. ▪ Awareness of nutrient loss processes allows for adjustment of nutrient strategies for specific circumstances. ▪ Leaf analysis is an important check on the adequacy of nutrient inputs. ▪ Records of soil tests, leaf analyses, rates and times of fertiliser applications, and yields enable informed decisions about nutrient inputs.
Nutrient / fertiliser applications ▪ Fertiliser application rates need to take other sources of nutrients into account, especially those resulting from fallow legumes, previous small crops and/or mill mud / ash applications. ▪ Fertiliser application rates need to reflect the requirements of each individual block of cane. ▪ Soil acidity can be reduced by regular use of lime or mill mud. ▪ Nutrient management programs should be adjusted during difficult times (e.g. when the sugar price is low or during drought). ▪ Required rates of individual nutrients need to be determined before choosing appropriate fertilisers for individual blocks of cane.

Figure 1 indicates that attendees' opinions of past soil / nutrition workshops (pre-SIX EASY STEPS) ranged from not finding the course helpful (8%) to 57% finding the course beneficial. Thirty-five percent of attendees were either neutral or did not provide a score. This contrasts strongly with the results of recent surveys conducted after delivery of 14 SIX EASY STEPS short-courses in north Queensland (Calcino *et al.*, 2010). Attendees at the SIX EASY STEPS workshops overwhelmingly found the course to be useful and would recommend it to others (Table 8). They also generally found it easy to understand and did not think it necessary to make changes. This change of attitude to the perceived rewards of attending soil / nutrient management short-courses is most encouraging. The surveys also indicated that in excess of 85% of attendees (Figure 1) either agreed or strongly agreed that the concepts of knowledge of soils, understanding nutrient / soil processes and the use of balanced nutrition were important in managing nutrient appropriately on-farm.

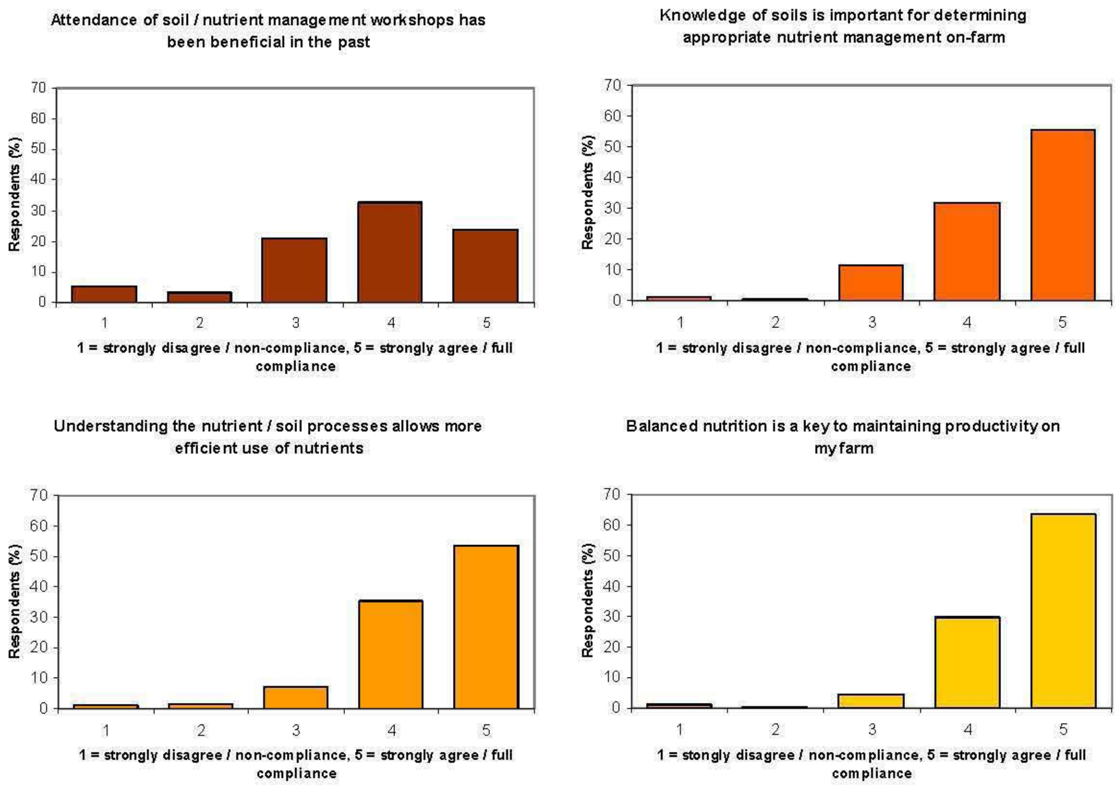


Figure 1 – Percentage responses to statements relating to "soils/ nutrition" in the self-assessment surveys prior to SIX EASY STEPS short-courses

Table 8 – Results of 14 SIX EASY STEPS workshop attitudinal surveys conducted across all regions in north Queensland (Calcino *et al.*, 2010)

Question	Number of respondents		
	Yes	Partly	No
Was the course useful?	175	2	0
Would you recommend the course to other growers?	175	1	0
Was the course too difficult to understand?	3	32	130
Is there anything you would like changed or dropped from the course?	10	0	160

In excess of 75% of attendees either agreed or strongly agreed that soils samples should be collected from all blocks prior to planting to determine nutrient requirements and that the soil tests results should be discussed with local extension / advisory staff (Figure 2). In contrast, attendees were less inclined to use leaf analyses as a means of checking on the adequacy of their nutrient inputs (Figure 2). About 35% each were either non-committal (neither positive nor negative) or agreed to some extent with the statement about leaf analyses. Record keeping was seen as a useful and necessary tool for making on-farm decisions about nutrient inputs with 46% and 42% of attendees respectively agreeing / strongly agreeing with this sentiment (Figure 2). Most attendees recognised the need to take all sources of nutrients into account when undertaking nutrient management planning, that fertiliser rates needed to reflect the requirements of each individual block, and these individual needs should be assessed before choosing appropriate fertilisers (Figure 3). However, there was a spread of opinions about whether nutrient management programs should be adjusted during difficult economic times (Figure 3).

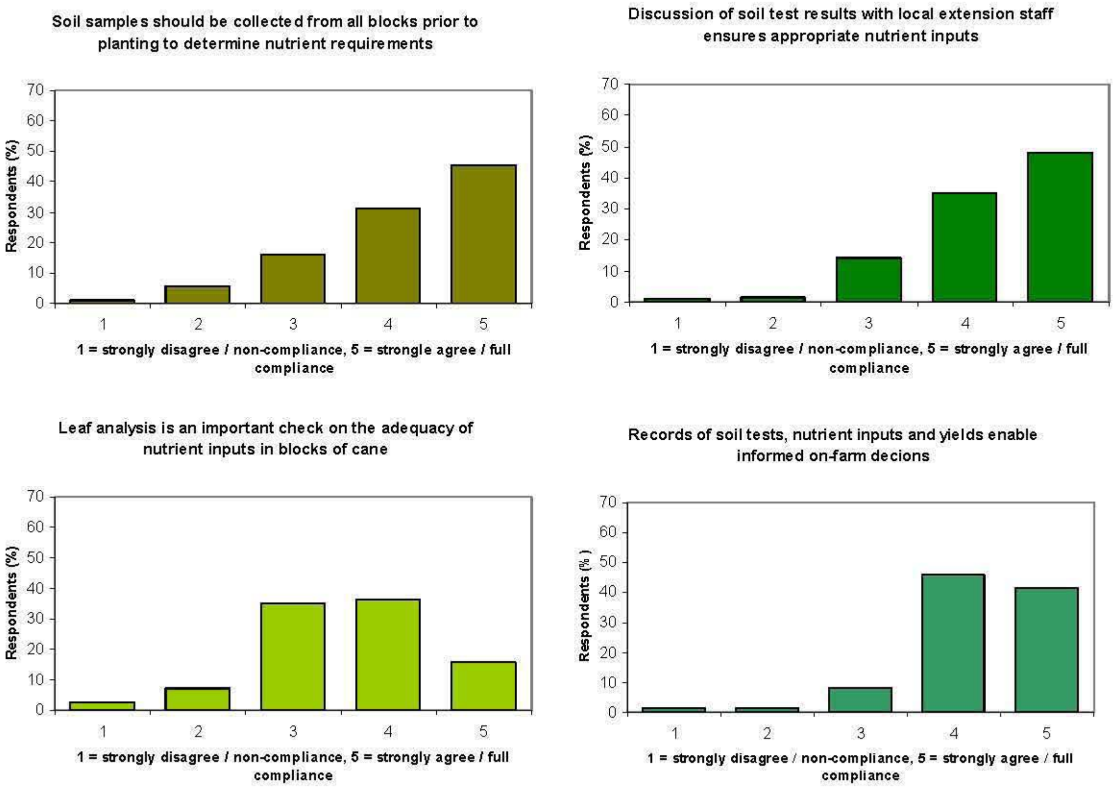


Figure 2 – Percentage responses to statements relating to "sampling" in the self-assessment surveys prior to SIX EASY STEPS short-courses

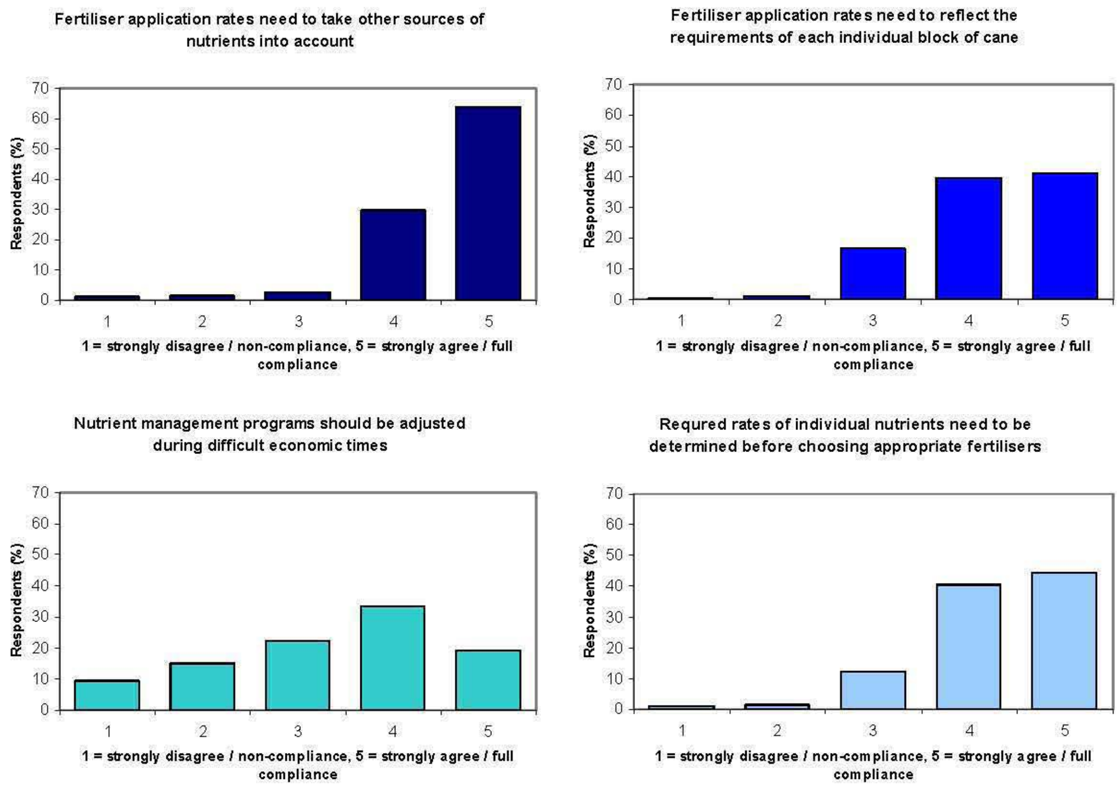


Figure 3 – Percentage responses to statements relating to "nutrient / fertiliser applications" in the self-assessment surveys prior to SIX EASY STEPS short-courses

4.0 ACHIEVEMENT OF OBJECTIVE 2

Developing a Soil Constraints and Management Package (SCAMP) for improving on-farm management decision making

4.1 Introduction

Sustainable soil management depends on an assessment of the intrinsic soil constraints to productivity and adoption of management practices that ameliorate or tolerate these constraints without penalty to long-term productivity. This philosophy is in line with the concepts of best management practice advocated by the SIX EASY STEPS nutrient management program. The Soil Constraints And Management Package (SCAMP) was developed as a decision support framework to assist with the systematic development of sustainable soil management guidelines at block, farm or catchment scale. It has provided useful information in developing the soil-specific management options provided in the soil reference booklets that have been developed within the SIX EASY STEPS program for various sugarcane-producing districts (Schroeder *et al.*, 2006a).

4.2 Methodology

SCAMP was developed as a decision support framework to enable systematic derivation of soil-specific management strategies. It utilises basic soil morphological, chemical and physical data to:

- Identify intrinsic soil constraints to long-term productivity, and then
- Indicate management practices that will either remove or minimise the impacts of these constraints on productivity.

SCAMP builds on the Fertility Capability Classification of Sanchez *et al.* (1981, 2003), by:

- Considering a range of basic soil properties to determine constraints to productivity
- Utilising surrogates to infer several key soil properties, and
- Including a temporal assessment of the pathways of water flow for identifying the risk of off-site nutrient movement.

The soil attributes considered in SCAMP are indicated in Table 9. These attributes can be obtained either:

a. from examination of a 'mini pit' in the field accompanied by some supporting chemical analyses or
b. from a knowledge of the soil type being examined. Indicative values for most of the required attributes are available from soil survey reports.

Table 9 – Soil attributes considered in SCAMP

Source	Attributes
Field	Texture, colour, structure and consistence, permeability, drainage, erosion hazard, field pH, field EC, dispersion
Laboratory analyses	Organic C, effective CEC, P buffer capacity, pH buffer capacity

These attributes, based on pre-set criteria (Tables 10 and 11) are then used to determine the appropriate SCAMP descriptors. Text fields are used in the *SCAMP* database to document practices for managing each constraint, and input data and management strategies are summarised in a hard copy report. If data are not available for some of the soil attributes listed in Table 9, constraints such as acidification hazard and low nutrient retention can still be inferred from other attributes such as texture, and such inferences are described in Moody *et al.* (2008a,b).

Where geo-referenced soil survey data are available, the *SCAMP* Access database can be used to assign specific attributes to individual soil types, and the database is interfaced with any Geographic Information System (GIS) such as MapInfo or ARCGIS to produce maps of constraints or specific soil attributes.

The advanced draft version of the SCAMP manual is provided in Attachment 15. This manual details the field observation and laboratory analyses that are required for input into the package. It also describes the criteria used in the SCAMP database for allocating SCAMP descriptors and constraints. Data are entered into SCAMP in Excel format.

Table 10 – *SCAMP* descriptors and the attributes and criteria used to determine the descriptors. Unless otherwise specified, criteria refer to 0-20 cm and 40-60 cm soil samples

SCAMP descriptor	Soil attributes	Criteria
	Texture type	
S, L, C (texture)	Field texture	*S*: sand, loamy sand; *L*: sandy loam, loam, clay loam; *C* : clay, heavy clay
	Clay content	*S*: <20% clay; *L*: 20-35% clay; *C*: >35% clay
	Pathway of water movement	
runoff, ponding, drainage	Drainage class (1-6), Permeability class (1-4)	see Table 11
Soil pH and acidity constraints		
a (acidity)	Field or lab pH	pH_{water} <5.2
ar (acidification hazard: *low*, *moderate* or *high*)	Calculated pH buffer capacity (0-20 cm): pHBC (g $CaCO_3$/kg soil.pH unit) = [0.995*OC% + 0.011*clay%] * 1.2 where OC is uncorrected Walkley Black organic C (Walkley and Black 1934), and soil bulk density is assumed to be 1.2 Mg/m^3 (Aitken *et al.* 1990)	*low*: pHBC >2 g $CaCO_3$/kg soil/pH unit *moderate*: pHBC 1-2 g $CaCO_3$/kg soil/pH unit *high*: pHBC <1 g $CaCO_3$/kg soil/pH unit
b (calcareous)	Field or lab pH	pH_{water} 8.0-8.5
	Cation constraints	
e (low nutrient retention)	Effective CEC (0-20 cm)	ECEC <4 $cmol_c$/kg
s(salinity); s^- (marginal salinity)	Field or laboratory EC	*s* $\geq$ 4 dS/m EC_{se} s^-: 2-4 dS/m EC_{se}
n (sodicity); n^- (marginal sodicity)	Na saturation	*n*: ESP $\geq$15% ; n^-: ESP 6-15%
	Clay fraction constraints	
i (high P fixation)	P buffer capacity using a single point P buffer index (Burkitt *et al.*, 2002) (0-20 cm)	PBI > 281
v (vertic properties)	Field observation (0-20 cm)	
	Clay content and CEC/clay ratio (0-20 cm)	>35% clay and CEC/clay% >0.8
om (low organic C)	Uncorrected Walkley Black (1934) organic C (0-20 cm)	*S* texture: <0.5%; *L* texture: <0.9%; *C* texture: <1.2%
geric (variable charge characteristics)	Delta (pH_{KCl} – pH_{water})	Delta (pH_{KCl} – pH_{water}): >-0.1
	Landscape constraints	
er (erosion hazard 1-5: *slight*-*extreme*)	Field observation or slope	*slight*: <2% slope; *moderate*: 2-5% slope; *high*: 5-10% slope; *very high*: 10-15% slope; *extreme*: >15% slope
	Soil structural constraints	
hs (hard-setting)	Field observation	Firm- extremely firm consistence; visible surface crust
comp (compaction layer)	Field observation (0-50 cm)	Marked increase in resistance to penetration

Table 11 – Major pathways of water movement associated with permeability and drainage classes (classes as defined in McDonald et al., 1990). D: drainage; R/P: runoff if slope >1%, ponding if slope <1%

Permeability class	Drainage class					
	1	2	3	4	5	6
1	R/P	R/P	R/P	R/P	D+R/P	D+R/P
2	R/P	R/P	R/P	D+R/P	D+R/P	D+R/P
3	R/P	R/P	D+R/P	D+R/P	D+R/P	D
4	R/P	R/P	D+R/P	D+R/P	D	D

4.3 Results and discussion

A series of booklets on soil-specific nutrient management for various sugarcane districts (Wood *et al.*, 2003, Schroeder *et al.*, 2006, Schroeder *et al.*, 2007a,b) have been developed as part of the overall SIX EASY STEPS program. In these booklets, the occurrence, formation, field appearance, physical properties, chemical properties, tillage and water management and environmental risk management are documented for each major soil type of the district. To systematise the comments made in the 'tillage and water management' and 'environmental risk management' sections, attributes of representative profiles of each soil type were entered into the *SCAMP* database. A report was generated for each soil type showing the appropriate constraints and management strategies for ameliorating those constraints. An example is shown in Table 12 for a Liverpool soil found south of the Liverpool Creek in the Johnstone Catchment (Figure 4). This information was then used to assist with developing the soil type reports in each of the booklets. Tables 13 and 14 identify the key soil attributes and derived constraints and management implications for two other soils with contrasting soil properties (Pin Gin and Bulgun series soils) also from the Johnstone Catchment.

The Pin Gin soil (Table 13) has a clay loam texture, and is acidic, well-drained, with a very low cation exchange capacity and high P fixing ability. The net variable surface charge is near zero indicating that management practices such as increasing soil organic matter levels and increasing the soil pH will be required to generate more cation exchange capacity. The Bulgun soil (Table 14) is also a clay loam and acidic, but is poorly drained and of low permeability. This soil is subject to water-logging and so denitrification is likely to be a major loss pathway for N fertiliser. Improving drainage in the crop row by mounding and splitting N fertiliser applications will be required to reduce denitrification risk. The hard-setting nature of this soil necessitates minimum tillage and the requirement to maintain soil surface moisture by trash blanketing.

Figure 4 – Liverpool soil found south of Liverpool Creek in the Johnstone Catchment

Table 12 – SCAMP constraints report for a Liverpool soil

SCAMP constraints report **Project** Wet tropics **Sample Code** J 1

Australian Soil Order	Orthic Tenosol			Farmer	
Common name	Liverpool			District	
Site characteristics					
Lat	S 55K 0399741	Landform	alluvial plain	Permeability class	4
Long	E 55K 8042208	Landscape position	floodplain	Drainage class	5
Elevation (m)		Erosion hazard	moderate erosion hazard	Surface dispersion class	2
Slope (%)	2	Vegetation		Subsoil dispersion class	2
		Surface condition		SCAMP Texture Type:	S
Specific features					
Vertic		Water pathway	drainage	Compaction	No
Hardsetting	hardsetting	Waterlogging		Acidification risk	high acidification risk
Gravel		Rooting depth		P fixation	very low P fixation

Constraint	**Implications/Management**
Soil texture type:	High infiltration rate; low plant available water-holding capacity.
Erosion Hazard:	Requires surface soil protection by stubble retention, minimum tillage and contour cultivation.
Water logging:	
Surface soil acidity/Al toxicity:	Plants sensitive to Al-toxicity will be affected unless lime is applied; root activity will be restricted below depth of lime incorporation. Grow acid tolerant crops.If exchangeable magnesium levels are low, use dolomitic limestone or dolomite to correct soil pH. Mn-toxicity may occur on some of these soils.
Acidification risk:	Change to less acidifying cropping systems. Apply lime regularly based on monitoring of soil pH. Use nitrate-based fertilisers.
Calcareous:	
Low cation Exch. capacity:	Low
Surface salinity	
Subsoil salinity	
Surface sodicity:	
Subsurface sodicity:	
K status:	Low ability of subsoil to supply K in times of dry surface soil. Deep place K fertiliser.
P fixation status:	Requires high rates of P fertiliser. Use acid-soluble forms of P fertiliser such as reactive rock phosphate. If using water-soluble P fertilizers, then band apply. Use organic amendments and plant residues to supply P.
Vertic properties	
Low organic matter content:	Low organic carbon content; reduced microbial activity and nutrient cycling. Improve organic matter levels by: mulching and incorporating 'green manure' crops such as legumes or forage grasses; retaining all crop residues in the field; do not burn crop residues; use minimum or zero tillage farming systems, strip or alley cropping; apply organic materials (such as fym).
Hardsetting:	Low infiltration rate; poor crop germination and establishment; limited rooting depth. Use surface mulch to maintain soil surface moisture. Limit tillage and machinery traffic.
Compaction:	

Table 13 – Key soil (0-20 cm) attributes and derived constraints and management implications for a Red Ferrosol (Pin Gin series) from the Johnstone Catchment

Soil series	Soil attribute	Value	Constraint	Implication
Pin Gin	Texture	Clay loam	*C* (clayey)	Because *C* is accompanied by *i*, this soil is relatively easy to till when dry, but will compact and stick to implements when wet; suited to zonal tillage to reduce erosion risk; reduced tillage will conserve soil structure and maintain soil moisture; during high intensity rainfall events there is potential risk of off-site sediment movement- minimise this by green cane trash blanketing and grassed waterways and headlands.
	pH_{water}	4.8	*a* (acidity)	Sugarcane is tolerant to soil acidity, and the calcium status of the soil determines whether cane production is limited on acidic soils. However, break crops such as soybean are not as tolerant to soil acidity as sugarcane, and for sustainable production it is necessary to maintain a soil pH (in water) of 5.5 in the surface soil.
	pH buffer capacity	2.6 g $CaCO_3$/kg soil/pH unit	*ar(low)* (acidification hazard)	With soils of moderate or high pH buffer capacity, there is a low risk of soil acidification. However, regular monitoring of soil pH is highly desirable to ensure that subsoil acidification is not occurring. Once subsoil acidification occurs, it is extremely difficult and costly to correct.
	ECEC	1.0 $cmol_c$/kg	*e* (low cation retention)	Low ability to retain K, Ca and Mg against leaching; applications of these nutrients and of N fertilisers should be split; soil or leaf analysis should be undertaken frequently to ensure nutrients are in adequate supply.
	P Buffer Index	596	*i* (high P fixation)	Adjust P fertiliser inputs according to amount of extr. P. High P sorbing soils may require more P than low fixing soils at the same level of BSES extractable soil P.
	Organic C (W-B)	2.0%	*om (high)* (organic matter)	
	pH_{KCl} - pH_{water}	-0.1	*variable charge*	Little net surface charge indicates very little capacity to retain nutrient cations such as K, Ca and Mg, but probable accumulation of nitrate and sulfate due to an appreciable anion exchange capacity; apply small frequent applications of nutrient cations; liming the surface soil to pH (in water) 5.5 will increase soil CEC; trash blanket to retain/improve soil organic matter levels.
	Permeability class	4		
	Drainage class	5		
	Water pathway	drainage		Soils with drainage as the major water movement pathway may lose nutrients such as nitrate-N by leaching, resulting in accelerated soil acidification and ground water pollution; split fertiliser applications to reduce risk of leaching
	Hard-setting	No		

Table 14 – Key soil (0-20 cm) attributes and derived constraints and management implications for a Grey Dermosol (Bulgun series) in the Johnstone catchment

Soil series	Soil attribute	Value	Constraint	Implication
Bulgun	Texture	Clay loam	*C* (clayey)	If tilled when too wet this soil is prone to compaction and will produce large clods and poor seedbeds; use strategic tillage and mounding to manage waterlogging, and controlled traffic to manage compaction
	pH_{water}	5.0	*a* (acidity)	Sugarcane is tolerant to soil acidity, and the calcium status of the soil determines whether cane production is limited on acidic soils. However, break crops such as soybean are not as tolerant to soil acidity as sugarcane, and for sustainable production it is necessary to maintain a soil pH (in water) of 5.5 in the surface soil.
	pH buffer capacity	3.0 g $CaCO_3$/kg soil/pH unit	*ar(low)* (acidification hazard)	With soils of moderate or high pH buffer capacity, there is a low risk of soil acidification. However, regular monitoring of soil pH is highly desirable to ensure that subsoil acidification is not occurring. Once subsoil acidification occurs, it is extremely difficult and costly to correct.
	ECEC	2.9 $cmol_c$/kg	*e* (low cation retention)	Low ability to retain K, Ca and Mg against leaching; applications of these nutrients and of N fertilisers should be split; soil or leaf analysis should be undertaken frequently to ensure nutrients are in adequate supply.
	P Buffer Index	312	*i* (high P fixation)	Adjust P fertiliser inputs according to the amount of extractable P. High P fixing soils may require more P than low fixing soils at the same level of BSES extractable soil P.
	Organic C (W-B)	2.8%	*om (high)*	
	pH_{KCl} - pH_{water}	-0.7		Little net surface charge indicates very little capacity to retain nutrient cations such as K, Ca and Mg, but probable accumulation of nitrate and sulfate due to an appreciable anion exchange capacity; apply small frequent applications of nutrient cations; liming the surface soil to pH (in water) 5.5 will increase soil CEC; trash blanket to retain/improve soil organic matter levels.
	Permeability class	3		
	Drainage class	3		
	Water pathway	ponding		Because of excessive soil wetness during the growing season, tillage, planting, and other practices may not be able to be performed in a timely manner; artificial drainage or mounding may be necessary; denitrification can occur during periods when the water table is high and N carryover may be poor; to reduce denitrification use mound planting, place N fertiliser into the mound and split N applications; during flood events there is potential risk of off-site sediment movement- minimise this by green cane trash blanketing and grassed waterways and headlands.
	Hardsetting	yes	*hs* (hardsetting)	Hardsetting surfaces result in low infiltration rate, poor crop establishment and limited rooting depth; use surface mulch and trash blanket to maintain soil surface moisture; limit tillage and machinery traffic.

The above examples indicate the usefulness of SCAMP for identifying inherent soil constraints and systematically arriving at appropriate management options to deal with these constraints. With this knowledge, fertiliser practices such as timing and placement can be adjusted to minimise losses in productivity and environmental consequences. The use and advantages of SCAMP were described in a paper (Moody *et al.*, 2008) presented at the Australian Society of Sugar Cane Technologists Conference in Townsville in 2008. The paper is included here as Appendix 4.

An electronic copy of the SCAMP manual (Appendix 15) will hopefully be located on the DERM *ReefWiseFarming* website. However, if this is not possible, it will be accessible via the BSES website.

5.0 ACHIEVEMENT OF OBJECTIVE 3

Facilitating the use of nutrient management plans at block and farm scales and the implementation of soil/site-specific fertiliser applications using a participative approach

5.1 Introduction

Changing economic and environmental pressures, both in the local and international arenas, have necessitated changes in attitudes to nutrient inputs on-farm. Apart from the need to reduce the overall cost of production and to maintain the long-term health of soils, the Australian sugar industry has been under mounting pressure to improve its environmental credentials by minimising losses from applied fertiliser. As a result growers needed to gain confidence in applying principles of sustainable nutrient management on-farm and to receive appropriate training, particularly in the use of the SIX EASY STEPS program and developing nutrient management plans at farm and block scales. It was important to ensure that the SIX EASY STEPS short-course was reaching the target 'audience' and resulting in the development and use of nutrient management plans on-farm.

5.2 Method

The effectiveness of the SIX EASY STEPS approach was assessed by:

- Reviewing the short-course format
- Considering the results of surveys that had been conducted to determine the attitude of growers to the workshops and whether sustainable practices were being adopted on-farm
- Ensuring that articles relating to the SIX EASY STEPS program were published in appropriate forms to stimulate industry stakeholders to adopt sustainable nutrient management practices on-farm.

5.3 Results an discussion

5.3.1 Review of the short-course program

The overall objective of the SIX EASY STEPS program is to facilitate the use of better nutrient management on-farm. Given the requirement for sustainable sugarcane production, in which optimum productivity and profitability need to be achieved in combination with environmental responsibility, the SIX EASY STEPS aims to accelerate the adoption of best practice nutrient management across the industry. The SIX EASY STEPS approach is based on the premise that nutrient management guidelines should be linked to soil type (Schroeder and Kingston, 2000; Bruce 2002). Facilitation of the use of the SIX EASY STEPS package for nutrient management planning meant that growers needed to have confidence in the use of the modified guidelines contained in the package. We have made a concerted effort to explain that the SIX EASY STEPS guidelines are based on a logical process and were developed using: (i) knowledge of soil properties and processes (Nelson, *et al.*, 2002), (ii) past data (Wood, *et al.*, 1997; Schroeder, *et al.*, 1998; Schroeder and Wood, 2002), and (iii) results of recent field trials, glasshouse experiments and laboratory investigations (Schroeder and Wood, 2001; Wood and Schroeder, 2004). Simple pedo-transfer functions were used to assist in extrapolating nutrient management guidelines to the industry as a whole.

The SIX EASY STEPS approach provides growers with the ability to undertake 'stepwise' improvements in managing nutrients within their farming enterprises. Information has been presented in numerous forums at three levels of complexity. Basic or individual components of the 'SIX EASY STEPS' were delivered to growers by oral presentations at 'shed meetings' (attended by 10 - 30 growers) or using poster presentations at 'field days'. More detailed information about the "SIX EASY STEPS' has been presented at half-day workshops using a workbook entitled "An integrated approach to sustainable nutrient management for sugarcane". In depth workshops are presented to growers (12 – 16 attendees) with the aim of progressively developing their abilities to use the 'SIX EASY STEPS' to produce nutrient management plans for their farms. These workshops, entitled "Accelerating the adoption of best practice nutrient management", are regionally specific and essentially consist of component parts that correspond to the 'steps' within the SIX EASY STEPS package (Table 15). The essential part of the workbook used in the Burdekin region is presented as an example in Appendix 21. Different workbooks exist for each of the regions. A typical workshop is presented over a 6 - 7 hour period including breaks for lunch and morning and afternoon tea. A fundamental part of the workshop is a Power-Point presentation that comprehensively covers all aspects of the SIX EASY STEPS approach. The presentation used in the Burdekin region is provided as an example in Appendix 22. The workshop is very interactive, with attendees being encouraged to ask questions and to interact with each other, especially during the practical exercises that involve developing nutrient management plans for a hypothetical farm.

Table 15 – Details of the regional workshops aimed at accelerating the adoption of best practice nutrient management.

Section 1: Knowing our soils, understanding and managing nutrient processes and losses. This part of the workshop is aimed at establishing the need for improved nutrient management and providing a sound basis for soil specific nutrient guidelines. It covers: 1. The concept of best-practice nutrient management. 2. The 'SIX EASY STEPS' approach. 3. STEP 1 – KNOWING OUR SOILS: Soil field properties and what they mean; soil chemical properties. 4. STEP 2 – UNDERSTANDING AND MANAGING NUTRIENT PROCESSES AND LOSSES: Nutrient availability and balanced nutrition.

Section 2: Adopting best practice nutrient management This part of the workshop is aimed at progressing the 'SIX EASY STEPS' approach to ensure that the ingredients for successful nutrient management plans are in place. It covers: 1. STEP 3 – SOIL TESTING REGULARLY. 2. STEP 4 – ADOPTING SOIL SPECIFIC FERTILISER RECOMMENDATIONS: Up-to-date soil- and district-specific nutrient management guidelines. 3. Developing a nutrient management plan for a hypothetical farm.
Section 3: Developing nutrient management plans for your farm. Growers are encouraged to develop nutrient management plans for their own farms. This part of the course covers: 1. Consolidating the value of the 'SIX EASY STEPS' approach. 2. STEP 5 – CHECKING ON THE ADEQUACY OF FERTILISER INPUTS (e.g. leaf analysis, on-farm strip trials). 3. STEP 6 – KEEPING GOOD RECORDS AND MODIFYING NUTRIENT INPUTS 4. Suggesting how growers can initiate the development of nutrient management plans for their farms.

5.3.2 Grower attitudes to the short-course program

The training program is proving to be popular with growers. For instance about 250 growers have attended the workshops in the southern region (Bundaberg/Isis) over the past few years. To June 2009, about 630 growers from the northern and central regions have attended a SIX EASY STEPS workshop. The combined Queensland industry figure represents 20% of the total number of growers (covering about 35% of the cane producing area). In excess of 120 extension and productivity staff and agribusiness advisors have also attended a SIX EASY STEPS workshop over the years. Since then, more training has occurred in all regions, including courses for the recently appointed Queensland Government Reef Protection Officers.

In the northern region the SIX EASY STEPS workshops have been delivered using partial funding from the Federal Government's Reef Rescue Program through Terrain Natural Resource Management. A paper entitled "Extension and adoption of the 'SIX EASY STEPS' nutrient management program in sugarcane production in north Queensland" was presented at the International Society of Sugar Cane Technologists Conference in March 2010 (Calcino *et al.*, 2010). This paper, included here as Appendix 5, reports on the assessment of the SIX EASY STEPS educational process and progress in facilitating nutrient management planning. As indicated in a previous section of this report (3.3.4), a short survey conducted after conclusion of some of the northern workshops confirmed a very positive opinion of the value of this extension activity among participants (Table 8).

Calcino *et al.* (2010) reported the results of a Rural Water Use Efficiency Initiative (RWUEI) survey of 88 canegrowers from several regions across Queensland who had completed a SIX EASY STEPS workshop (Toni Anderson pers. comm., 2009). The survey was aimed at an assessment of on-farm practical changes that had been made following attendance at a workshop. Results confirmed that the initial positive impact of the workshops translated into the adoption of sustainable practices. Some of the survey results included:

- 95% of growers had taken a soil test in the two years previous to the survey to determine the most appropriate nutrient management program for a particular cane block or area of the farm.
- 61% changed the type of fertiliser they used to a more economical or nutritionally appropriate product.
- 58% reduced fertiliser rates. The confidence they gained from the course to reduce fertiliser rates without fear of loss of productivity was stated as a significant factor in the decision to reduce nutrient inputs.
- Almost all growers who grew an alternative crop reduced fertiliser inputs in the following plant cane crop.

Surveys conducted after the presentation of the SIX EASY STEPS short-courses in the Northern region (Herbert district northward) indicate that attendees rate the workshops as being very useful (David Calcino pers. comm., 2010). Of the 351 growers who have attended a workshop up until April 2011, 92% rated the workshop as 8 or above (on a scale from 1 to 10, with 1 being a waste of time and 10 being excellent). With the introduction of Queensland Government's Reef Regulations, growers are now required to apply N and P fertiliser according regulated method. Irrespective of this, we estimate that in excess of 90% of growers are applying N and P within the SIX EASY STEPS guidelines. The majority of growers attending the short-course program indicate that the SIX EASY STEPS provides a logical framework for making informed decisions about nutrient inputs on-farm.

5.3.3 Developing a nutrient management plan

As indicated in the SIX EASY STEPS workbook (Appendix 21), there is no set requirement for a nutrient management plan to be compiled in a certain way or format. However, in our opinion a nutrient management plan should be developed using the steps shown below. The plan should be revisited from time to time (at least annually) with modifications made when and where necessary.

- Step 1: Collate appropriate farm details and past records
- Step 2: Get a soils map for the farm that shows block boundaries
- Step 3: Make sure you are familiar with the soil type(s) within each block
- Step 4: Develop a soil sampling program
- Step 5: Gather any soil and leaf analysis reports / data
- Step 6: Collate previous fertiliser histories of each block
- Step 7: Determine the nutrient and fertiliser requirement for each block
- Step 8: Determine the fertiliser requirement for the farm
- Step 9: Plan the fertiliser application input strategies

5.3.4 Articles to stimulate industry stakeholders to adopt sustainable nutrient management practices

Fourteen technical papers covering all aspects of this project have been published and presented at conferences (Section 16 of this report). The full papers are included in this report as Appendices 1-14. A series of 50 grower-orientated articles was also written for the *Australian Canegrower* magazine and included in successive issues (see Section 16 of this report). Examples of these articles are provided in Appendices 16-20. These articles followed the logical 'steps' that comprise the SIX EASY STEPS process. The overall objective was to provide the information to growers in 'bite-sized' pieces and to facilitate the SIX EASY STEPS 'thinking' on-farm. Feedback from CANEGROWERS indicated that the 50-article series was successful and well read by the grower community.

5.3.5 Communication of project outcomes and output

Apart from the ongoing SIX EASY STEPS short-course program and the combination of technical publications (Section 16.1) and industry-focused articles (Section 16.2), the project team held a round of industry meetings to summarize the outcomes and outputs from the project, including likely impacts on water quality (as identified by the vulnerability maps and SafeGauge for Nutrients (section 6 of this report) and demonstration of NutriCalc (section 9 of this report). These meetings were held in the Mackay, Burdekin, Herbert and Johnstone districts in May 2010.

6.0 ACHIEVEMENT OF OBJECTIVE 4

Assessing the risk of on- and off-site impacts of land management practices using vulnerability maps at catchment scale.

6.1 Introduction

Soil/block specific management is underpinned by knowledge of constraints to productivity based on the position of the block in the landscape and key soil characteristics. Landscape and soil attributes affect the pathway of water movement (which determines the potential for off-site movement of nutrients and pesticides) while soil attributes determine productivity constraints such as susceptibility to compaction, tendency to acidify, and ability to supply and retain nutrients. These inherent attributes determine 'hazard', while management practices determine the 'risk' of the hazard causing an adverse effect on- or off-site, either from an environmental or productivity viewpoint. Informed management at block scale therefore requires information on potential hazards so that land management practices can be adopted to ameliorate/mitigate these hazards.

Spatial information derived from climate data (rainfall, evapotranspiration), digital elevation models, soil surveys, and land use can be used to construct 'hazard' (or vulnerability) maps that identify local issues that need to be addressed by block-specific management practices.

6.2 Methodology

6.2.1 Vulnerability maps

The spatially referenced soil surveys available for the Herbert River Catchment (Wood and Bramley 1996), Wet Tropics (Cannon *et al.* 1992; Murtha *et al.* 1994) and Burdekin Delta (Christianos and McClurg 2003) were used to produce maps of various hazards.

Acidification and nutrient loss hazards were assigned to each soil type of the Herbert catchment by identifying those soil types with *S* (sandy) and/or *a* with *ar(high)* (strongly acidic soils with a low pH buffer capacity), and/or *e* (low ECEC) attributes from their SCAMP assessments (see Section 4). It was reasoned that soils with these constraints would be most susceptible to rapid acidification and also loss of nutrients (cations, nitrate) by leaching.

The primary pathways of water movement were identified for the soil types of the Wet Tropics and Burdekin Delta by attributing each soil with a permeability class, drainage class, and erosion hazard as defined in McDonald *et al.* (1990) and assigning the water pathway based on Table 11 in Section 4.2 of this report. Land-use data were accessed for these areas using the spatial surfaces from the Queensland Land Use and Mapping Program (Queensland Department of Natural Resources and Water). Land uses are based on 1999 data (irrigated sugarcane and vegetables) and 2006 data (bananas), and used the Australian Land Use and Management classification (Bureau of Rural Sciences 2006). Areas of bananas (Wet Tropics), irrigated sugarcane (Burdekin Delta) and vegetables and herbs (Burdekin Delta) were calculated for the different water pathway categories.

6.2.2 SafeGauge for Nutrients

SafeGauge is a site-specific CD-based decision support system (DSS) originally developed to assess the qualitative risk of off-site pesticide movement (Simpson *et al.*, 2003). Because the principles of pesticide movement are similar to those of nutrient movement, *SafeGauge* has been modified/enhanced to *SafeGauge for Nutrients* (*SfN*). *SfN* combines embedded site-specific basic soil data (permeability class, drainage class and erosion hazard sourced from soil survey data) and long term rainfall data (sourced from the SILO database) with user-entered information on fertiliser management to assess the qualitative risk of off-site nitrogen (N) and phosphorus (P) movement from different management scenarios. Figure 5 indicates the various components that are used in *SfN* to derive a qualitative risk rating for movement of N and P to surface waters, groundwater and loss of N by denitrification.

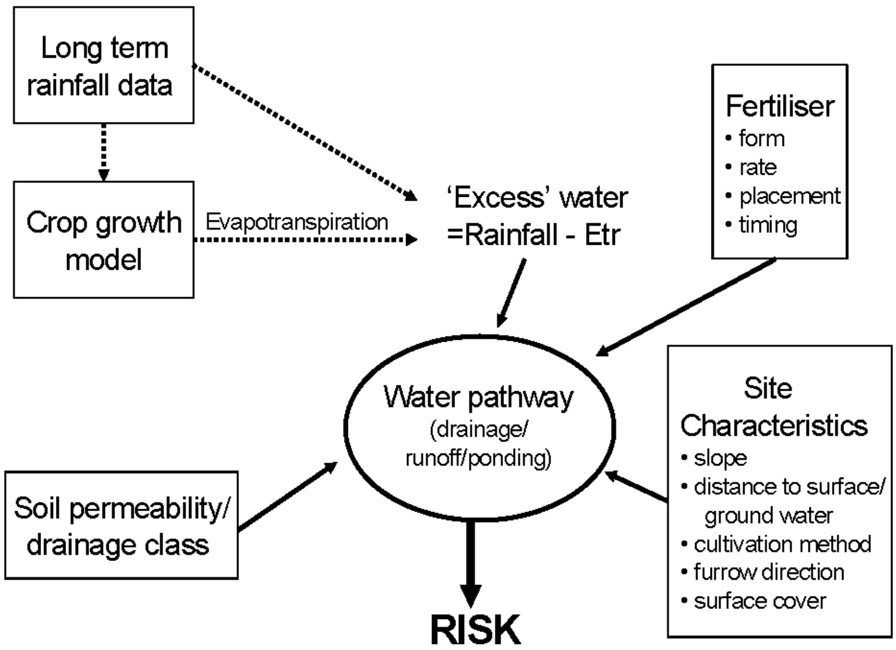


Figure 5 – Components of *SafeGauge for Nutrients.*

6.3 Results and discussion

6.3.1 Hazards of acidification and nutrient loss

Figure 6 indicates that large areas of strongly acidic soils with low ECEC occur along the riverbanks of the Herbert catchment. A liming program will be required to maintain the long term productivity of these soils and fertiliser (particularly nitrogen) management will need to minimise the potentially high risk of off-site nutrient movement.

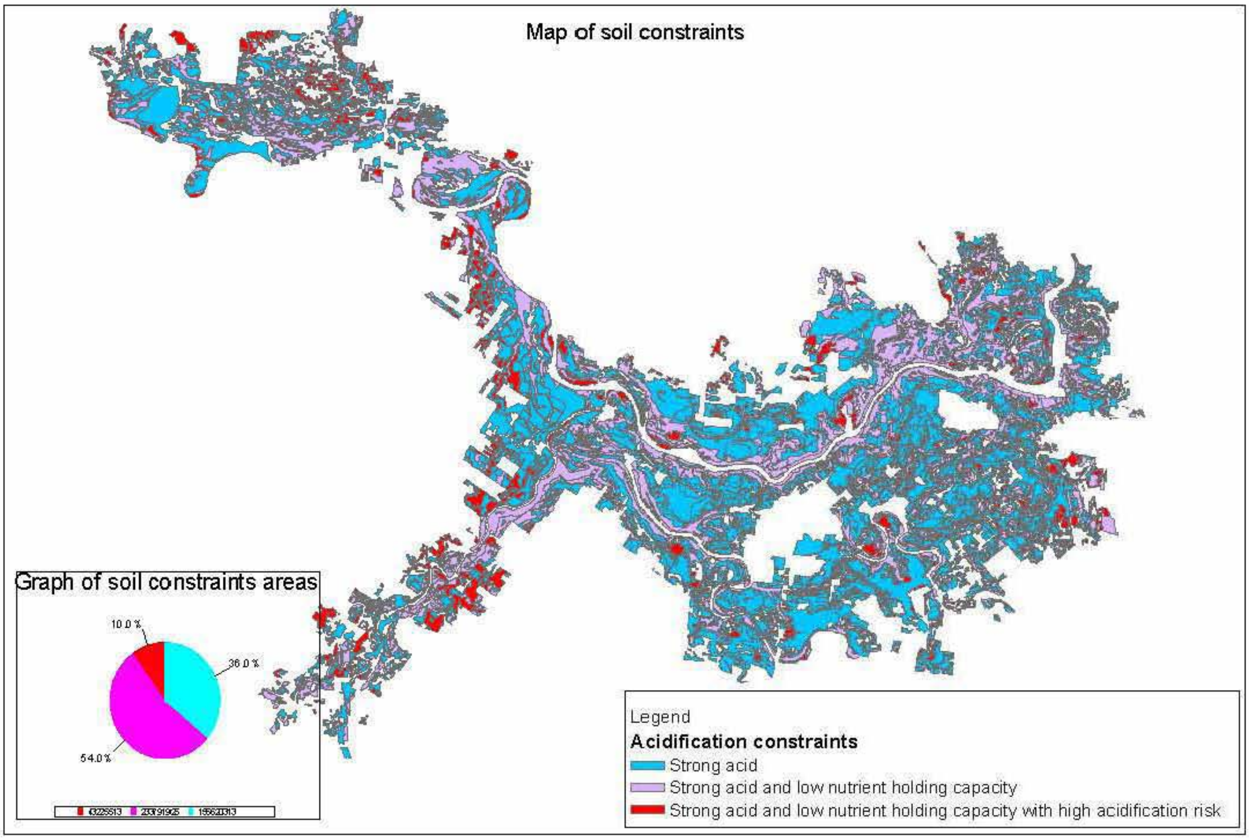


Figure 6 – Map of soils in the Herbert River catchment that are strongly acid [pH(water)<5.5], with low nutrient holding capacity (ECEC <4 $cmol_c$ /kg soil), and high acidification risk (pH buffer capacity <1.5 kmol H^+/kg.pH unit).

6.3.2 Hazards of off-site and pesticide movement

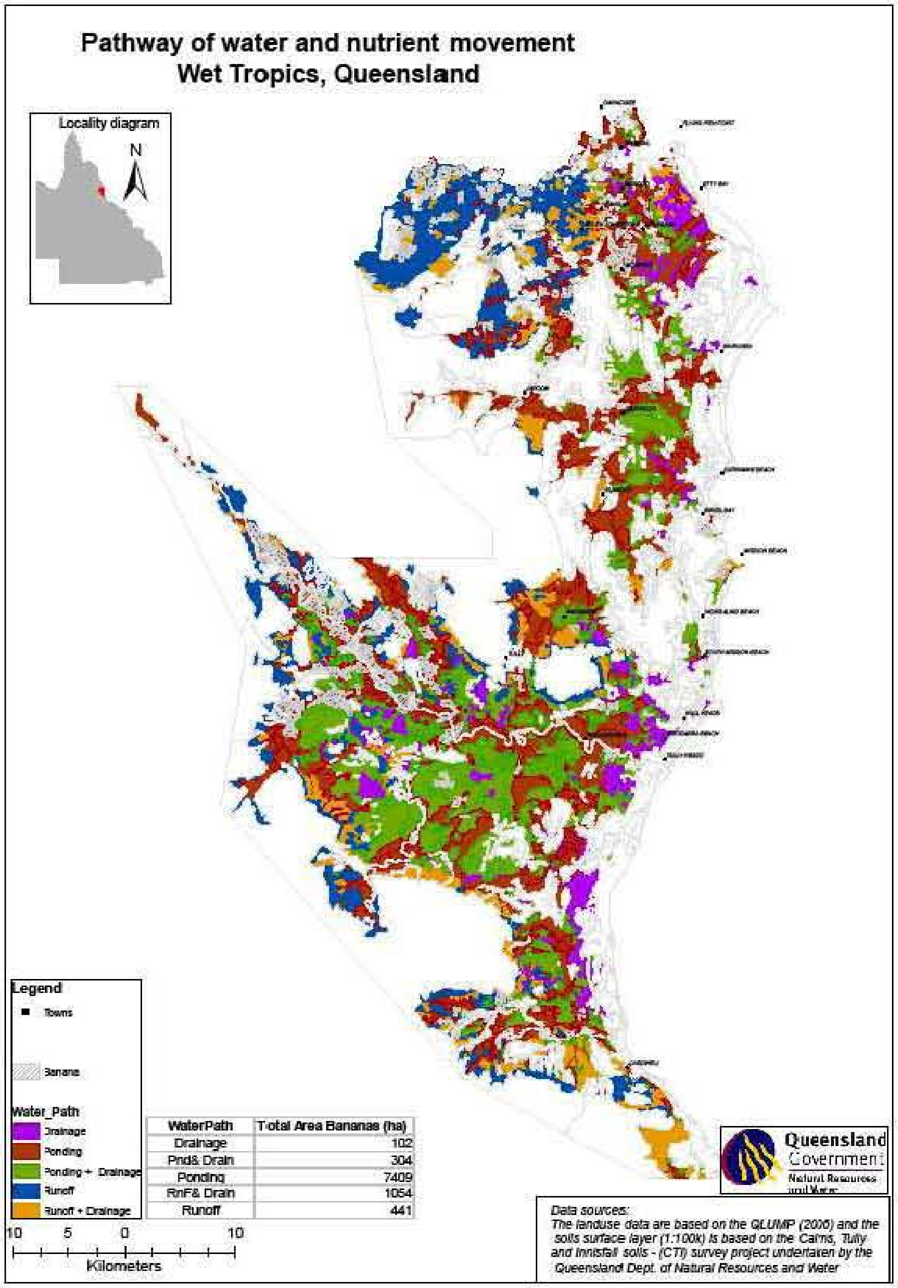
The primary pathway of water movement will determine the directional movement of nutrients (and pesticides) both in dissolved phases and also attached to suspended sediments.

Where drainage (or lateral sub-surface flow) is the primary pathway of water movement, the primary hazard to water quality is the off-site movement of dissolved nutrients (and pesticides) into groundwater and/or perched watertables. Where runoff is the primary pathway of water movement, the main hazard to water quality is the off-site movement of both dissolved and sediment-bound nutrients (and pesticides) into surface water. Ponding poses a hazard of emission of the potent greenhouse gas, nitrous oxide, through denitrification of nitrate. Knowledge of the primary pathway of water movement for a particular soil in a particular landscape position is therefore critical for minimising risk by adopting best practice nutrient management on a soil-specific basis to minimise off-site nutrient (and pesticide) movement.

In the Wet Tropics, the major pathways of water movement in the Tully catchment are ponding (80%) and runoff + drainage (11%) (Figure 7) whereas runoff + drainage is a feature of the better drained volcanic soils of the Johnstone catchment.

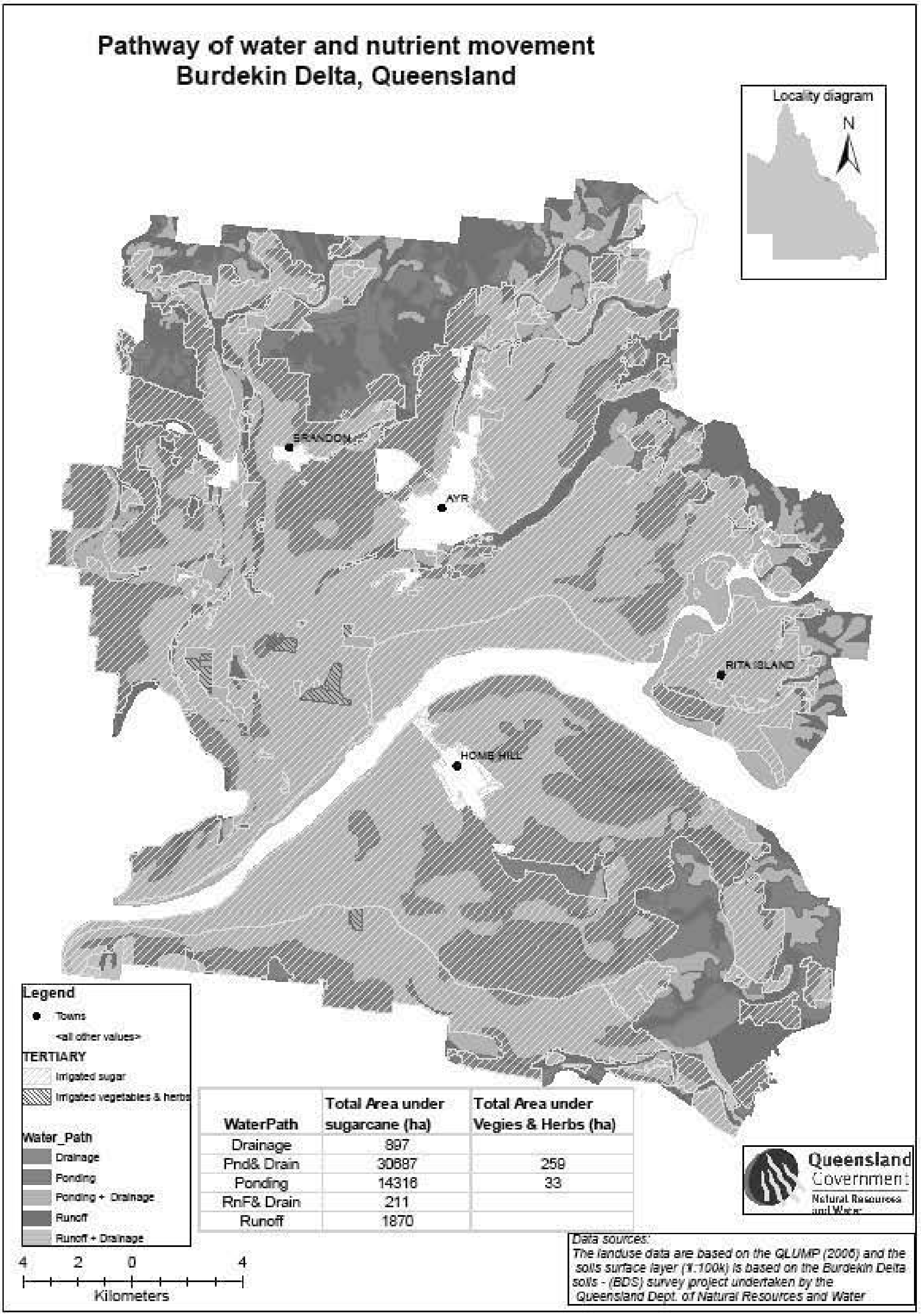
In the Burdekin Delta, ponding + drainage comprises 63% of the drainage pattern with another 30% comprising ponding (Figure 8).

It is apparent that in both areas ponding of water is common, and best practice nutrient management must aim to reduce the risk of denitrification and the off-site movement of dissolved and sediment-bound nutrients in surface drainage water.



WaterPath	Total Area Bananas (ha)
Drainage	102
Pnd& Drain	304
Ponding	7409
RnF& Drain	1054
Runoff	441

Figure 7 – Map of soils in the Wet Tropics showing the primary pathway(s) of water movement



WaterPath	Total Area under sugarcane (ha)	Total Area under Vegies & Herbs (ha)
Drainage	897	
Pnd& Drain	30687	259
Ponding	14316	33
RnF& Drain	211	
Runoff	1870	

Figure 8 - Map of soils in the Burdekin Delta showing the primary pathway(s) of water movement

In summary, hazards can be mapped at catchment scale to identify 'hot spots' which can be targeted for remediation or awareness programs for the landholders. Catchment scale maps can also be used by government and catchment management authorities for the purposes of land use planning and risk assessment for such off-site issues as nutrient movement (with impacts on water quality) and on-site land degradation issues such as soil acidification.

Subsequent to this study (BSS268), DERM Reef Sciences has produced hazard maps of the catchments in the Wet Tropics and Burdekin Dry Tropics where Reef Regulations apply, and is in the process of extending this to include the Mackay-Whitsunday region. The water movement pathways indicated in these hazard maps are based largely on the methodology demonstrated in the maps shown above.

6.3.3 SafeGauge for Nutrients

Two cane blocks comprising a Pin Gin soil and a Bulgun soil were located in the Johnstone catchment using the *SfN* mapping tool and the following fertiliser management information was entered: The plant crop yield goal was 120 tonnes cane /ha and this required 160 kg N/ha. DAP was band-applied at planting at a rate of 100 kg /ha to supply 20 kg P/ha, followed by a surface broadcast application of urea at 300 kg /ha, 6 weeks after emergence, to supply the balance of the required N.

For the Pin Gin soil, leaching of N to groundwater was identified as the greatest risk, while for P, the greatest risk was off-site movement of P attached to sediment. For the Bulgun soil, the major loss pathways identified were denitrification for N, and off-site sediment movement for P. Alternative scenarios for fertiliser management were investigated by changing application timing and placement. These scenarios indicated that incorporation, rather than surface broadcasting, of the side-dressed urea reduced the risk of N loss from both soils, as did earlier application of the side-dress.

SfN allows different fertiliser management scenarios to be assessed for their likely effect on off-site nutrient movement. Because of its user-friendly front end, *SfN* is a powerful awareness-building tool that highlights the links between soil attributes, water movement and fertiliser management. Additionally, *SfN* produces a hard copy report on the site characteristics, fertiliser management and risk assessments (Figure 9). This report could be useful for record-keeping purposes, particularly with respect to the development of farm nutrient management plans.

A description of *SfN* and its use were included in a paper delivered at the ASSCT Conference in Townsville in 2008 (Appendix 4).

A prototype version of *SfN* has been produced on CD for use by the project team. However, as illustrated in Figure 36, it is envisaged that a web-based version of *SfN* will be freely accessible to growers and their advisors through NutriCalc (which will be located on the BSES website). DERM are currently negotiating with the National Centre for Engineering in Agriculture (NCEA) to develop the on-line version of SfN. Growers assessing NutriCalc (on the BSES website) will hopefully in the future have the option of linking to SfN to determine the risk of off-site movement (run-off and/or drainage) of their intended on-farm N and P fertiliser strategies.

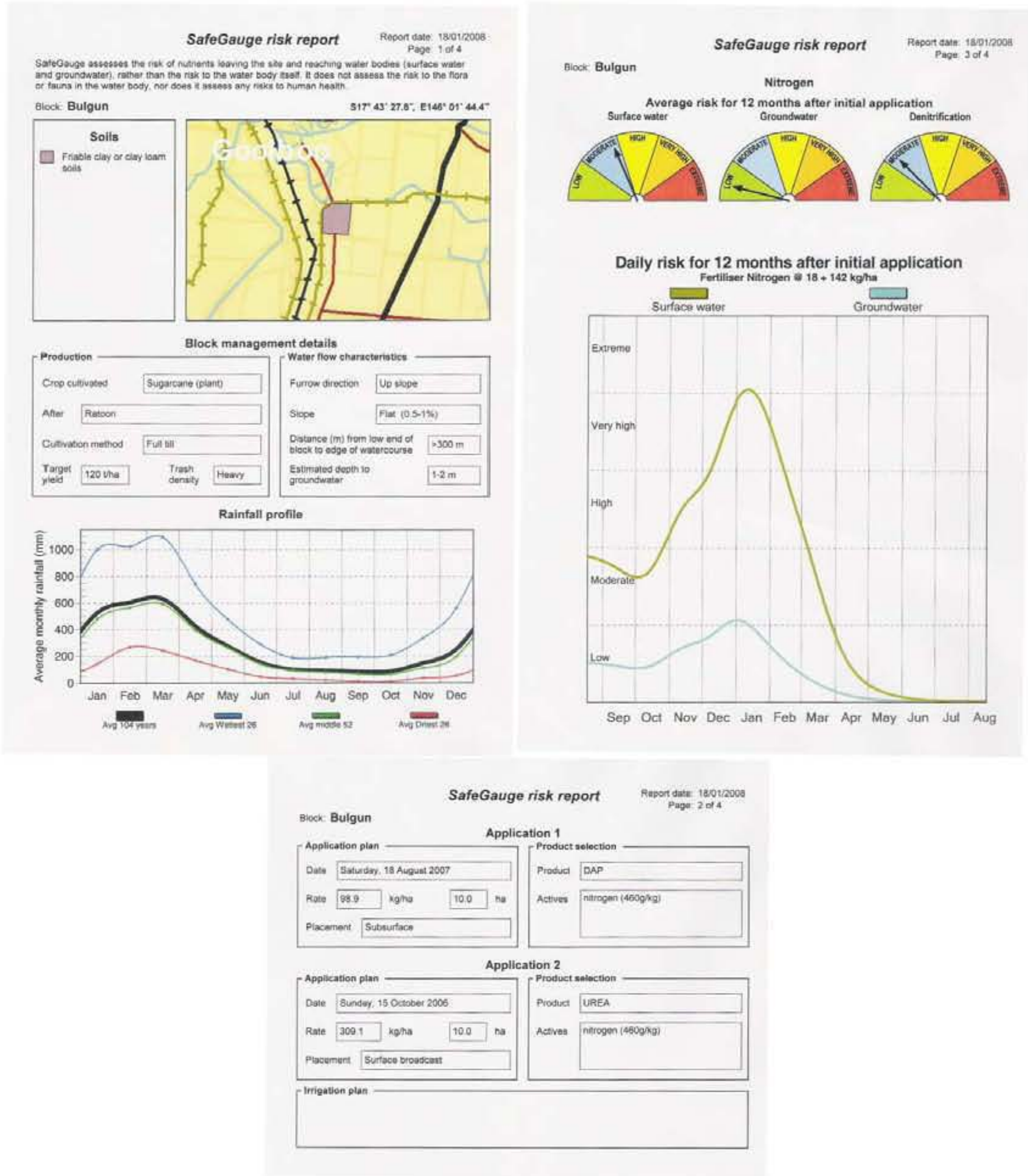


Figure 9 – *SafeGauge for Nutrients* report for an individual cane block on a Bulgun soil

7.0 ACHIEVEMENT OF OBJECTIVE 5

Demonstrating the benefits of best practice nutrient management practices with on-farm strip trials

7.1 Introduction

As indicated previously, the SIX EASY STEPS program is aimed at promoting the adoption of sustainable nutrient management on-farm through the use of best-practice guidelines. These guidelines are the result of a re-evaluation and subsequent fine-tuning of prior generalised recommendations into sets of soil-specific nutrient management guidelines for use at district levels (Schroeder *et al.*, 2006b). Persuading growers to move away from the traditional and grower-developed nutrient management strategies required a series of replicated strip trials that could be used to compare grower practices to inputs based on the SIX EASY STEPS guidelines and to demonstrate that the use of soil-specific guidelines for achieving sustainable sugarcane production.

7.2 Method

7.2.1 Replicated demonstration strip-trials

A substantial number of replicated strip trial sites were established in various regions / districts across the Queensland industry (Bundaberg, Central, Burdekin, Herbert and Wet Tropics (Johnstone district)) with the intent of comparing traditional grower practice (in terms of nutrient inputs) to the SIX EASY STEPS guidelines (as indicated in Salter *et al.*, 2008 (Appendix 6). These were co-ordinated locally to ensure ownership and acceptance of the trials and their results, on-going interaction with collaborating growers, and feedback of results to grower groups. Those involved were:

- Bundaberg: John Panitz (BSES Limited)
- Mackay / Plane Creek: Dr Barry Salter, John Jackson, Sam Henty and Jason Perna (BSES Limited)
- Proserpine: John Agnew (Proserpine Sugar Services Ltd)
- Burdekin: Jayson Dowie (BSES Limited)
- Herbert: Dr Andrew Wood (CSR Ltd)
- Wet Tropics (Johnstone district): Glen Park (BSES Limited) and Bob Stewart (Johnstone River Catchment Management Association Inc.)

The following process was followed at each site:

- Potential trial sites were identified using a consultative process – grower groups were approached to identify co-operators and appropriate sites.
- These sites were assessed in terms of suitability (size of the block, uniformity of the standing plant crop, uniformity of the block, etc)
- Major soil type(s) in each identified block were identified.
- Separate composite top (0-200 mm) and subsoil (400-600 mm) samples were collected from different parts of the block and dispatched to a commercial laboratory for analysis. Apart from gaining information on the soil fertility status of the block, this sampling also enabled the uniformity of the trial area to be evaluated.
- The analysis results were discussed with the applicable grower.
- SIX EASY STEPS (best-practice) nutrient inputs were determined from soil test values.
- Each grower used their own method for identifying their planned nutrient inputs.
- In each case the trial was then established using the identified treatments within randomised and replicated layouts. An example is shown in Figure 10.
- Leaf samples were collected during the leaf-sampling season (Feb – April) from the treatment areas in each strip-trial and sent for analysis. On receipt of results, reports were generated and dispatched to the district co-ordinators for distribution and discussion with the co-operating growers.
- Trials were visually assessed for differences in plant growth.
- The trials were harvested within the growers allocated harvest cycle.

- The size of the replicated strips enabled yield (tonnes cane/ha) and CCS data to be collected at the mill after harvest.
- Partial net return per hectare were calculated using a standardised 'cane payment formula' to determine the partial net return per hectare to the grower:
    - *Grower partial net return = ((price of sugar x (0.009 x (ccs-4)+0.6)) x cane yield) - (cane yield x estimated harvesting costs plus levies) - (fertiliser cost) (kg/ha) – (cane yield x estimated harvesting costs plus levies)*
- Summaries of results were provided to the co-operating grower and grower groups.
- Trials were continued for as many successive seasons as possible.
- Where appropriate, results were reported in papers presented at ASSCT conferences (e.g. a paper entitled "Recognising differences in soil type to guide nutrient inputs on-farm – a case study from Bundaberg" (Schroeder et al., 2007c) was presented at the ASSCT Conference in Cairns in 2007 (Appendix 7)).

Grower JH & RJ Chambers

Farm No. 11586

Block No. 15A

Treatments applied 2 November 2005

Treatments	kg/ha				Product and rate
	N	P	K	S	
Grower					Cal-Am 140(S) @ 884 kg/ha
Best Practise Nutrient Management (BPNM)	134	12	100	22	Cal-Am 140(S) @ 738 kg/ha

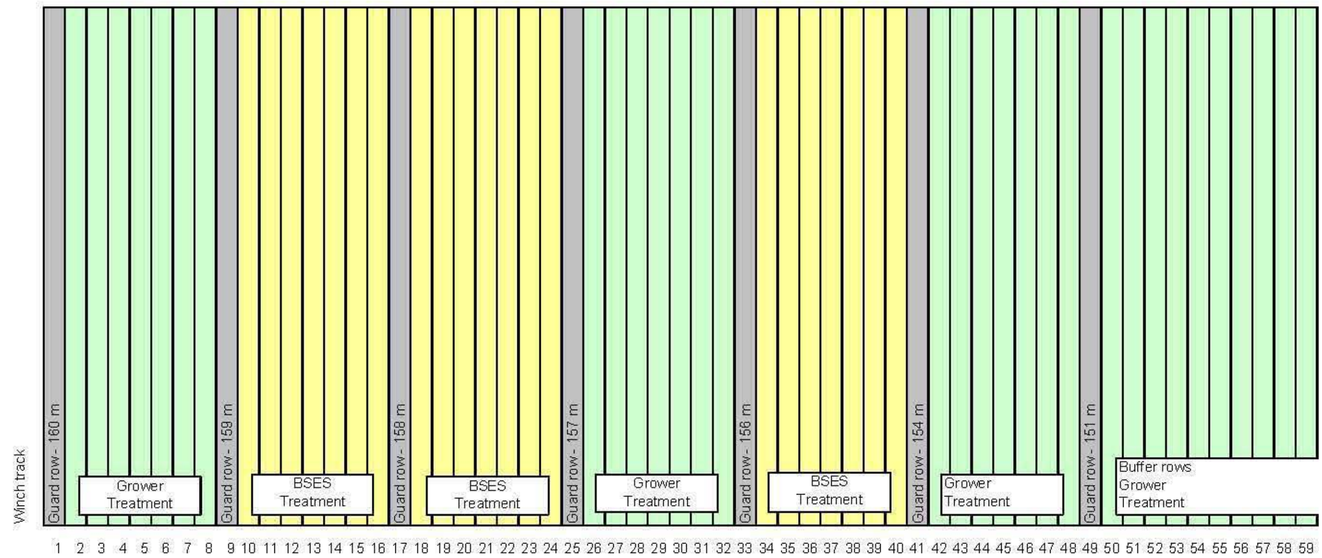


Figure 10 – Example of the layout of a randomised and replicated strip-trial in which standard grower practice is compared to the best-practice option

7.2.2 Replicated small-plot experiments

Several replicated small-plot experiments were also established at various locations to further validate the SIX EASY STEPS guidelines or to provide additional information to further refine these guidelines (as indicated in Wood *et al.*, 2008 and included here as Appendix 8). These included eight separated trials:

- *Herbert 1*: Four rates of N (0, 75, 150 and 225 kg N/ha) and three varieties (Q158, Q179$^{\Phi}$ and NCo310) on a River Bank soil (Macknade series). Data from this trial were also used to assess the validity of four different N management strategies:

- Traditional: maximising productivity and linking N application rates to sugar price (Chapman, 1994);
- Grower developed: minimising risk of yield losses (Johnstone, 1995; Wegener 1990);
- SIX EASY STEPS: aimed at sustainable sugarcane production (Schroeder *et al.*, 2005; Wood *et al.,* 2003);
- N Replacement: minimising N application rates and with a focus on N-use efficiency (Thorburn *et al.*, 2007, 2009).

▪ *Herbert 2 and 3*: Two trials to compare responses to N applied to sugarcane grown conventionally (1.5 m rows) with that grown on pre-formed beds (1.8 m row) following a legume crop. These trials were located on a sandy River Bank soil (Macknade series) and a heavier Clay Loam soil (Leach series).

▪ *Bundaberg 1*: Four rates of N (0, 75, 150 and 225 kg N/ha) and four rates of potassium (K): 0, 60, 120 and 180 kg K/ha) after peanuts on a Red Clay loam soil (Otoo series).

▪ *Bundaberg 2*: Four rates of N (0, 75, 150 and 225 kg N/ha) and four rates of phosphorus (P): 0, 15, 30 and 45 kg P/ha) after soybeans on Humic Gley soil (Fairymead series).

▪ *Mackay*: Four rates of N (0, 75, 150 and 225 kg N/ha) and four 'farming systems' treatments on a non-calcic brown (Pioneer series) soil. The 'farming system' treatments included combinations of row spacing (1.5 m *vs.* 1.8 m rows), fallow management (bare *vs.* legume), tillage practices (conventional *vs.* minimum tillage on pre-formed beds) and previous green *vs.* burnt systems.

▪ *Tully 1*: Four rates of N (Plant 0, 50, 100 and 150 kg N; ratoons: 0, 80, 160 and 240 N/ha) sited on a previous long-term green cane *vs.* burnt systems trial. Data from this trial were also used to assess the validity of four different N management strategies

▪ *Tully2:* Different rates of N on a soil with very high organic C.

7.3 Results and discussion

7.3.1 Replicated demonstration strip-trials

Useful data have been obtained from most of the 48 trials established (Table 16). Although it was originally intended to obtain yield data from 60 harvests over the project period, data were ultimately obtained from 85 harvests over the period 2006 to 2008. This was made possible by securing additional funding from other sources in some areas to enable the trials to continue for extra seasons. Importantly, 27 trials conducted in the Central region, the Johnstone district and Bundaberg were conducted over two or more consecutive crops. The data and information from the Central and Johnstone series trials are shown in detail below and specific examples are used from the Bundaberg and Burdekin trials for illustrative purposes. A paper entitled "Validating the 'SIX EASY STEPS' nutrient management guidelines in the Johnstone Catchment" (Schroeder *et al.*, 2009a) was presented at the ASSCT Conference at Ballina in 2009. It is included here as Appendix 9).

In each trial the usual grower practices (in terms of nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) inputs) were compared to those recommended by the SIX EASY STEPS program (as calculated from the specific soil test data for those particular sites). The soil test data used for establishing the SIX EASY STEPS nutrient requirements in the Johnstone district and Central region trials are shown in Tables 17 and 18, respectively. These data also indicate the range of soil types and the spread of soil chemical properties. Nutrient application rates for each trial are shown in Tables 19 and 20 for the Johnstone trials, and in Tables 21, 22 and 23 for the trials conducted in the Central region. In each case the actual, rather than the intended application rates, are shown because of inaccuracy of fertiliser applicator calibrations. In some cases, the SIX EASY STEPS guidelines required other inputs such as magnesium (Mg), lime or micro-nutrients.

Average yield (tonnes cane/ha (tc/ha) and tonnes sugar/ha (ts/ha)) based on the mean of three replicates together with partial net returns for the Johnstone district trials: 2007 and 2008 (Tables 19 and 20 respectively) and Central region trials: 2006, 2007 and 2008 (Tables 21, 22 and 23 respectively) indicate the validity of the SIX EASY STEPS approach. In comparison to the usual grower practices, the SIX EASY STEPS inputs resulted in generally maintained yields, improved profitability and less risk to the environment (due to lower N and/or P inputs).

Table 16 – Replicated demonstration strip-trials conducted in various sugarcane districts in Queensland

District	Trial No.	2006 Crop	2007 Crop	2008 Crop
Bundaberg	B-ST1	Harvested	Discontinued after 2006	
	B-ST3	Harvested	Harvested	Harvested
	B-ST4	Harvested	Harvested	Harvested
	B-ST5	Harvested	Harvested	Harvested
	B-ST6	Harvested	Harvested	Harvested
	B-ST 8	Established Mar 2006	Harvested cane lost	Harvested
	B-ST9	Harvested	Harvested	Harvested
	B-ST10	Harvested	Harvested	Harvested
	B-ST11		Established in 2007	Harvested
Central	P-ST1	Harvested	Discontinued after 2006	
	P-ST2	Harvested	Harvested in 2007 and then discontinued	
	P-ST3	Harvested without notice and therefore discontinued		
	P-ST4	Harvested	Discontinued after 2006	
	P-ST5	Harvested	Discontinued after 2006	
	P-ST6	Harvested	Discontinued after 2006	
	P-ST7	Harvested	Discontinued after 2006	
	C-ST1	Harvested	Harvested	Harvested
	C-ST2	Harvested	Harvested	Harvested
	C-ST3	Harvested	Harvested	Harvested
	C-ST4	Harvested	Harvested	Harvested
	C-ST5	Harvested	Harvested	Harvested
	C-ST6	Harvested	Harvested	Harvested
	C-ST7	Harvested	Harvested	Harvested
	C-ST8	Established Sep 2006	Harvested	Harvested
	C-ST9	Established Oct 2006	Harvested	Harvested
Herbert	H-ST1	Harvested	Discontinued after 2006	
	H-ST2	Harvested	Harvested in 2007 and then discontinued	
	H-ST3	Harvested	Harvested in 2007 and then discontinued	
	H-ST4	Harvested	Discontinued after 2006	
	H-ST5	Harvested	Harvested in 2007 and then discontinued	
	H-ST6	Harvested without notice and then discontinued		
	H-ST7	Harvested	Discontinued after 2006	
	H-ST8	Harvested	Discontinued after 2006	
	H-ST9	Harvested without notice and then discontinued		
	H-ST10	Harvested	Discontinued after 2006 harvest	
	H-ST11	Harvested	Discontinued after 2006 harvest	

District	Trial No.	2006 Crop	2007 Crop	2008 Crop
Burdekin	Bkn-ST1	-	Established in 2007	Discontinued
	Bkn-ST2	-	Established in 2007	Harvested
	Bkn-ST3	-	Established in 2007	Harvested
Wet Tropics	J-ST1	Harvested	Harvested	Harvested
	J-ST2	Harvested	Harvested	Harvested
	J-ST3	Harvested	Harvested	Harvested
	J-ST4	Cyclone damage	Harvested	Harvested
	J-ST5	Cyclone damage	Harvested	Harvested
	J-ST6	Harvested	Harvested	Harvested
	J-ST7	Established Nov 2006	Harvested	Harvested
	J-ST8	Un-replicated (Nov 06)	Harvested in 2007 and 2008, data not used	
	J-ST9	Established Nov 2006	Harvested	Harvested

Table 17 – Selected soil chemical properties for the participative replicated demonstration strip trials conducted in the Johnstone district.

Soil type[1]	Soil pH[2]	Org C[3] (%)	PBI[4]	BSES P	Sulphate S	Cu[5]	Zn[5]	ECEC[6]	Nitric K	Exch. cations K	Exch. cations Ca	Exch. cations Mg
				(mg/kg)				(me%)				
Brosnan	5.8	0.65	55	115	3	0.91	1.03	1.65	0.36	0.08	0.95	<0.2
Bulgun	5.5	2.60	435	125	185	0.25	0.58	4.58	1.75	0.20	1.80	0.85
Eubenangee	5.6	1.60	385	49	52	1.20	0.29	2.70	0.40	0.14	1.60	0.65
Innisfail	4.7	1.25	380	103	49	0.63	0.79	4.83	4.40	0.23	0.78	0.49
Maria	5.4	1.90	200	67	6	0.15	0.15	2.33	0.46	0.06	0.80	<0.2
Mundoo	5.0	1.60	505	31	115	1.65	0.58	1.15	0.15	0.08	0.40	0.20
Pin Gin	4.9	1.95	835	41	275	0.68	0.36	1.98	0.25	0.16	0.98	0.26
Thorpe	5.7	1.02	76	105	2	0.12	0.47	1.77	0.16	0.04	1.10	<0.2
Tully	4.9	0.90	180	24	18	0.45	0.35	3.5	5.10	0.14	1.00	0.31

[1] Murtha (1986), [2] $pH_{(water)}$, [3] Walkley-Black organic C (Walkley and Black, 1934)
[4] Phosphorus buffer index, [5] DTPA extractable Cu and Zn, [6] Effective cation exchange capacity

Table 18 – Selected soil chemical properties for the participative replicated demonstration strip trials conducted in the Central region.

Soil type[1]	Soil pH[2]	Org C[3] (%)	PBI[4]	BSES P	Sulphate S	Cu[5]	Zn[5]	ECEC[6]	Nitric K	Exch. cations K	Exch. cations Ca	Exch. cations Mg
				(mg/kg)				(me%)				
Mirani	5.8	0.37	22	59	4.5	0.97	0.47	2.60	1.10	0.95	1.75	0.59
Pioneer	5.9	1.25	81	280	5.6	0.87	2.00	6.01	1.10	0.15	4.1	1.7
Tannalo	4.8	0.63	47	52	13	0.29	0.36	2.08	0.90	0.10	0.7	0.33
Kattabul	5.6	0.75	95	39	12	1.3	1.35	7.80	0.48	0.15	4.8	2.5
Marian/Calen	6.0	0.66	42	35	6.9	0.61	0.40	3.90	0.92	0.09	2.5	1.02
Victoria Plains	7.3	1.90	165	47	18	2.4	0.53	42.6	1.35	0.49	24.0	17.0
Mirani	4.9	0.59	76	47	14	0.93	0.66	2.85	0.88	0.13	1.0	0.63

[1] Holz and Shields (1985), [2] $pH_{(water)}$, [3] Walkley-Black organic C (Walkley and Black, 1934)
[4] Phosphorus buffer index, [5] DTPA extractable Cu and Zn, [6] Effective cation exchange capacity

Table 19 – 2007 yield data and calculated partial net returns for the different nutrient management strategies used in the participative replicated demonstration strip trials in the Johnstone district

Soil	Nutrient strategy	Nutrients applied						Yield		Partial net return[3] (Benefit using the SIX EASY STEPS strategy shown in brackets)	
		N	P	K	S	Other[2]	Cost				
		(kg/ha)					($/ha)	(tc/ha)	(ts/ha)	($/ha)	
Brosnan	6ES[1]	150	13	114	29	Mg	417	72.2	9.9	912	(-16)
	Grower	135	12	141	0	-	382	74.2	10.0	928	
Bulgun	6ES	101	0	101	0	-	258	64.7	7.6	589	(128)
	Grower	165	8	90	10	-	380	68.4	7.8	461	
Eubenangee[4]	6ES	125	8	126	1	Zn	351	71.5	7.2	277	(66)
	Grower	140	11	137	1	-	356	64.5	6.5	212	
Innisfail	6ES	127	0	104	0	-	288	99.0	12.8	1320	(124)
	Grower	177	17	128	13	-	449	106.4	13.4	1196	
Maria	6ES	115	0	121	5	Zn, Cu	399	77.1	10.3	930	(9)
	Grower	162	0	95	0		332	77.2	10.0	921	
Mundoo	6ES	133	13	138	1	Mg	404	59.4	7.0	385	(-115)
	Grower	148	0	86	0	-	304	58.6	7.0	500	
Pin Gin	6ES	120	11	124	1	Lime	340	82.3	9.5	696	(31)
	Grower	135	13	97	10	-	339	78.5	9.1	665	
Thorpe	6ES	130	0	111	21	Zn	391	101.3	11.3	800	(189)
	Grower	184	16	111	1	-	400	95.5	10.2	611	
Tully	6ES	138	24	96	14	Lime	371	109.6	13.5	1239	(29)
	Grower	162	0	95	0	-	332	105.0	12.9	1210	
Mean	6ES	127	7	114	9	Various	359	83.2	10.2	859	(47)
	Grower	159	8	105	4		365	83.0	10.9	812	

[1] SIX EASY STEPS.
[2] Other nutrients or amendments applied (20% of cost included in calculation of partial net returns).
[3] Partial net return = (Sugar price x 0.009(CCS-4)+0.6) x tc/ha)-(tc/ha x harvesting costs ($/tc))-(Fertiliser cost $/ha) Assumptions: sugar price = $285/t, harvesting costs plus levies = $7.20, fertiliser costs according to 2007 prices.
[4] Data not included in means because these were un-replicated plots

Table 20 – 2008 yield data and calculated partial net returns for the different nutrient management strategies used in the participative replicated demonstration strip trials in the Johnstone district

Soil	Nutrient strategy	Nutrients applied						Yield		Partial net return[3] (Benefit using the SIX EASY STEPS strategy shown in brackets)	
		N	P	K	S	Other[2]	Cost				
		(kg/ha)					($/ha)	(tc/ha)	(ts/ha)	($/ha)	
Brosnan	6ES[1]	150	13	114	29	(Table 21)	524	77.0	10.0	968	(-172)
	Grower	126	12	130	0	-	400	79.3	10.3	1140	
Bulgun	6ES	97	0	98	0	-	273	47.0	7.4	1030	(159)
	Grower	177	11	111	23	-	472	48.6	7.7	871	
Eubenangee[4]	6ES	125	16	120	1	(Table 21)	422	76.0	9.5	943	(89)
	Grower	110	0	110	0	-	308	66.3	8.1	854	
Innisfail	6ES	127	0	103	0	-	323	90.6	10.5	1071	(98)
	Grower	155	15	112	11	-	414	88.9	11.7	973	
Maria	6ES	124	0	124	5	(Table 21)	420	90.8	12.3	1456	(264)
	Grower	155	16	118	2	-	445	88.2	11.1	1192	
Mundoo	6ES	124	12	127	1	(Table 21)	420	71.2	8.8	873	(22)
	Grower	142	0	83	0	-	325	67.3	8.4	851	
Thorpe	6ES	114	0	114	23	(Table 21)	394	91.0	11.0	1125	(97)
	Grower	149	0	124	36	-	407	88.1	10.5	1028	
Tully	6ES	137	24	95	14	(Table 21)	423	94.2	12.2	1391	(81)
	Grower	160	0	94	0	-	367	86.2	11.2	1310	
Mean	6ES	125	7	111	10	(Table 21)	397	80.3	10.3	1131	(79)
	Grower	152	8	110	10	-	404	78.1	10.1	1052	

[1] SIX EASY STEPS.
[2] Other nutrients or amendments applied (20% of cost included in calculation of partial net returns).
[3] Partial net return = (Sugar price x 0.009(CCS-4)+0.6) x tc/ha)-(tc/ha x harvesting costs ($/tc))-(Fertiliser cost $/ha) Assumptions: sugar price = $320/t, harvesting costs plus levies = $7.50, fertiliser costs according to 2008 prices.
[4] Data not included in means because these were un-replicated plots

Table 21 – 2006 yield data and calculated partial net returns for the different nutrient management strategies used in the participative replicated demonstration strip trials in the Central region

Soil	Nutrient strategy	Nutrients applied N (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)	Cost ($/ha)	Yield (tc/ha)	Yield (ts/ha)	Partial net return[3] (Benefit using the SIX EASY STEPS strategy shown in brackets) ($/ha)	
Mirani	6ES[1]	160	0	97	22	331	103.7	16.0	2697	(54)
	Grower	205	0	98	26	397	104.1	16.1	2643	
Pioneer	6ES	105	0	0	0	133	136.6	13.0	1302	(274)
	Grower	180	0	113	20	391	138.8	13.1	1028	
Kuttabul	6ES	153	0	123	10	361	107.6	15.2	2331	(71)
	Grower	189	25	90	21	434	107.2	15.2	2260	
Marian/Calen	6ES	153	10	102	15	358	106.1	15.5	2442	(8)
	Grower	182	0	108	29	400	105.9	15.6	2434	
Victoria Plains	6ES	122	11	0	0	187	81.8	10.6	1550	(188)
	Grower[2]	180	16	105	20	420	86.9	11.0	1362	
Mirani	6ES	142	0	95	9	307	107.3	16.5	2789	(-17)
	Grower	166	0	97	23	275	104.4	16.2	2806	
Mean	6ES	139	4	70	9	280	107.2	14.5	2185	(96)
	Grower	184	7	102	23	386	107.9	14.5	2089	

[1] SIX EASY STEPS; [2]Grower treatment: one replicate only

[3] Grower partial net return = (Sugar price x 0.009(PRS-4)+0.6) x tc/ha)-(tc/ha x 7.5 $/tc)-(Fertiliser cost $/ha) Assumptions: sugar price = $350/t, harvesting costs plus levies = $7.50, fertiliser costs according to 2006 prices.

Table 22 – 2007 yield data and calculated partial net returns for the different nutrient management strategies used in the participative replicated demonstration strip trials in the Central region

Soil	Nutrient strategy	Nutrients applied N (kg/ha)	P (kg/ha)	K (kg/ha)	S (kg/ha)	Cost ($/ha)	Yield (tc/ha)	Yield (ts/ha)	Partial net return[3] (Benefit using the SIX EASY STEPS strategy shown in brackets) ($/ha)	
Mirani	6ES[1]	161	0	92	14	298	90.7	12.9	1401	(38)
	Grower	205	0	95	14	369	92.3	13.1	1363	
Tannalo	6ES	143	10	96	14	319	99.5	13.5	1396	(12)
	Grower	193	0	118	21	398	101.1	13.9	1384	
Kuttabul	6ES	153	0	123	10	390	104.3	15.2	1679	(191)
	Grower	189	25	90	21	486	108.7	15.2	1488	
Marian/Calen	6ES	156	0	95	17	366	106.4	17.3	2199	(69)
	Grower	173	0	105	19	406	107.4	17.3	2130	
Victoria Plains	6ES	135	13	0	0	204	83.0	12.2	1460	(102)
	Grower[2]	188	17	110	20	479	95.9	13.8	1358	
Mirani	6ES	161	0	92	14	298	112.9	14.0	1305	(57)
	Grower	180	0	103	15	333	110.2	13.7	1248	
Mean	6ES	152	4	83	12	312	99.5	14.2	1573	(78)
	Grower	188	7	104	18	412	102.6	14.5	1495	

[1] SIX EASY STEPS; [2] Grower treatment: one replicate only

[3] Partial net return = (Sugar price x 0.009(PRS-4)+0.6) x tc/ha)-(tc/ha x 8.5 $/tc)-(Fertiliser cost $/ha) Assumptions: sugar price = $280/t, harvesting costs plus levies = $8.50, fertiliser costs according to 2007 prices.

Table 23 – 2008 yield data and calculated partial net returns for the different nutrient management strategies used in the participative replicated demonstration strip trials in the Central region

Soil	Nutrient strategy	Nutrients applied N	P	K	S	Cost	Yield		Partial net return[3] (Benefit using the SIX EASY STEPS strategy shown in brackets)	
		(kg/ha)				($/ha)	(tc/ha)	(ts/ha)	($/ha)	
Mirani	6ES[1]	160	0	91	15	503	98.3	14.5	1770	(57)
	Grower	205	0	97	18	628	99.8	14.9	1713	
Tannalo	6ES	161	0	107	14	727	96.2	15.4	1851	(83)
	Grower	188	0	125	17	848	97.0	15.6	1768	
Kuttabul	6ES	153	0	123	10	734	74.8	11.8	1213	(83)
	Grower	189	25	90	21	934	79.3	12.5	1130	
Marian/Calen	6ES	153	0	102	14	688	86.9	13.4	1493	(43)
	Grower	161	0	107	14	727	86.7	13.4	1450	
Victoria Plains	6ES	138	0	0	0	367	64.0	9.2	1038	(-74)
	Grower[2]	182	16	110	21	930	88.0	13.0	1176	
Mirani	6ES	165	0	93	16	518	69.8	9.5	863	(-11)
	Grower	184	0	104	18	577	71.7	9.9	874	
Mean	6ES	153	0	88	12	582	85.5	12.6	1369	(30)
	Grower	184	7	107	19	749	88.9	13.0	1280	

[1] SIX EASY STEPS; [2] Grower treatment: one replicate only
[3] Grower partial net return = (Sugar price x 0.009(PRS-4)+0.6) x tc/ha)-(tc/ha x 8.5 $/tc)-(Fertiliser cost $/ha) Assumptions: sugar price = $320/t, harvesting costs plus levies = $7.50, fertiliser costs according to 2006 prices.

In relation to nutrient inputs, it was found that in the seasons considered the SIX EASY STEPS N application rates were generally lower than that of the usual grower practice (Johnstone: 126 kg N/ha versus 156 kg N/ha (means of data from Tables 19 and 20) and Central: 148 kg N/ha versus 185 kg N/ha (means of data from Tables 21, 22 and 23)). In the Johnstone trials, P inputs were similar for both strategies over 2007 and 2008. Potassium and S inputs associated with the SIX EASY STEPS approach were slightly higher than the grower inputs in 2007. In the Central region trials P, K and S inputs were lower in the SIX EASY STEPS compared to the usual grower practice (mean of 3 kg P/ha versus 7 kg P/ha, 80 kg K/ha versus 104 kg K/ha and 11 kg S/ha versus 17 kg S/ha, respectively). Maintenance of yield, despite rationalised nutrient inputs, is an important outcome, as it ensures that profitable cane production can be achieved in combination with enhanced environmental outcomes. It also illustrates that the concept of 'balanced nutrition' (as recommended by the SIX EASY STEPS approach) is more appropriate than a standard nutrient 'mix' applied across the farm.

Although the calculated partial net returns were generally in favour of the SIX EASY STEPS, exceptions did occurred. For instance, this occurred in the Johnstone at the Brosnan and Mundoo sites (Tables 19 and 20)) when the SIX EASY STEPS inputs included magnesium oxide. However, the inclusion of micro-nutrients (copper and/or zinc) and lime into the SIX EASY STEPS inputs at many of the other sites did not negatively affect the partial net return (despite the added cost). This provides evidence that these nutrients were indeed required. The results also highlight the effect of season on profitability, not only in terms of weather, but also due to the costs of inputs and the price of sugar.

Three replicated demonstration strip trials were established in the Burdekin district. In these trials three different nutrient management strategies were compared (Table 24):

- Usual grower practice
- SIX EASY STEPS approach
- N Replacement theory

Although the same general methodology was used (as indicated previously), the N contribution from the irrigation water was included in decisions about nutrient inputs. All other major nutrients were applied when requirements were indicated by the soil test results.

Table 24 – Summary: demonstration strip trials in the Burdekin district

Trial No.	Soil type	Selected soil properties			Ratoon N application rate (kg N/ha)		
		Soil $pH_{(water)}$	Org C (%)	CEC (me%)	Grower	SIX EASY STEPS	N Repl.
Bkn-ST1	Non-sodic duplex (Dyd)	6.9	0.41	5.5	238	180	207
Bkn-ST2	Cracking clay (UGb)	6.6	0.78	15.6	230	108*	82
Bkn-ST3	Sandy clay loam (Uma)	6.7	0.58	9.0	232	180	167

* N reduced because of nitrate in the irrigation water

Unfortunately, yield data from only two of these trials were obtained. Trial Bkn-ST1 was harvested by the grower without notice and hence no results are available.

A summary of the results from the other two trials are presented in Table 25.

Table 25 – Demonstration strip trials conducted in the Burdekin district (2008)

Site	Treatment	Nutrients applied (kg/ha)				Yield			Return
		N	P	K	S	(tc/ha)	CCS	(ts/ha)	($/ha)
Bkn – ST2	Grower	248	0	98	8	128	14.3	18.2	2237
	SIX EASY STEPS	119	0	100	10	122	15.0	18.3	2735
	N Replacement	88	0	96	18	114	15.3	17.3	2692
Bkn – ST3	Grower	233	0	0	0	125	15.3	19.1	2583
	SIX EASY STEPS	180	0	0	0	131	15.3	20.0	2891
	N Replacement	167	0	0	0	128	15.3	19.7	2888
Mean	Grower	241	0	49	4	126	14.8	18.6	2410
	SIX EASY STEPS	150	0	50	5	126	15.2	19.2	2813
	N Replacement	128	0	48	9	121	15.3	18.5	2790

Sugar price = $325/t
Return = ((Sugar price x 0.009 (PRS-4)+o.6) x tc/ha) – (tc/ha x 8.5 $/tc) – (Fertiliser cost ($/ha)
2008 Fertiliser prices used

Results from the Burdekin trials indicate that the SIX EASY STEPS approach to nutrient management produced positive results (yields were similar to those achieved with the usual grower practice). Importantly, the average partial net return ($2813/ha) calculated for the SIX EASY STEP approach was about $400 better than that achieved from the grower determined inputs.

An example from Bundaberg illustrates the use of appropriate management strategies following a fallow peanut crop. The particular trial (B-ST3 (Table 16)) was established on an Alluvial soil (NRW soil Mapping Unit = Burnett) in a block of sugarcane (variety Q205$^{\Phi}$) after harvest of the plant crop. Two successive crops of peanuts had been grown in the block prior to the plant crop.

In terms of the SIX EASY STEPS approach, the nutrient requirement calculated from a soil test for the 1st ratoon crop was 150 kg N/ha, 0 kg P/ha and 100 kg K/ha. However, the strategy that was actually used took into account the residual N from the fallow peanut crops. As a result the nutrient requirement was decreased to 100 kg N/ha, 0 kg P/ha and 100 kg K/ha. The grower practice in this case, which also recognised the N contribution from the peanut crops, was 130 kg N/ha, 11 kg P/ha and 100 kg K/ha. The grower achieved this by applying his usual ratoon fertiliser blend, but at a lower rate. The harvest results indicated that yields (sugarcane and sugar) were similar in both cases (Figure 11).

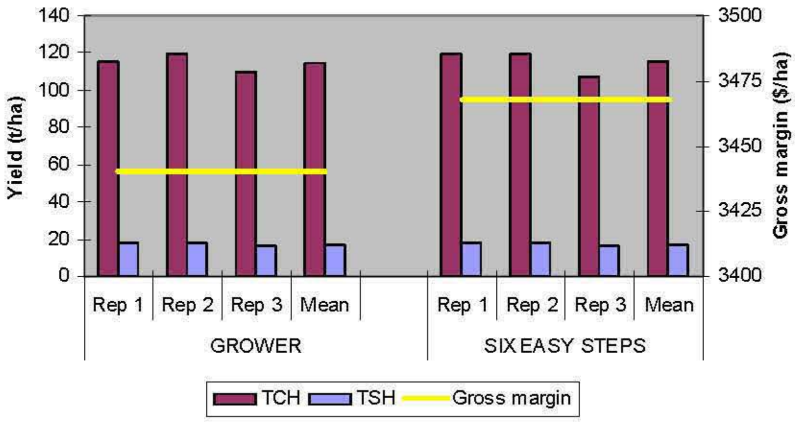


Figure 11 – Bundaberg trial B-ST3: First ratoon yield data (sugarcane and sugar) and calculated net returns (gross margins) for the grower versus SIX EASY STEPS strategies

In relation to the second ratoon crop, the SIX EASY STEPS strategy was to test whether any residual N from the peanut crops was still available within the system. As a result the nutrient requirement remained unchanged from the previous crop (100 kg N/ha, 0 kg P/ha and 100 kg K/ha). The grower practice in this case was to revert to his usual fertiliser application rate. This resulted in the following nutrient application: 150 kg N/ha, 13 kg P/ha and 116 kg K/ha. Apart from the P applied, this practice is very close to the unadjusted original SIX EASY STEPS approach.

As with the first ratoon, the second ratoon yields were again similar across treatments (Figure 12). The net return (gross margins) were in favour of the best practice (SIX EASY STEPS) option by a cumulative \$170 /ha.

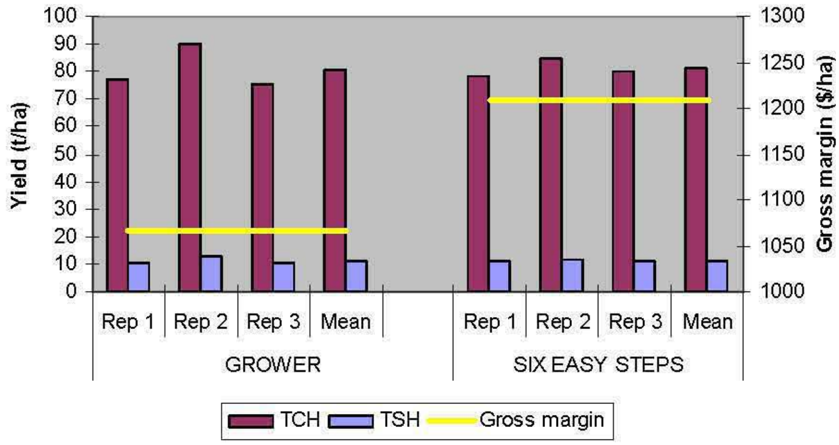


Figure 12 – Bundaberg trial B-ST3: Second ratoon yield data (sugarcane and sugar) and calculated net returns (gross margins) for the grower versus SIX EASY STEPS strategies

The results of the full series of replicated strip trials indicate that in terms of sustainability, it is important to maintain soil fertility and apply nutrients at appropriate rates. Over application, on the other hand can also lead to losses in profitability for both the growers and the industry as a whole (growers and millers) and have negative environmental consequences. A sound scientifically based system, such as the SIX EASY STEPS program, enables informed decisions about nutrient inputs and contributes to the overall adoption of best practice management on-farm.

7.3.2 Replicated small-plot experiments

The following is a summary of the results from the replicated small-plot experiments

Herbert 1:

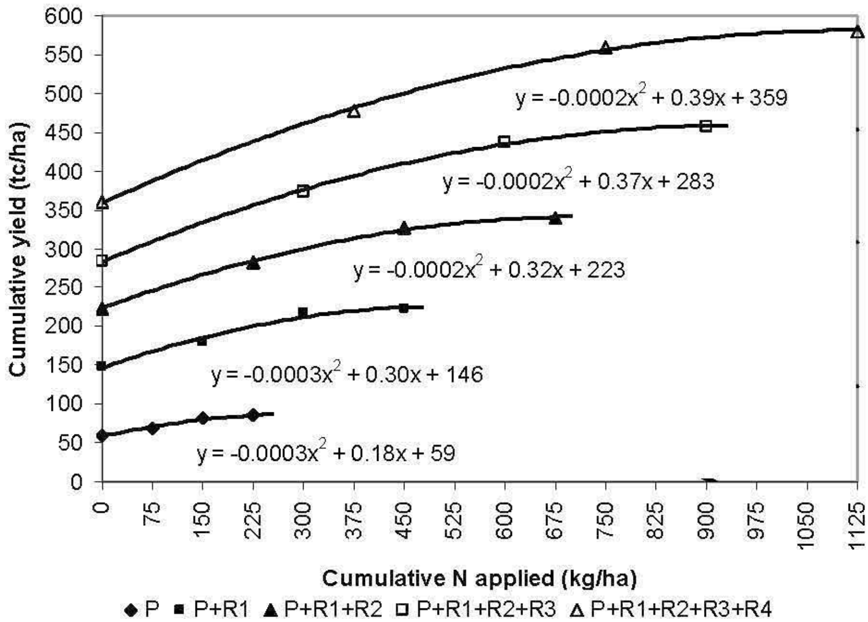
Data collected from the plant crop and four ratoons support the SIX EASY STEPS nitrogen guidelines for the particular soil type (River Bank) and for the sugarcane varieties included in the trial (Q158, Q179$^{\Phi}$ and NCo310).

Cumulative response curves for both cane and sugar yields were produced by summing yields from successive crops within the crop cycle and plotting these yields against cumulative N rates. These curves were used to calculate industry partial net returns for each of the N management strategies (as indicated above) according to the following equation: *Industry partial net return = (sugar yield x price of sugar) – (fertiliser cost x application rate (kg/ha) – (cane yield x estimated harvesting costs plus levies).* This equation was chosen because it reflects the total net return (grower and miller components). An alternative was a generalised commercial cane sugar content (CCS) based cane payment formula as used for the demonstration strip trails. However, that formula only reflects the net return to the grower.

At this site the residual N had been 'run down' by growing cane for two seasons without applied N. As the soil at this site had a soil organic carbon (C) content of 0.7%, the potential for mineralising N during the unfertilised period was low (Schroeder and Wood, 2001).

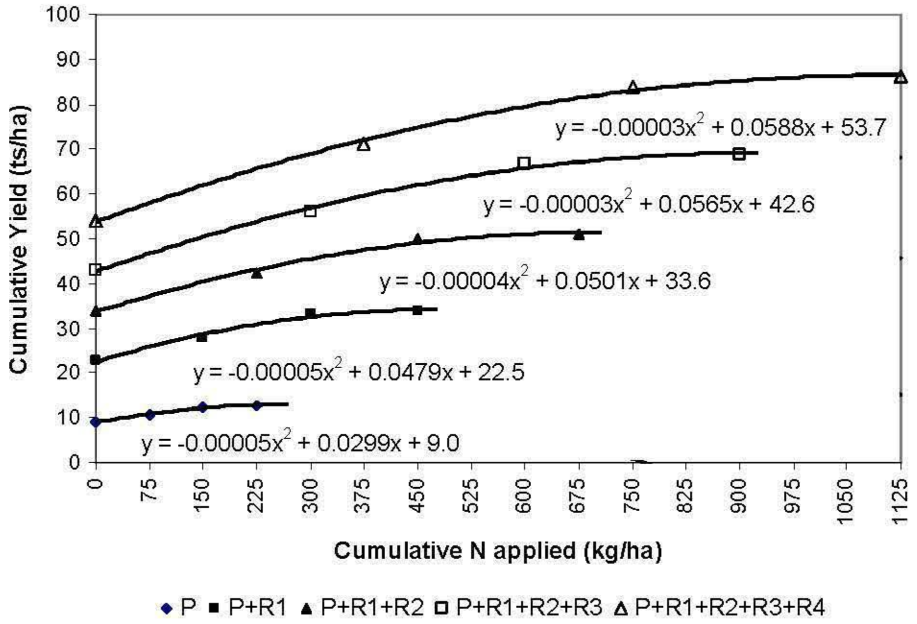
The cumulative cane and sugar yield response curves (relationships shown within Figures 13 and 14) enabled yields to be determined for any N input strategy by progressively moving from one response curve to the next (as the crop cycle advanced). The estimated yields (cane and sugar) for the grower-developed, traditional, SIX EASY STEPS and N Replacement approaches that were tested are shown in Table 26.

The 'industry partial net return' values for the different approaches are shown in Table 27. The 'grower-developed' approach (180 kg N/ha/crop) yielded 550 t cane/ha (Table 26) and 82.3 t sugar/ha (Table 27) over the crop cycle. This resulted in an industry net return of $20832/ha over 5 years or an average of $4166/ha/year (Table 27). The 'traditional' approach (160 kg N/ha/crop) resulted in a total crop cycle yield of 545 t cane/ha and 81 t sugar/ha, with an average industry net return of $4173/ha/year. The SIX EASY STEPS N input rate (150 kg N/ha/crop) produced an estimated crop of 541 t cane/ha and 80.9 t sugar/ha for the crop cycle, with a calculated industry net return of $4165/ha/year. The N Replacement strategy, with N inputs varying according to the yield of the previous crop (Table 26), resulted in a total crop cycle yield of 502 t cane/ha and 75.2 t sugar/ha. The calculated industry net return in this case was $3993/ha/year.



P: SE = 2.65; LSD(0.05) = 7.86
P+R1: SE = 4.80; LSD(0.05) = 14.26
P+R1+R2: SE = 7.85; LSD(0.05) = 23.33
P+R1+R2+R3: SE = 9.60; LSD(0.05) = 28.53
P+R1+R2+R3+R4: SE = 11.54; LSD(0.05) = 34.28

Figure 13 – Herbert trial: cumulative cane yield responses to N applied over a crop cycle (plant crop (P) and four ratoons (R), with SE and LSD values from the analysis of variance



P: SE = 0.46; LSD(0.05) = 1.37
P+R1: SE = 0.83; LSD(0.05) = 2.47
P+R1+R2: SE = 1.23; LSD(0.05) = 3.65
P+R1+R2+R3: SE = 1.42; LSD(0.05) = 4.21
P+R1+R2+R3+R4: SE = 1.76; LSD(0.05) = 5.16

Figure 14 – Herbert trial: cumulative sugar yield responses to N applied over a crop cycle (plant crop (P) and four ratoons (R), with SE and LSD values from the analysis of variance

Table 26 – Herbert trial: N inputs and cumulative cane yields for each of the N management strategies

	Grower-developed			Traditional			SIX EASY STEPS			N Replacement		
	N applied per Crop	Cumulative values		N applied per crop	Cumulative values		N applied per crop	Cumulative values		*N applied per crop	Cumulative values	
		N applied	Yield		N applied	Yield		N applied	Yield		N applied	Yield
	(kg/ha)	(kg/ha)	(tc/ha)	(kg N/ha)		(tc/ha)	(kg N/ha)		(tc/ha)	(kg N/ha)		(tc/ha)
Plant	180	180	81	160	160	80	150	150	79	**90	90	72
R1	180	360	217	160	320	213	150	300	211	72	162	188
R2	180	540	340	160	480	333	150	450	328	116	278	298
R3	180	720	444	160	640	436	150	600	432	110	388	395
R4	180	900	550	160	800	545	150	750	541	98	485	502

* 1 kg N/t cane in previous crop (Thorburn *et al.*, 2007); ** Cane yield of 90 t/ha assumed for the last ratoon of the previous crop cycle. No allowance was made for N removal in the penultimate ratoon.

Table 27 – Cumulative sugar yields (t sugar/ha) and calculated industry partial net returns for the Herbert trial

Cumulative crop	Grower-developed	Traditional	SIX EASY STEPS	N Replacement
	Cumulative yield (t sugar/ha)			
P	12.7	12.5	12.3	11.3
P+R1	33.3	32.8	32.4	29.0
P+R1+ R2	49.0	48.5	48.1	44.5
P+R1+R2+R3	67.8	66.5	65.7	60.0
P+R1+R2+R3+R4	82.3	81.5	80.9	75.2
*Industry net return ($/ha)	20832	20864	20825	19916
Average industry net return ($/ha/year)	4166	4173	4165	3993
Difference in industry net return from SIX EASY STEPS approach ($/ha/year)	1	8	-	-182

* Assumptions: Sugar price = $330/tonne, cost of N = $2.60/kg, harvesting costs = $7.25/tonne of cane,

These results (Schroeder *et al.*, 2008) were initially reported at the Nitrogen Symposium held as part of the ASSCT Conference in Townsville in 2008 (Appendix 10). Update information was included in a paper entitled "Alternative nitrogen management strategies for sugarcane production in Australia: the essence of what they mean" (Schroeder *et al.*, 2009b) at the ASSCT Conference at Ballina in 2009 (Appendix 11).

Herbert 2 and 3:

Nutrient management guidelines within the SIX EASY STEPS program are based on trial data gathered when the sugarcane was grown mainly in a 'conventional' farming system. These Herbert-based trials were aimed at ensuring that the guidelines are still appropriate for sugarcane grown within the 'new farming system' as defined by the Sugar Yield Decline Joint Venture (Garside and Bell, 2006). In these trials, the establishment of the legume crop was good on the better drained sandy River Bank soil. On the heavier Clay Loam soils establishment was better on the half of the block closest to the river. On the other half, germination and establishment was very poor in the conventional treatment, but was better on the permanent beds. This variation in legume establishment allowed the opportunity to compare different N inputs to sugarcane from 'good' and 'poor' legume break crops.

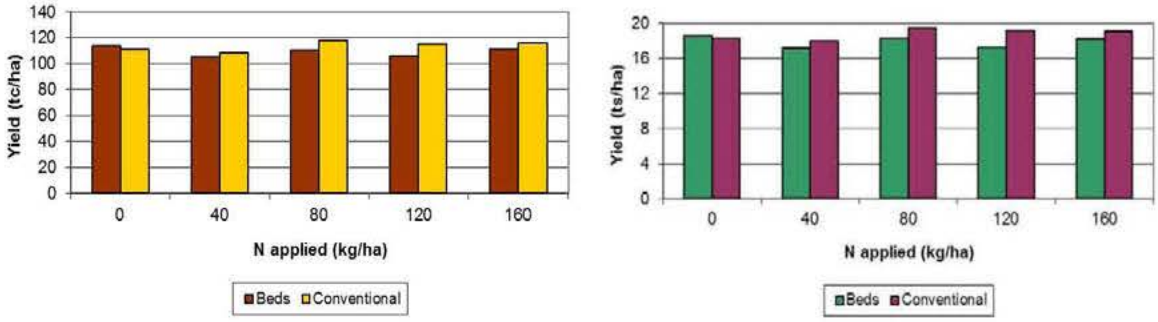
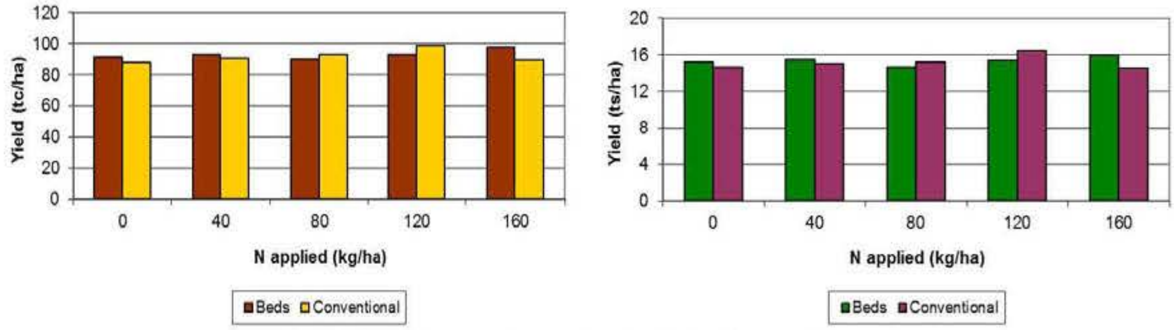
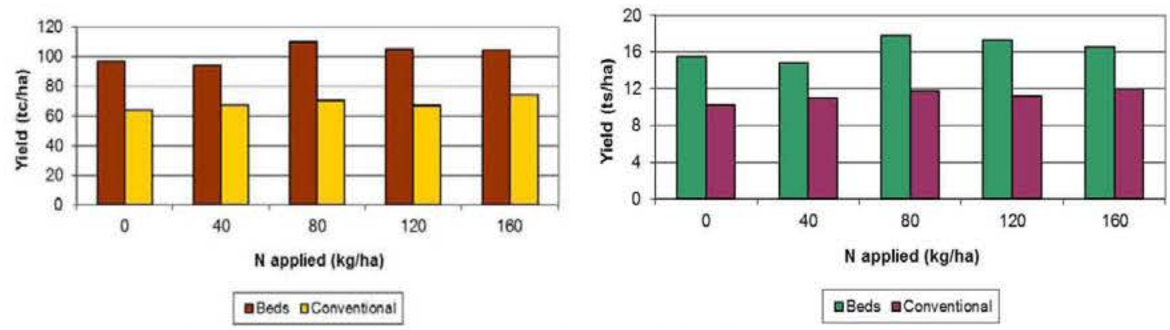


Figure 15 – Yield (tc/ha and ts/ha) plotted against N applied (kg/ha). The N treatments were applied to a sugarcane plant crop grown on a sandy River Bank soil following a good legume on permanent beds and in a 'conventional' farming system.



Good legume fallow: beds and conventional system



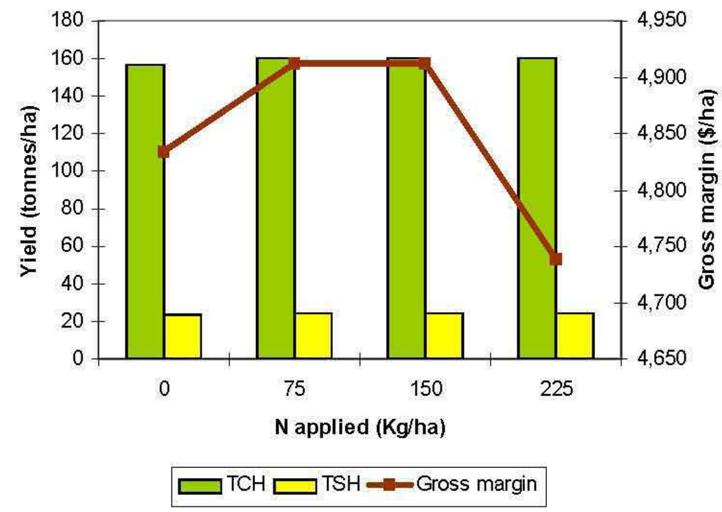
Moderate legume on beds, poor legume in the 'conventional' treatment

Figure 16 – Yield (tc/ha and ts/ha) plotted against N applied (kg/ha). The N treatments were applied to a sugarcane plant crop grown on a Clay Loam soil following a good legume on permanent beds and in a 'conventional' farming system.

***Bundaberg 1*:**

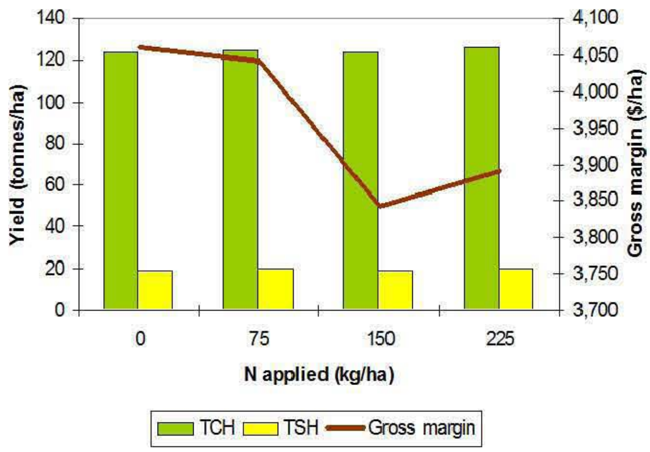
In the plant and first ratoon crops (Figures 17 and 18) there was no yield response to applied N. The calculated gross margins confirmed that no N was required for the plant crop (Figure 17, but an application of 75 kg N/ha would have been most appropriate for the first ratoon crop (Figure 18). These results were not unexpected and in line with recommendations from the Sugar Yield Decline Joint Venture. Such reduced N application rates take account of residual N from the peanut crop, previous fertiliser applications and the decomposition of the root systems. These results were included in a paper presented at the ASSCT Conference in Cairns in 2007 (Schroeder *et al.*, 2007c). The paper is included here as Appendix 7.

The trial also indicated the need for balanced nutrition. The application of combinations of N and K resulted in an interactive effect.



TCH: SE = 1.28 LSD (0.05) – NS
TSH: SE = 0.28 LSD (0.05) – NS

Figure 17 – Plant crop yield (TCH and TSH) and calculated gross margin (assuming a sugar price of $380/tonne and harvesting costs of $6.50/tonne of cane) plotted against N applied (following a fallow crop of peanuts)



TCH: SE = 2.16 LSD (0.05) – NS
TSH: SE = 0.38 LSD (0.05) – NS

Figure 18 – First ratoon yield (TCH and TSH) and calculated gross margin (assuming a sugar price of $380/tonne and harvesting costs of $6.50/tonne of cane) plotted against N applied (following a fallow crop of peanuts)

***Bundaberg 2*:**

A significant response to applied N occurred in the plant crop, and first and second ratoon crop, despite a relatively high soil organic C value and an assumed N contribution from the legume fallow crop. These unexpected large responses to applied N are believed to be related to denitrification which can occur during waterlogging that commonly occurs at this site. These losses are still being investigated.

Mackay:

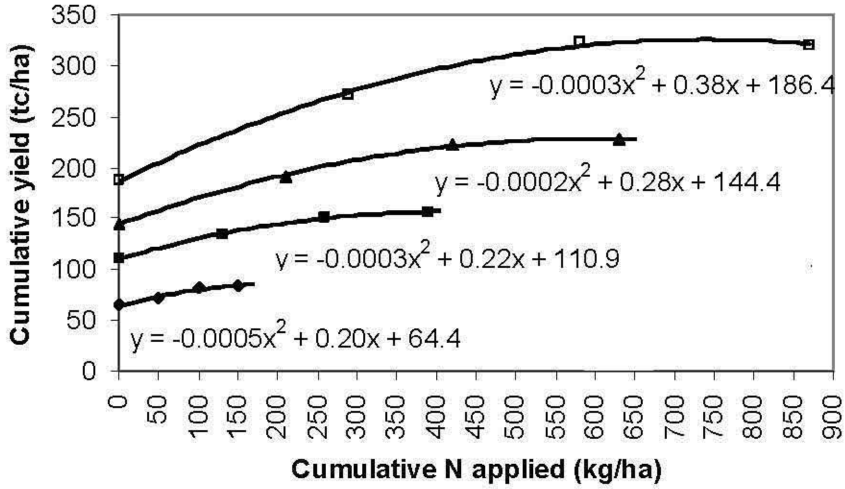
Significant nitrogen effects were observed in the plant crop, but there was no 'farming system' effect or interaction. The results confirmed recommendations that N is required after a poor soybean fallow crop and that the SIX EASY STEPS guideline of 150 kg N/ha for this site was the most appropriate (and profitable). This trial is continuing.

Tully 1:

The N trial at Tully had been fertilised according to normal practices within a green cane trash blanked system prior to the trial being planted after a bare fallow period. The final ratoon in the previous crop cycle yielded 117 t cane/ha. The soil at this site had a soil organic C content of 1.2% with a moderate to moderately low potential to mineralise N.

As with *Herbert 1*, the cumulative cane and sugar yield response curves (relationships shown in Figures 19 and 20) enabled yields to be determined for any N input strategy by progressively moving from one response curve to the next (as the crop cycle advanced). The estimated yields (cane and sugar) and calculated industry partial net returns for the different approaches that were tested using Tully data are shown in Table 28. The 'grower-developed' approach (150 kg N/ha for the plant crop and 180 kg N/ha/ratoon crop) yielded 304 t cane/ha and 51.2 t sugar/ha over the crop cycle. The industry net return in this case was $3114/ha/year. The 'traditional' approach (120 kg N/ha for the plant crop, and 160 kg N/ha for each of the ratoons) resulted in a total crop cycle yield of 305 t cane/ha and 51.3 t sugar/ha. The average industry net return was $3184/ha/year. The SIX EASY STEPS approach (120 kg N/ha for the plant crop and 140 kg N/ha for each ratoons) yielded 303 t cane/ha and 50.9 t sugar/ha for the crop cycle, with an average industry net return of $3198/ha/year. The N Replacement strategy (N inputs rates as shown in Table 28 and calculated according to the size of the previous crop), resulted in a total crop cycle yield of 277 t cane/ha and 46.3 t sugar/ha. The calculated industry net return was $3027/ha/year.

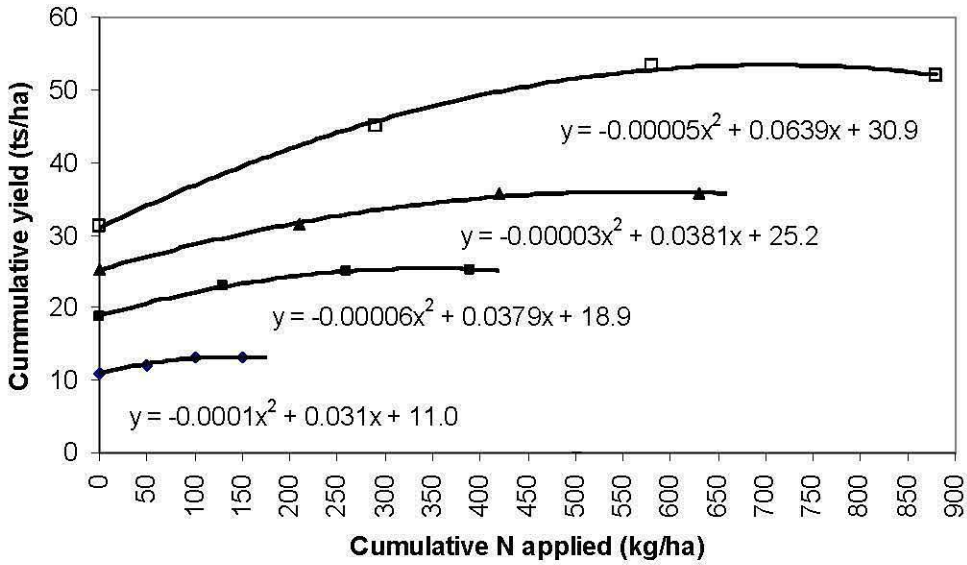
These results were included in the paper presented at the ASSCT Conference in 2009 (Appendix 11).



◆ Pl ■ P+R1 ▲ P+R1+R2 □ P+R1+R2+R3

P: SE = 2.57; LSD(0.05) = 8.90
P+R1: SE = 4.38; LSD(0.05) = 15.17
P+R1+R2: SE = 5.41; LSD(0.05) = 18.73
P+R1+R2+R3: SE = 7.47; LSD(0.05) = 25.83

Figure 19 – Tully trial: cumulative cane yield responses to N applied over a crop cycle (plant crop (P) and three ratoons (R), with SE and LSD values from the analysis of variance



◆ Pl ■ P+R1 ▲ P+R1+R2 □ P+R1+R2+R3

P: SE = 0.50; LSD(0.05): NS
P+R1: SE = 0.84; LSD(0.05) = 2.89
P+R1+R2: SE = 0.89; LSD(0.05) = 3.10
P+R1+R2+R3: SE = 1.23; LSD(0.05) = 4.27

Figure 20 – Tully trial: cumulative sugar yield responses to N applied over a crop cycle (plant crop (P) and three ratoons (R), with SE and LSD values from the analysis of variance

Table 28 – Tully trial: N inputs, cumulative cane yields and calculated industry partial net returns for each of the N management strategies

	Grower-developed			Traditional			SIX EASY STEPS			N Replacement		
	N applied per Crop	Cumulative values		N applied per crop	Cumulative values		N applied per crop	Cumulative values		*N applied per crop	Cumulative values	
		N applied	Yield		N applied	Yield		N applied	Yield		N applied	Yield
	(kg/ha)		(tc/ha)	(kg N/ha)		(tc/ha)	(kg N/ha)		(tc/ha)	(kg N/ha)		(tc/ha)
Plant	150	150	84	120	120	82	120	120	82	**117	117	81
R1	180	330	151	160	280	150	140	260	148	81	198	143
R2	180	510	236	160	440	229	140	400	225	62	260	204
R3	180	690	304	160	600	305	140	540	303	61	321	277

Cumulative crop	Grower-developed	Traditional	SIX EASY STEPS	N Replacement
	Cumulative yield (t sugar/ha)			
Plant	13.4	13.2	13.2	13.2
Plant + R1	24.8	24.8	24.8	24.7
Plant + R1 + R2	36.4	36.2	35.6	33.1
Plant + R1 + R2 + R3	51.2	51.3	50.9	46.3
***Industry net return ($/ha)	12386	12645	12687	11973
Average industry net return ($/ha/year)	3114	3184	3198	3027
Difference in industry net return from SIX EASY STEPS approach ($/ha/year)	-75	- 10	-	-190

* 1 kg N/t cane in previous crop (Thorburn *et al.*, 2007); ** Cane yield of 117 t/ha for the last ratoon of the previous crop cycle; ***Assumed sugar price = $330/t, cost of N = $2.60/kg, harvesting costs = $7.25/t of cane

The Tully data (Table 28) showed that the SIX EASY STEPS approach was the most favourable in terms of the calculated industry net return. The 'grower-developed' approach resulted in a reduced profit of $75/ha/crop compared to the SIX EASY STEPS. The N Replacement strategy gave rise to the lowest industry net return ($190/ha lower than that of the SIX EASY STEPS approach). The higher N inputs associated with the 'grower-developed' approach were not warranted because they did not produce substantially higher yields compared with the SIX EASY STEPS strategy. As with the Macknade scenario, the N Replacement approach resulted in lower N inputs, but with lower cane and sugar yields.

In terms of the current circumstances (escalating input costs, moderately low sugar prices, decreasing cane supply and environmental pressures), it is important to ensure that on-farm strategies enable growers to remain profitable and sustainable. This can only be achieved if they select management options that allow maintenance of yields (cane and sugar) in combination with inputs that are cost effective and are environmentally responsible.

Our assessment (Herbert 1 and Tully 1) shows that these objectives are possible when the SIX EASY STEPS approach is used. Alternative approaches, that are either wasteful of nutrient inputs (and are therefore environmentally unacceptable) or that lead to productivity losses (and are therefore likely to affect industry viability) should not be considered as appropriate N inputs strategies for sugarcane production.

***Tully 2*:**

The SIX EASY STEPS system uses a combination of district yield potential (DYP) and a soil nitrogen (N) mineralisation index to determine the appropriate amounts of N to apply to specific soils. Soil organic carbon content is used as an indicator of the N mineralisation potential of a soil. Nitrogen guidelines have not been clearly defined for soils with very high organic carbon values, but have been included in the general organic carbon category of > 2.4% organic C. At present, the SIX EASY STEPS N guidelines suggest 80 kg N/ha and 100 kg N /ha be applied to plant and ratoon crops respectively. There are a number of soil types within the wet tropics that have organic C levels well in excess of 2.4%. As these soils tend to be located in a wet environment, this may influence the N mineralisation potential.

This trial was established at the BSES Tully Experiment Station on a Hewitt series soil with an organic carbon of 4.1% C. The objective was to validate current the SIX EASY STEPS guidelines for N requirements for soils with very high organic carbon content or if adjustments were required. Six rates of N were applied within a randomised block design. Yield data (Table 29) indicated that there was only a significant response to applied N in terms of sugar yield in the first ratoon. However, the general trends suggest that some N is needed to optimize yield, and that the Six EASY STEPS guidelines for soils with organic C > 2.4% remain appropriate at present, but further interpretation and possible fine-tuning could occur as more data becomes available (this and other sites).

Table 29 – Tully trial: N treatments and yield data for a plant and a first ratoon crop

N applied (kg/ha)	Yield					
	Plant crop			First ratoon		
	(tc/ha)	ccs	(ts/ha)	(tc/ha)	ccs	(ts/ha)
0	109.1	16.4	17.9	57.8	16.4	9.5
50	116.3	16.8	19.5	69.4	16.8	11.6
80	116.7	16.6	19.4	67.2	16.7	11.3
110	109.3	17.2	18.8	71.6	16.8	12.0
140	115.9	16.9	19.6	69.6	16.9	11.8
170	114.5	16.7	19.1	70.5	16.7	11.7
SE	4.7	0.28	0.69	4.0	0.30	0.58
P	0.64	0.38	0.47	0.15	0.86	0.04

8.0 ACHIEVEMENT OF OBJECTIVE 6

Reviewing the N-use efficiency factors associated with relevant trials.

8.1 Introduction

As indicated above, the N guidelines in the SIX EASY STEPS program are based on a combination of DYP and a soil N mineralisation index. The DYP is determined from the best possible yield averaged over all soil types within a district and is defined as the estimated highest average annual district yield (tonnes cane/ha) multiplied by a factor of 1.2. The DYP for the Wet Tropics, Herbert, Plane Creek, Bundaberg/Isis and Maryborough is 120 tonnes cane/ha (estimated highest average annual yield of 100 tonnes cane /ha multiplied by 1.2). This concept of DYP recognises differences in the ability of districts and regions to produce cane. While the DYP for the Proserpine and Mackay regions is set at 130 tonnes cane/ha, two values have been set for the Burdekin region depending on perceived longer-term yields: 150 tonnes cane/ha and 180 tonnes cane/ha.

The DYP is used to establish the base N application rate according to an estimate previously developed by CSIRO scientists. According to this estimate, 1.4 kg N per tonne of cane is required up to a cane yield of 100 tonnes/ha and 1 kg N per tonne/ha thereafter. This gives rise to a base-line N application rate of 160 kg N/ha for the Wet Tropics, Herbert, Plane Creek, Bundaberg/Isis and Maryborough districts, 170 kg N/ha for the Proserpine and Mackay districts, and 190 kg N/ha and 220 kg N/ha for the Burdekin region (Table 30). With the SIX EASY STEPS approach, inputs are adjusted according to an N mineralisation index, which is based on soil organic carbon (%) values (Table 30). This produces a range of N application rates for replant and ratoon cane that corresponds to these N mineralisation classes within each of the districts. As it is recognised that plant cane following a bare or grass fallow requires less fertiliser N than these values, a range of N application rates have been established for plant cane grown on soils with various soil organic carbon values (Table 30). In terms of N use, management strategies aim to improve efficiency of applied N, whether it be in the plant or ratoon crops.

Table 30 – N requirement for plant and ratoon crops (Schroeder *et al.*, 2010)

Crop	Soil organic carbon (%)						
	0 – 0.4	**0.4 – 0.8**	**0.8 – 1.2**	**1.2 – 1.6**	**1.6 – 2.0**	**2.0 – 2.4**	**> 2.4**
Wet Tropics, Herbert, Plane Creek, Bundaberg/Isis, Maryborough (DYP* = 120 tc/ha)							
Replant cane and ratoon after replant	160	150	140	130	120	110	100
Plant cane after a grass/bare fallow	140	130	120	110	100	90	80
Proserpine and Mackay (DYP = 130 tc/ha)							
Replant cane and ratoon after replant	170	160	150	140	130	120	110
Plant cane after a grass/bare fallow	150	140	130	120	110	100	90
Burdekin (DYP = 150 tc/ha)							
Replant cane and ratoon after replant	190	180	170	160	150		
Plant cane after a grass/bare fallow	150	140	130	120	110		
Burdekin (DYP = 180 tc/ha)							
Replant cane and ratoon after replant	220	210	200	190	180		
Plant cane after a grass/bare fallow	180	170	160	150	140		

*DYP = district yield potential

8.2 Method

We defined two terms for reporting on N-use efficiency. These are:

- N-fertiliser utilisation index (kg N/t cane produced) = N applied (kg N/ha) / yield (t cane/ha)
- Fertiliser N-use efficiency factor (t cane/kg N) = yield (t cane/ha) / N applied (kg N/ha)

In terms of N use, management strategies aim to improve efficiency by ensuring that the first calculated term (N fertiliser utilisation index) is as low as possible, and the second calculated term (fertiliser N-use efficiency) is as high as possible, without affecting productivity and profitability. As the ‘efficiency’ terms are reciprocals of each other, both the rate of N applied and the cane yield influence these calculated values.

The two N-use efficiency factors were calculated for:

- The SIX EASY STEPS N guidelines (target values)
- The grower and SIX EASY STEPS treatments in each of the replicated demonstration strip trials conducted in the Central region (2006 – 2008), the Johnstone district (2007 – 2008) and in Bundaberg (2005 – 2008) as detailed in Section 7 of this report
- The trials conducted within Project CSE011 from papers published (Thorburn et al.., 2007, 2009) where at least three years of consecutive data were shown

Data from two trials conducted in the northern districts (Herbert and Tully) were used to assess four different N management strategies in terms of productivity, profitability and environmental implications.

8.3 Results and discussion

8.3.1 Target N-use efficiencies

The values shown in Table 30 (recommended application rates and DYP) were used to determine the target N fertiliser utilisation index (N application rate / DYP) and fertiliser N-use efficiency (district potential yield / N application rate) values that apply to replant / ratoon cane and plant cane in each of the districts (Table 31). This shows that the **target** N fertiliser utilisation index value ranges from 1.33 kg N/tc (for replant / ratoon cane grown on soils with very low soil organic C in districts with a yield potential of 120 tc/ha) to 0.61 kg N/tc (for plant cane grown on soils with 1.6% organic C in the higher yield potential (180 tc/ha) areas of the Burdekin region.

As the SIX EASY STEPS program also recognises the N inputs from other sources (legume fallow crops, residual mineral N remaining after horticultural crops that are grown in rotation with sugarcane and irrigation water), lower N fertiliser utilisation index values and higher fertilisation N-use efficiencies will occur in each case (as shown in Table 31) when these are taken into account. Examples of the calculated target values for the efficiency factors when the N contribution from legume fallow crops is taken into account during a plant crop are shown in Table 32 (areas with a yield potential of 120 tc/ha). Where the other sources of N supply enough N to meet the N requirement for sugarcane production, the N fertiliser utilisation index will be zero.

The SIX EASY STEPS program also recognises that if a sub-district or farm *consistently* produces higher yields than the DYP, the baseline application rate should be adjusted upward by 1 kg N per tonne of cane above the DYP. For example if the average yield on a farm in the Bundaberg/Isis district, calculated over a ten year period, is 130 tonnes cane/ha, then the baseline N application should be set at 170 kg N/ha. The N application rates based on soil organic carbon would then be 10 kg N/ha greater than those shown in Table 30 and be in line with the values shown for the Mackay / Proserpine district. Conversely, if a sub-district *consistently* produces lower yields than the DYP, the baseline N application rate should be decreased using the same approach. Obviously if these adjustments are made, the two target N-use efficiency factors will be influenced.

The concepts of target fertiliser N-use efficiency and N fertiliser utilisation index values and how they relate to the N guidelines in the SIX EASY STEPS guidelines were included in the paper presented at the International Society of Sugar Cane Technologists Conference that was held in Mexico in 2010 (Schroeder *et al.*, 2010). It is included here as Appendix 3.

Table 31 – Target fertiliser N-use efficiency and N fertiliser utilisation index values calculated for the N management guidelines in the SIX EASY STEPS program

Crop	Soil organic carbon (%)						
	0 – 0.4	0.4 – 0.8	0.8 – 1.2	1.2 – 1.6	1.6 – 2.0	2.0 – 2.4	> 2.4
Wet Tropics, Herbert, Plane Creek, Bundaberg/Isis/Maryborough (DYP* = 120 tc/ha)							
Replant cane and ratoon after replant	**160**	**150**	**140**	**130**	**120**	**110**	**100**
Target N fertiliser utilisation index (kg N / t cane)	1.33	1.25	1.17	1.08	1.00	0.92	0.83
Target fertiliser N use efficiency (t cane/kg N)	0.75	0.80	0.86	0.92	1.00	1.09	1.20
Plant cane after a grass/bare fallow	**140**	**130**	**120**	**110**	**100**	**90**	**80**
Target N fertiliser utilisation index (kg N / t cane)	1.17	1.08	1.00	0.92	0.83	0.75	0.67
Target fertiliser N use efficiency (t cane/kg N)	0.86	0.92	1.00	1.09	1.20	1.33	1.50
Proserpine and Mackay (DYP = 130 tc/ha)							
Replant cane and ratoon after replant	**170**	**160**	**150**	**140**	**130**	**120**	**110**
Target N fertiliser utilisation index (kg N / t cane)	1.31	1.23	1.15	1.08	1.00	0.92	0.85
Target fertiliser N use efficiency (t cane/kg N)	0.76	0.81	0.87	0.93	1.00	1.08	1.18
Plant cane after a grass/bare fallow	**150**	**140**	**130**	**120**	**110**	**100**	**90**
Target N fertiliser utilisation index (kg N / t cane)	1.15	1.08	1.00	0.92	0.85	0.77	0.69
Target fertiliser N use efficiency (t cane/kg N)	0.87	0.93	1.00	1.08	1.18	1.30	1.44
Burdekin (DYP = 150 tc/ha)							
Replant cane and ratoon after replant	**190**	**180**	**170**	**160**	**150**		
Target N fertiliser utilisation index (kg N / t cane)	1.27	1.20	1.13	1.07	1.00		
Target fertiliser N use efficiency (t cane/kg N)	0.79	0.83	0.88	0.94	1.00		
Plant cane after a grass/bare fallow	**150**	**140**	**130**	**120**	**110**		
Target N fertiliser utilisation index (kg N / t cane)	1.00	0.93	0.87	0.80	0.73		
Target fertiliser N use efficiency (t cane/kg N)	1.00	1.07	1.15	1.25	1.36		
Burdekin (DYP = 180 tc/ha)							
Replant cane and ratoon after replant	**220**	**210**	**200**	**190**	**180**		
Target N fertiliser utilisation index (kg N / t cane)	1.22	1.17	1.11	1.06	1.00		
Target fertiliser N use efficiency (t cane/kg N)	0.82	0.86	0.90	0.95	1.00		
Plant cane after a grass/bare fallow	**180**	**170**	**160**	**150**	**140**		
Target N fertiliser utilisation index (kg N / t cane)	0.83	0.78	0.72	0.67	0.61		
Target fertiliser N use efficiency (t cane/kg N)	1.20	1.29	1.38	1.50	1.64		

*DYP = district yield potential

Table 32 – Target fertiliser N use efficiency and N fertiliser utilisation index values calculated for the N management guidelines for plant cane following legume fallow crops (Wet Tropics, Plane Creek, Bundaberg/Isis and Maryborough: DYP = 120 tc/ha)

Crop	Soil organic carbon (%)						
	0 – 0.4	0.4 – 0.8	0.8 – 1.2	1.2 – 1.6	1.6 – 2.0	2.0 – 2.4	> 2.4
Plant (baseline N application rate)	**140**	**130**	**120**	**110**	**100**	**90**	**80**
Target N fertiliser utilisation index (kg N/t cane	1.17	1.08	1.00	0.92	0.83	0.75	0.67
Target fertiliser N-use efficiency (t cane/kg N)	0.86	0.92	1.00	1.09	1.20	1.33	1.50
Plant following a poor legume fallow	**90**	**80**	**70**	**60**	**50**	**40**	**30**
Target N fertiliser utilisation index (kg N/t cane	0.75	0.67	0.58	0.50	0.42	0.33	0.25
Target fertiliser N-use efficiency (t cane/kg N)	1.33	1.50	1.71	0.92	2.00	3.00	4.0
Plant following a good legume harvested for grain	**70**	**60**	**50**	**40**	**30**	**20**	**10**
Target N fertiliser utilisation index (kg N/t cane	0.58	0.50	0.42	0.33	0.25	0.17	0.08
Target fertiliser N-use efficiency (t cane/kg N)	1.71	2.00	2.40	3.00	4.00	6.00	12.0

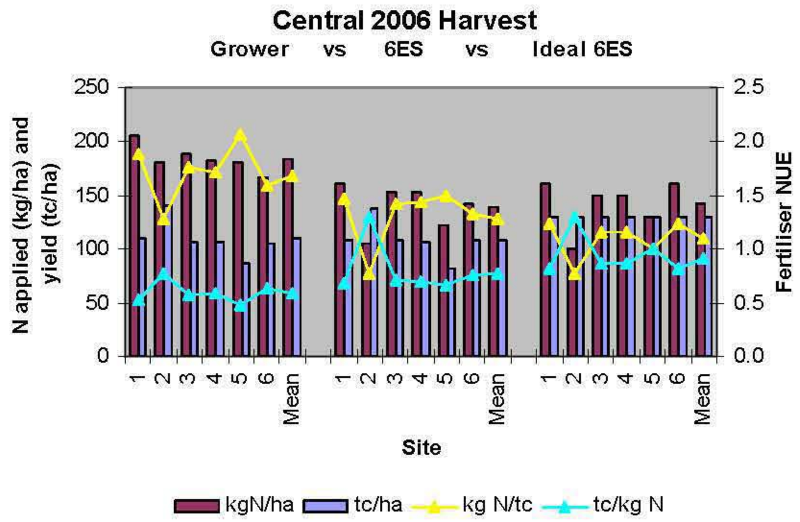
8.3.2 N-use efficiencies associated with several replicated demonstration strip trials

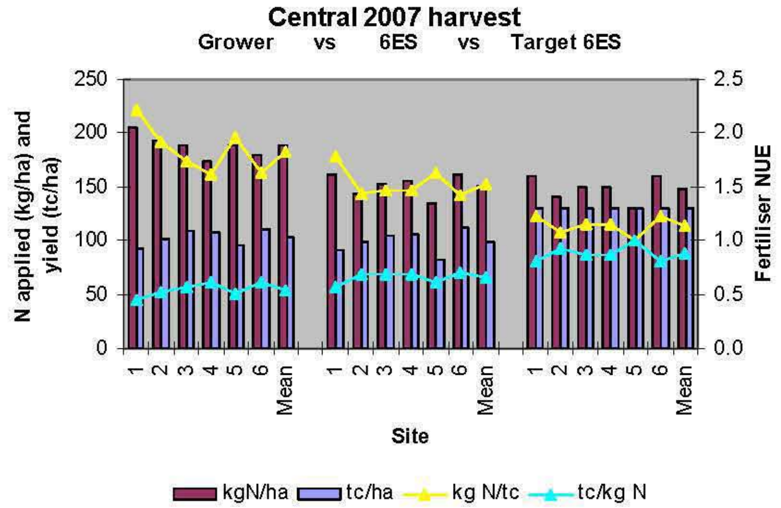
The two N-use efficiency factors were calculated for the grower and SIX EASY SYEPS treatments in each of the replicated demonstration strip trials conducted in the Central region (2006 – 2008) and Johnstone district (2007 – 2008). These values together with the N application rates and the mean yields (tc/ha) are presented in Figures 21 and 22 respectively. These figures also include the target SIX EASY STEPS N input values, yield goals and the calculated target N efficiency factors. The mean values for each of the parameters shown in Figures 21 and 22 are included in Tables 33 and 34 respectively.

The data from the Central region (Figure 21) indicate that the N guidelines used within the SIX EASY STEPS (for those specific soils) are aimed at N-fertiliser utilisation index values ranging from 1.0 to 1.2 kg N/t cane with the corresponding target fertiliser N-use efficiency factors ranging from 1.0 to 0.8 t cane/kg N, respectively. As expected, the actual N application rates and yields associated with SIX EASY STEPS inputs (Table 33) resulted in higher N-fertiliser utilisation index values (mean = 1.54 kg N/t cane) and lower fertiliser N-use efficiency factors (mean = 0.65 t cane/kg N). However, the grower strategies (Table 33) resulted in even higher N-fertiliser utilisation index values (mean = 1.86 kg N/t cane) which is indicative of relatively low N use efficiency (mean = 0.54 t cane/kg N). The progression from 2006 to 2008 indicates that the N-fertiliser utilisation index values increased with time for both the SIX EASY STEPS and grower N input strategies. This supports the strategy that the N inputs on older ratoons can be reduced when the crop is expected to produce a yield much lower than the DYP.

Table 33 – Mean N application rates, yield data, calculated N fertiliser utilisation indices (kg N/t cane) and fertiliser N-use efficiency values (t cane/kg N) for the replicated strip trials harvested in the Central region in 2006 to 2008 (Grower strategy vs actual SIX EASY STEPS vs Target SIX EASY STEPS)

District and year	Treatment	N applied (kg/ha)	Yield (t cane/ha)	N fertiliser utilisation index (kg N/t cane	Fertiliser N-use efficiency (t cane/kg N)
Central 2006	Grower	184	109	1.69	0.59
	6ES	139	108	1.28	0.78
	Target 6ES	142	130	1.09	0.92
Central 2007	Grower	188	103	1.83	0.55
	6ES	152	100	1.52	0.66
	Target 6ES	148	130	1.14	0.88
Central 2008	Grower	185	87	2.13	0.47
	6ES	155	82	1.89	0.53
	Target 6ES	148	130	1.14	0.88
Central Mean 06 – 08	Grower	186	100	1.86	0.54
	6ES	149	97	1.54	0.65
	Target 6ES	146	130	1.12	0.89





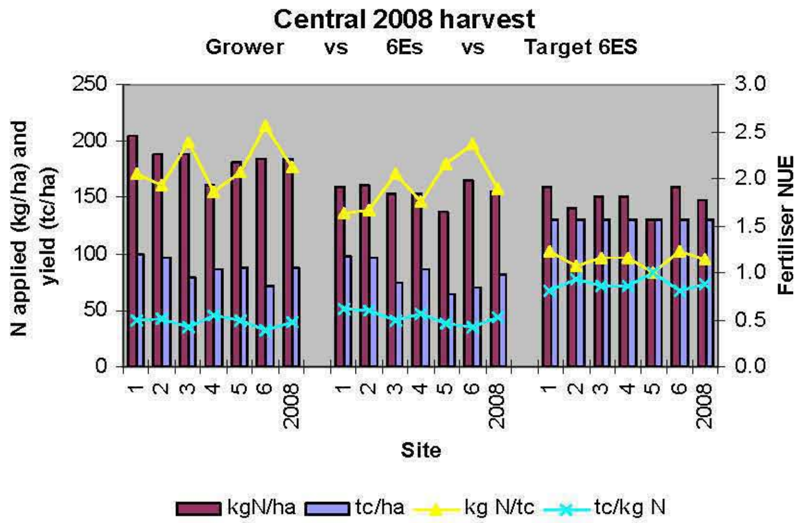
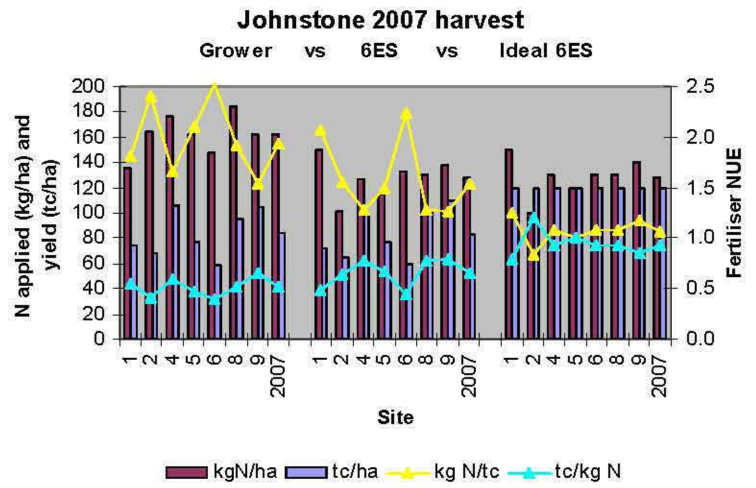


Figure 21 – N application rates and yield data for the Central region replicated strip trials (1 – 6) together with the calculated N fertiliser utilisation index (kg N/t cane) and fertiliser N-use efficiency (t cane/kg N) values: 2006 – 2007 (Grower strategy vs actual SIX EASY STEPS vs Target SIX EASY STEPS)

The data from the Johnstone district (Figure 22) indicate that the N guidelines used within the SIX EASY STEPS (for those specific soils) are aimed at N-fertiliser utilisation index values ranging from 0.8 to 1.3 kg N/t cane with the corresponding target fertiliser N-use efficiency factors ranging from 1.2 to 0.8 t cane/kg N respectively. As expected, the actual N application rates and yields associated with SIX EASY STEPS inputs (Table 34) resulted in higher N-fertiliser utilisation index values (mean = 1.55 kg N/t cane) and lower fertiliser N-use efficiency factors (mean = 0.65 t cane/kg N). However, the grower strategies resulted in even higher N-fertiliser utilisation index values (mean = 1.94 kg N/t cane) which is indicative of relatively low N-use efficiency (mean = 0.52 t cane/kg N). The progression from 2007 to 2008 indicates that the N-fertiliser utilisation index values (and fertiliser N-use efficiency factors) remained more or less constant over the two seasons.

These data suggest that slightly different N-fertiliser utilisation index values may be applicable for different regions. In the Wet Tropics (as illustrated by the trials conducted in the Johnstone district) a higher N use efficiency factor (possibly 1.5 kg N/t cane up to 100 t cane/ha and 1.0 kg N/t cane thereafter) may be more applicable than the currently accepted value used within the SIX EASY STEPS program (1.4 kg N/t cane up to 100 t cane/ha and 1.0 kg N/t cane thereafter).



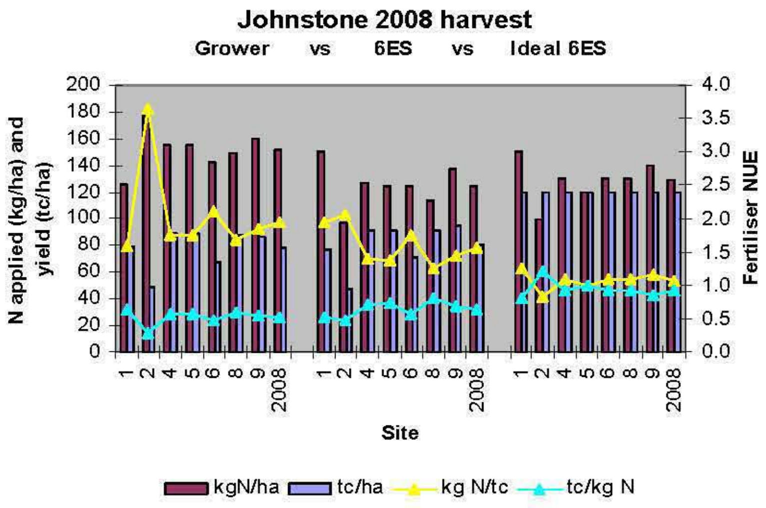


Figure 22 – N application rates and yield data for the Johnstone district replicated strip trials (1 – 9) together with the calculated N fertiliser utilisation index (kg N/t cane) and fertiliser N-use efficiency (t cane/kg N) values: 2006 – 2007 (Grower strategy vs actual SIX EASY STEPS vs Target SIX EASY STEPS)

Table 34 – Mean N application rates, yield data, calculated N fertiliser utilisation indices (kg N/t cane) and fertiliser N-use efficiency values (t cane/kg N) for the replicated strip trials harvested in the Johnstone district during 2007 and 2008(Grower strategy vs actual SIX EASY STEPS vs Target SIX EASY STEPS)

District and year	Treatment	N applied (kg/ha)	Yield (t cane/ha)	N fertiliser utilisation index (kg N/t cane	Fertiliser N-use efficiency (t cane/kg N)
Johnstone 2007	Grower	162	84	1.93	0.52
	6ES	128	83	1.54	0.65
	Target 6ES	130	120	1.08	0.93
Johnstone 2008	Grower	152	78	1.95	0.51
	6ES	125	80	1.56	0.64
	Target 6ES	130	120	1.08	0.93
Johnstone Mean 07 – 08	Grower	157	81	1.94	0.52
	6ES	127	82	1.55	0.65
	Target 6ES	130	120	1.08	0.64

Data from the replicated strip trials conducted in the Bundaberg district are used to illustrate some specific examples. In relation to the trial conducted at Tegege (Figure 23) the actual efficiency factors obtained from the SIX EASY STEPS inputs (mean N-fertiliser utilisation index value = 1.1 kg N/t cane and mean fertiliser N use efficiency = 0.9 t cane/kg N) were very similar to those that were targeted over the three seasons (2006 to 2008). In contrast, the grower strategy resulted in a relatively inefficient system (mean N-fertiliser utilisation index value = 1.5 kg N/t cane) which is indicative of relatively low N use efficiency (mean = 0.7 t cane/kg N). The relatively high target and actual fertiliser N-use efficiencies in this case (Figure 23) are related to the fact that a legume had been grown at the site prior to the sugarcane plant crop. This provides further evidence of the need to take account of this source of N in the first ratoon crop after a legume fallow crop.

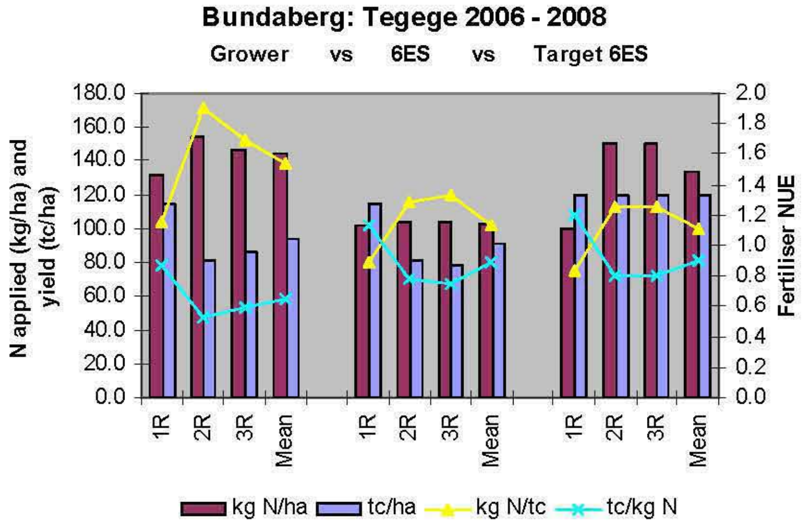


Figure 23 – N application rates and yield data for a Bundaberg replicated strip trials (conducted at Tegege) together with the calculated N fertiliser utilisation index (kg N/t cane) and fertiliser N-use efficiency (t cane/kg N) values: 2006 – 2008 (Grower strategy vs actual SIX EASY STEPS vs Target SIX EASY STEPS)

8.3.3 N-use efficiencies associated with the strip-trials conducted within project CSE01

The efficiency factors (N-fertiliser utilisation index and fertiliser N-use efficiency factor values) were calculated for trials conducted within project CSE011 (Figure 24). The information used to calculate theses values were obtained (or estimated) from published papers (Thorburn *et al.*, 2007, 2009) where at least three years of consecutive data was shown (seven out of a possible 11 trials). These trials, which compared the N Replacement strategy to usual grower practice, were conducted at various sites across the industry (one each in the Burdekin, Bundaberg, Innisfail, Mulgrave and Mossman, and two in Maryborough).

The information shown in Figure 24 indicates that the N Replacement strategy gave rise to a mean N-fertiliser utilisation index value of about 1.2 kg N/t cane calculated across trials and years. The corresponding mean fertiliser N-use efficiency factor is about 0.8 t cane /kg N. As in the SIX EASY STEPS related trials, the grower practices gave rise to less efficiency (mean N-fertiliser utilisation index value across grower treatments and year = 1.72 kg N/t cane, and a mean fertiliser N use efficiency factor = 0.58 t cane /kg N) than that resulting from the lower N input strategies. However, it was not always clear how N inputs for subsequent crop were calculated as the published multiplier for this purpose (1 kg N per tonne of cane in the previous year) did not always seem to be used consistently.

8.3.4 Assessment of four different N management strategies

As indicated in Section 7.3.2 of this report, data from two trials conducted in the northern region (Herbert and Tully) were recently used to assess alternative N management strategies and the meaning of these in terms of productivity, profitability and environmental implications (Schroeder *et al.*, 2009b). The four strategies that were considered were a grower-developed approach, a traditional approach, the N management guidelines within the SIX EASY STEPS program and the N Replacement concept. Cumulative response curves for both cane and sugar yields were then produced by summing yields from successive crops within the crop cycle and plotting these yields against cumulative N rates (Schroeder *et al.*, 2009b). These curves were used to calculate industry partial net returns for each of the N management strategies. N input and yield data from the Tully trial (Table 28) was used to calculate the N-use efficiency factors (as described above) for each of these N management strategies (Table 35).

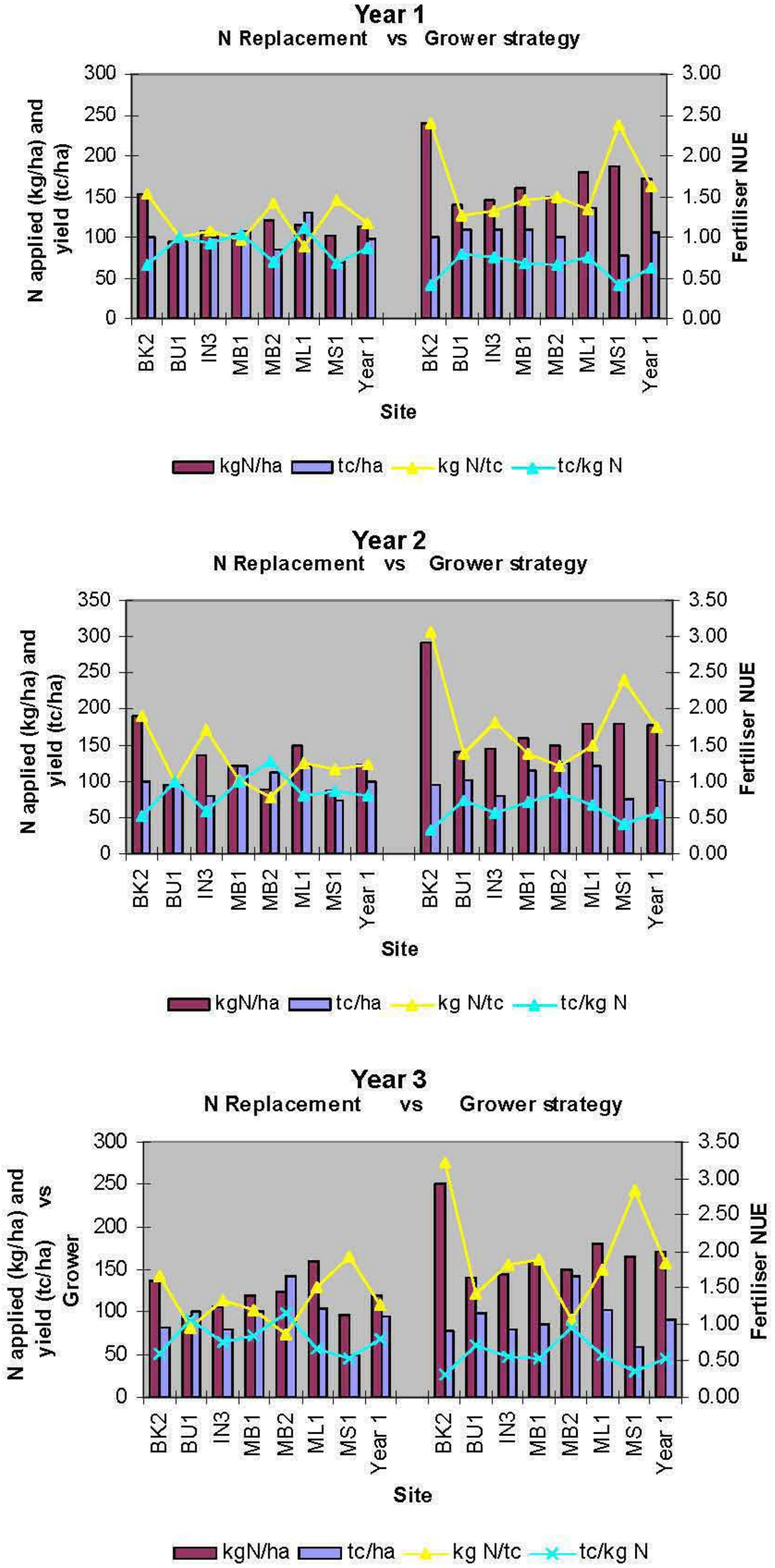


Figure 24 – Estimated N application rates and yield data for 7 trials conducted within project CSE011 together with the calculated N fertiliser utilisation index (kg N/t cane) and fertiliser N-use efficiency (t cane/kg N) values: years 1 to 3 (N Replacement vs Grower strategy). Information obtained or estimated from Thorburn *et al*. (2008; 2009).

The calculated N utilisation index values for the SIX EASY STEPS approach and the N Replacement strategy over the crop cycle (1.78 kg N/t cane and 1.16 kg N/t cane respectively) were lower than that of the grower-developed and traditional approaches (2.27 kg N/t cane and 1.97 kg N/t cane respectively). Although the N Replacement concept appears to be more efficient, the decrease in productivity (cane and sugar per hectare) resulted in losses in profitability compared to the SIX EASY STEPS approach. Based on sugar price and the cost of N as applicable in December 2008, average partial net returns for the N Replacement strategy were $190/ha/year less than that of the SIX EASY STEPS for the plant to the third ratoon crop (Table 35). The grower-developed approach also resulted in $75/ha/year loss in average partial net return (over the four crops). In this case the actual N-use efficiency was much lower than that of either the SIX EASY STEPS or the N Replacement strategies. The grower-developed strategy would be considered wasteful of N inputs as well as being environmentally unacceptable. When these calculations were repeated with updated N fertiliser prices (May 2009), the difference in partial net return between the SIX EASY STEPS and N Replacement approach increased to $240/ha/year.

The results shown above indicate that improvement in N fertiliser-use efficiency cannot be seen in isolation from productivity and profitability on farm. The SIX EASY STEPS approach that considers both these aspects is more appropriate than systems aimed at either maximum production or being overly environmentally focused. In overall terms the SIX EASY STEPS is aimed at sustainable sugar cane production that encompasses best practice management by considering a combination of agronomic, economic, environmental and social benefits.

Table 35 – Mean N application rates, yield data, calculated industry partial net return, calculated N fertiliser utilisation indices (kg N/t cane) and fertiliser N-use efficiency values (t cane/kg N) for the small plot trial conducted in the Tully district (Grower-developed approach vs Traditional approach vs SIX EASY STEPS vs N Replacement

N strategy	Crop	N applied	Cumulative yield		Average partial net return[1]	Difference in net return from SIX EASY STEPS	N fertiliser utilisation index	Fertiliser N-use efficiency
		(kg/ha)	(tc/ha)	(ts/ha)	($/ha/year)		(kg N/tc)	(tc/kg N)
Grower developed	Plant	150	84	13.4	3423	-27	1.79	0.56
	P+R1	330	151	24.8	3116	-102	2.19	0.46
	P+R1+R2	510	236	36.4	2992	-34	2.16	0.46
	P+R1+R2+R3	690	304	54.2	3225	-75	2.27	0.44
Traditional	Plant	120	82	13.2	3450	0	1.46	0.68
	P+R1	280	150	24.8	3184	-33	1.87	0.63
	P+R1+R2	440	229	36.2	3047	22	1.92	0.52
	P+R1+R2+R3	600	305	51.3	3289	-10	1.97	0.51
SIX EASY STEPS	Plant	120	82	13.2	3450	0	1.46	0.68
	P+R1	260	148	24.8	3218	0	1.76	0.57
	P+R1+R2	400	225	25.6	3026	0	1.78	0.56
	P+R1+R2+R3	540	303	50.9	3299	0	1.78	0.56
N Replacement	Plant	117	81	13.2	3465	15	1.44	0.69
	P+R1	198	143	24.7	3300	82	1.38	0.72
	P+R1+R2	260	204	33.1	2923	-103	1.27	0.79
	P+R1+R2+R3	321	277	46.3	3109	-190	1.16	0.86

[1] Assumptions: Sugar price = $330/t, cost of N = $2.60/kg, harvesting costs = $7.25/tc

9.0 ACHIEVEMENT OF OBJECTIVE 7

Developing a computer-based decision support system for the SIX EASY STEPS nutrient management package

9.1 Introduction

With the acceptance of the SIX EASY STEPS program as the basis for best-practice nutrient management in the Australian sugarcane industry, we decided to bring together the component parts of the package into a computer-based system. It was deemed particularly important to enable growers and their advisers to have access to an automated facility for determining nutrient inputs for specific blocks from soil test values. A computer-based package would also enable the keeping of various records of nutrient management (recommended inputs, details of actual fertilisers applied, costs, etc). It would also allow benchmarking of nutrient inputs and yields within the industry and for this data to be used to better understand crop nutrient requirements and off-farm losses under a range of environmental and climatic conditions.

The importance and urgency of determining appropriate nutrient inputs (particularly N and P), keeping good records and having the ability to provide records in summary form increased considerably with the introduction of the Queensland Governments' Reef Regulations (Anon, 2009).

We initially considered the development of a computer spreadsheet-based program. However the longer-term benefits of an on-line web-based nutrient management 'tool' soon became apparent. These included the ability to modify and update the system when necessary, and to use the records to monitor trends across districts and the industry.

The main objectives of this tool would be to function as an online nutrient management calculator (specifically for the Australian sugarcane industry) with an interactive data record management system and a tiered reporting capability. This would be achieved by providing growers and/or their advisors with a user-friendly and easily accessible system that was programmed to provide:

- A standardised form of data record entry and storage. This would include farm, block and soil/nutrient information
- A nutrient decision support framework using an automated 'interpretation' facility using results of soil tests
- The ability to undertake performance evaluations and identify appropriate recommendations for corrective action
- Routine collation and analysis of fertiliser application and nutrient balance data at industry and regional scales
- Security features to ensure that grower privacy is ensured

The National Centre for Engineering in Agriculture (NCEA) was chosen as the collaborating organisation to develop the web-based package. It is a leading provider of online data record management, performance auditing and economic tools for the agricultural sector. In particular, it has developed a range of online tools for benchmarking the performance of irrigation application systems (e.g. the Irrigation Performance Audit and Reporting Tool - IPART) through its involvement in the Rural Water Use Efficiency Initiative and South-east Queensland Irrigation Futures program. Many of these tools have been developed in close consultation with Industry staff to meet the specific needs of industry and growers.

9.2 Method

The web-based nutrient management tool, badged as BSES SIX EASY STEPS NutriCalc (NutriCalc), was developed by combining the technical nutrient, soil and industry information and guidelines (based on the SIX EASY STEPS program) with an appropriate computer-based framework and computer programming skills provided by NCEA. This combination ensured that the resulting online tool contains appropriate functionality and interfacing (Table 36) to suit users (growers and their advisors) within the Australian sugarcane industry.

The following key features of the program were identified as essential components of the package:

- A web-based computerised package that incorporates the ability to determine nutrient requirements, the ability to select appropriate fertiliser carriers and a record-keeping facility to enable trend and economic analyses
- Separate user accounts for individuals accessing the website, with privileges determining which pages and data the user can access
- Customised data entry forms. The data entry and nutrient balance screens will utilise an interface customised for each individual user
- Ability to enter pre- and post-season soil analysis data and utilise in nutrient calculations
- Harvest nutrient removal calculated using crop yield and assumed nutrient content levels sourced from published data
- Nutrient management report generation; creating a PDF file that contains the key input data and calculated nutrient management outputs for each field
- Ability to provide graphical output of seasonal nutrient management trends for blocks
- Statistical analysis (e.g. mean and variance) on both the entered and calculated data
- Ability to export key input and calculated data in CSV format

Table 36 – Basic functionality and interfacing identified during development of BSES SIX EASY STEPS NutriCalc

Function	**Description**
Deployment	Web enabled tool
Create Account	Create User Account in KMSI interface
Login	Login and password via KMSI front end
Data Entry	
Grower	Enter necessary grower details
Farm	Enter name of farm and rainfall details
Fields	Enter name, area details Enter soil detail (bulk density and soil type)
Location	Locate farm and fields on Google maps Determine the area for each section Determine the catchment Locate the soil test position
Crops	Enter the crop type relative to each field Enter ratoon information (for sugarcane) Enter the total area for each crop relative to fields Enter normal production / crop yields Enter season start and end date Enter irrigation practice details (if required)
Fertiliser practices	Enter fertiliser practice details relative to each crop (input based on product list and then apply calculation to get the constituents, based on SIX EASY STEPS nutrient calculator)
Lab / mill data	Enter soil test details relative to each crop Enter leaf sampling detail relative to each crop Enter harvest detail relative to each crop (yields and CCS)
Calculations	
Nutrient calculations	Calculated nutrient outputs for each field Graph for each crop for each season. Nutrient removal calculated data using crop yield and assumed nutrient content levels (based on BSES data)
Reporting Outputs	
Graphical output	Seasonal nutrient balance trend data for each crop
Statistical analysis	On both entered and calculated data. Limited by selected parameters (e.g. industry, region)
Export functions	
Export	Export key input and calculated data in PDF and CSV format

9.3 Results and discussion

BSES SIX EASY STEPS has been developed as an online nutrient management package according to the prerequisites and functionality identified above. It will be accessed via the BSES Limited Website but hosted on the University of Queensland (USQ)/NCEA server for at least the next three years. The package has received extensive testing and on-going refinement by Lidya Agustina (NCEA) and John Panitz (BSES Limited). It was 'road tested' by several agronomists, extension officers and growers. It will be accessible to all growers and/or their advisors via a secure login page (Figure 25). A User Manual is being developed.

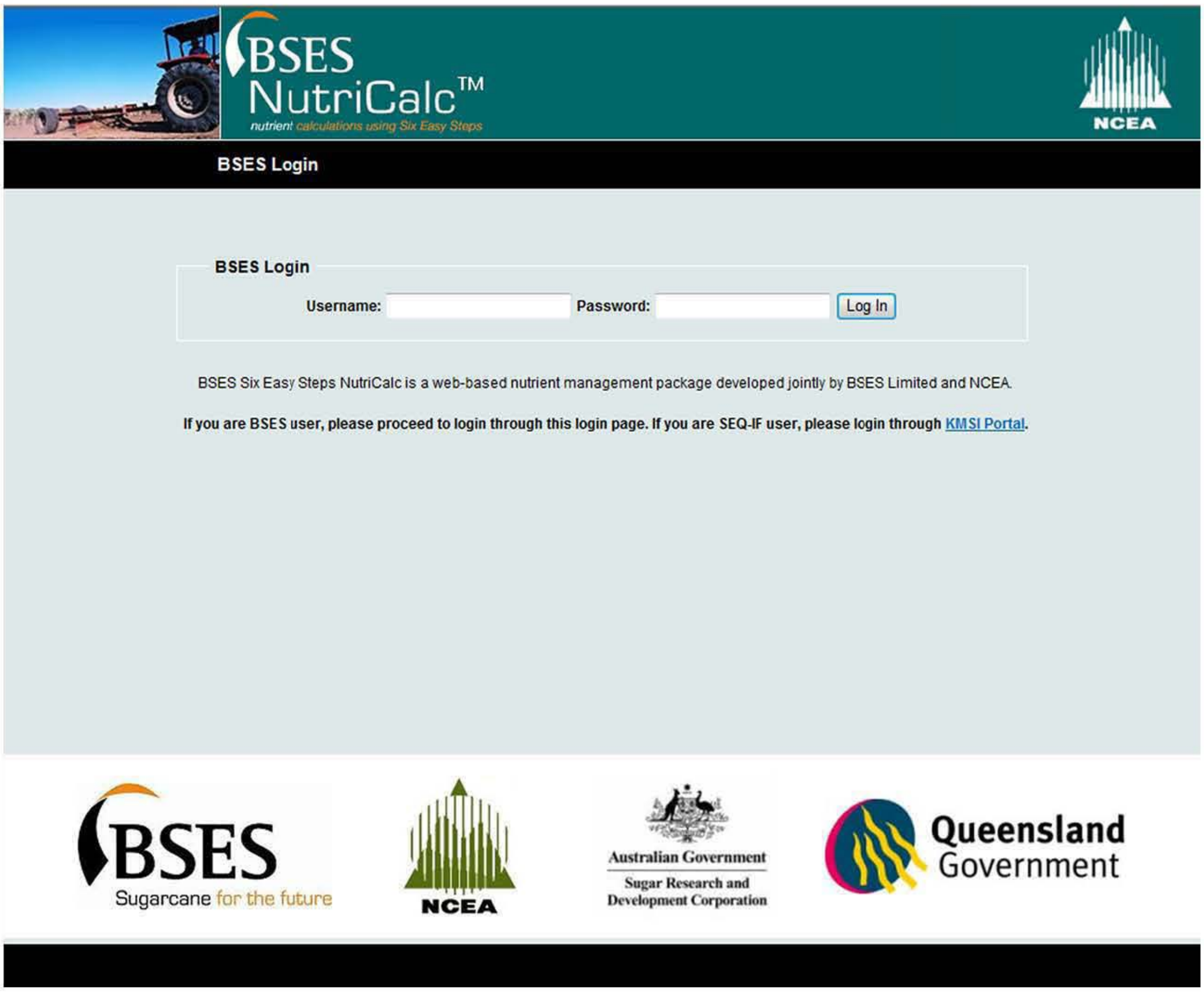


Figure 25 – BSES SIX EASY STEPS NutriCalc login page

The following is a summary of how NutriCalc works and what it contains:

Grower's details and block information can be entered into the system using the "New Evaluation" link. The location of the farm will be shown on the Google Map. Rainfall data can also be accessed at this point. Field data can be entered by clicking on the "Add New Field/Block" or by using the Google Map facility. The latter option enables block boundaries to be drawn and the block size will be automatically calculated. This information is then shown on the "Summary" page (Figure 26).

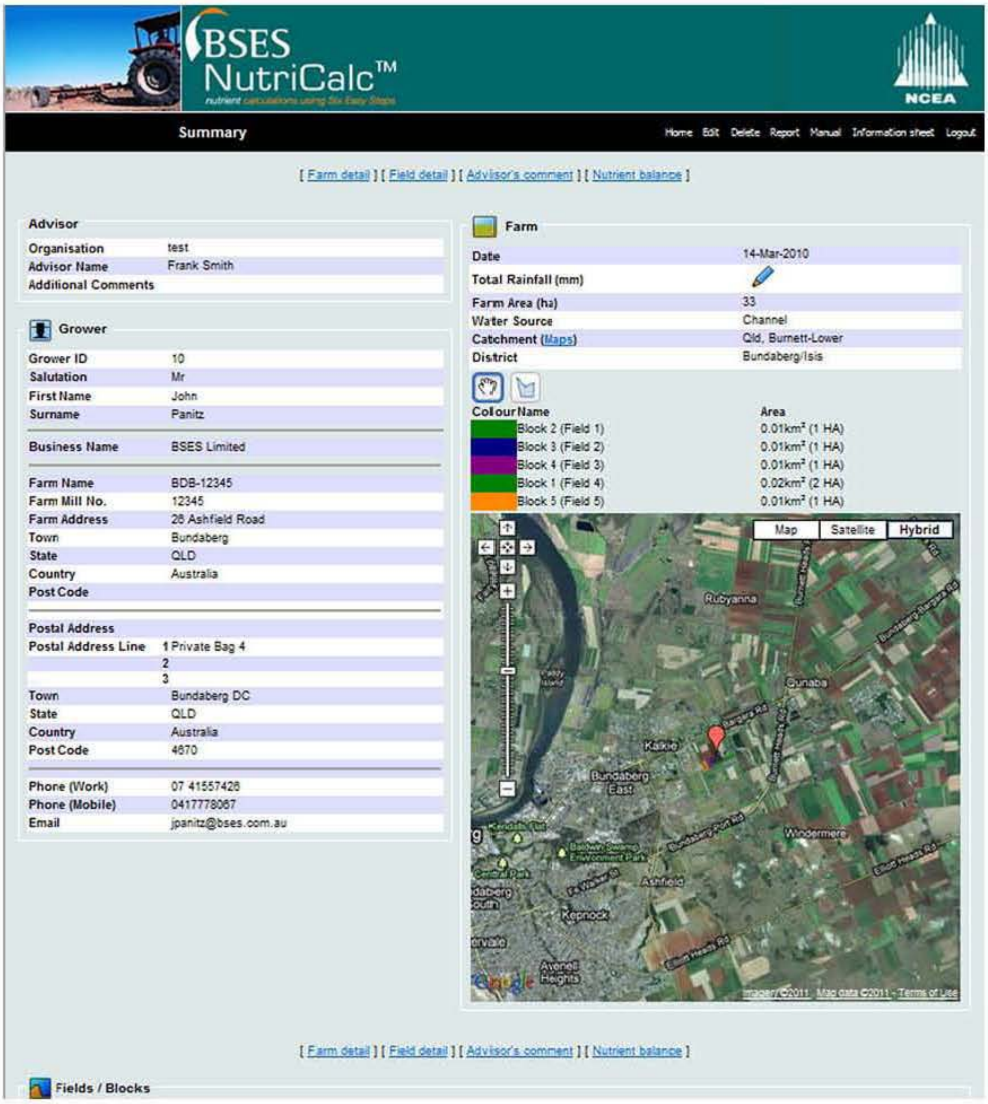


Figure 26 – Grower, farm and block information in NutriCalc

The "Edit" mode needs to be selected to enter data or make modifications for all blocks. Once a 'block' has been identified within the system, the appropriate 'block number' will appear under "Fields/Block". Having selected a particular 'block', four separate sections become available in a scroll-down format (Figure 27):

- "General Details"
- "Crop"
- "Lab Analysis"
- "Record of amendments, ameliorants and fertilisers"

The "Crop" section includes 'annual' information covering crop, crop class, block area, start/plant date, harvest date, yields, rainfall figures, etc. (Figure 28).

Several subsections occur within the "Lab Analysis" section (Figure 27). These include soil analysis, leaf analysis, harvest data and irrigation water analysis. The soil analysis section covers both the soil test data (Figure 29) and the facility to calculate the nutrient requirements based on the soil test values (Figure 30). The cost of the nutrients (based on up-to-date unit prices) is supplied to enable growers to compare prices supplied by fertiliser re-sellers. A ‘full’ report is possible for both the soil test data and the nutrient requirements (Figures 31 and 32 respectively).

The “Record of amendments, ameliorants and fertiliser” section covers actual inputs to be recorded. An example of the fertilisers applied to a particular block is shown in Figure 33. The “Fertiliser Recording” tool enables choices (products, dates, placement strategies, etc.) to be made from drop-down menus (Figure 34).

Figure 27 – “Field/block” page of NutriCalc showing four separate sections

Crops

Crops

View	Crop	Crop Class	Area (Ha)	Season Start / Planting Date	Season End / Harvest Date	Max Root Depth (cm)	Yield: Actual Yield	Yield: Trash Blanket	Bulk Density (g/cm^3)	Total Rain (mm)	Total Irrigation (mm)
	Soybean	(NA)	2	01/12/2006	01/04/2007				1.4	0	0
	Sugarcane	Plant	2	02/08/2007	15/09/2008				1.4	0	0
	Sugarcane	Ratoon 1	2	15/09/2008	02/10/2009				1.4	0	0
	Sugarcane	Ratoon 2	2	02/10/2009	15/10/2010				1.4	0	0
	Sugarcane	Ratoon 3	2	15/10/2010	31/12/9999				1.4	0	0

Figure 28 – “Crop” details within NutriCalc

Lab analysis

Soil test

Crop	Sample No	Sample Date	Sample Depth	pH (1:5 Water)	pH (1:5 CaCl2)	Cation Exch. Cap. (meq/100g)	Organic Carbon (%)	Phosphorus - BSES (mg/kg)	Potassium - Nitric K (meq/100g)	Potassium - Amm-acet. (meq/100g)	Calcium - Amm-acet. (meq/100g)	Magnesium - Amm-acet. (meq/100g)
Soybean, Dec-06	021099626	01/11/2006	20	5.2	4.3	4.17	2	16	3.1	0.13	1.2	0.4
Sugarcane, 07	021099626	01/11/2006	20	5.2	4.3	4.17	2	16	3.1	0.13	1.2	0.4
Sugarcane, 08	021099626	01/11/2006	20	5.2	4.3	4.17	2	16	3.1	0.13	1.2	0.4
Sugarcane, 09	021099626	01/11/2006	20	5.2	4.3	4.17	2	16	3.1	0.13	1.2	0.4
Sugarcane, 10	021099626	01/11/2006	20	5.2	4.3	4.17	2	16	3.1	0.13	1.2	0.4

Figure 29 – Summary of soil test values for a block of cane in NutriCalc

Sugarcane, 08

Farm: Danielle's Hideaway Field: 2

	Water (ML/ha)	N (kg/ha) *	P (kg/ha) *	K (kg/ha) *	S (kg/ha)	Ca (kg/ha)	Mg (kg/ha)	Cu (g/ha)	Zinc (g/ha)
Avg Fertiliser Application for catchment (n= 0)		0	0	0	0	0	0	0	0
Required		120	30	100			0		
Estimate $ cost		126	123.6	138	Total: $387.6		*Date of $ cost as of:*		***20-Jul-2010***
Exported		78.2	8.7	127.9	18.1	14.1	10.1	41.9	258.1

*N supplied as Urea, P supplied as DAP, K supplied as Muriate of Potash (MOP)

Figure 30 – Summary of calculated nutrient requirement

SOIL TEST (All Elements)
Farm: Danielle's Hideaway Field: 2

Print

Crop Name	Soybean, Dec-06	Sugarcane, 07	Sugarcane, 08	Sugarcane, 09	Sugarcane, 10
Sample No.	21099626	21099626	21099626	21099626	21099626
Lab Name	Incitec Pivot	Incitec Pivot	Incitec Pivot	Incitec Pivot	Incitec Pivot
Sample Date	01/11/2006	01/11/2006	01/11/2006	01/11/2006	01/11/2006
Sample Depth	20	20	20	20	20
Color	Grey	Grey	Grey	Grey	Grey
Texture	Loam	Loam	Loam	Loam	Loam
pH (1:5 Water)	5.2	5.2	5.2	5.2	5.2
pH (1:5 CaCl2)	4.3	4.3	4.3	4.3	4.3
Organic Carbon (%)	2	2	2	2	2
Nitrate Nitrogen (mg/Kg)					
Sulfate Sulfur - MCP (mg/Kg)	17	17	17	17	17
Phosphorus - BSES (mg/kg)	16	16	16	16	16
Phosphorus - Colwell (mg/Kg)	14	14	14	14	14
Potassium - Amm-acet. (Meq/100g)	0.13	0.13	0.13	0.13	0.13
Potassium - Nitric K (Meq/100g)	3.1	3.1	3.1	3.1	3.1
Calcium - Amm-acet. (Meq/100g)	1.2	1.2	1.2	1.2	1.2
Magnesium - Amm-acet. (Meq/100g)	0.4	0.4	0.4	0.4	0.4
Aluminium - KCl (Meq/100g)	2.4	2.4	2.4	2.4	2.4
Sodium - Amm-acet. (Meq/100g)	0.04	0.04	0.04	0.04	0.04
Chloride (mg/Kg)					
Elec. Conductivity (dS/m)	0.03	0.03	0.03	0.03	0.03
Copper - DTPA (mg/Kg)	0.27	0.27	0.27	0.27	0.27
Zinc - DTPA (mg/Kg)					
Zinc - BSES (mg/Kg)	0.96	0.96	0.96	0.96	0.96
Iron - DTPA (mg/Kg)	100	100	100	100	100
Silicon - BSES (mg/Kg)	190	190	190	190	190
Silicon - CaCl2 (mg/Kg)	23	23	23	23	23
Ammonium Nitrogen -KCl (mg/Kg)					
Cation Exch. Cap. (Meq/100g)	4.17	4.17	4.17	4.17	4.17
Calcium/ Magnesium Ratio	3	3	3	3	3
Aluminium Saturation (%)					
Sodium % of Cations - ESP (%)	1	1	1	1	1
Phosphorous Buffer Index - PBI-Col	510	510	510	510	510

Figure 31 – Full soil test report within NutriCalc

Required Nutrient (All Elements)
Farm: Danielle's Hideaway Field: 2

Print

	Avg Fertiliser Application for catchment (n= 0)	Required	Exported
Nitrogen (Kg/Ha)	0	120	78.2
N mineralisation index		Moderate High	
Phosphorus (Kg/Ha)	0	30	8.7
P sorption class		Very High	
Potassium (Kg/Ha)	0	100	127.9
Texture class		Loam	
Sulphur (Kg/Ha)	0		18.1
Calcium (Kg/Ha)	0		14.1
Magnesium (Kg/Ha)	0	0	10.1
Copper (g/Ha)	0		41.9
Iron (g/Ha)	0	0	3300
Manganese (g/Ha)	0	0	2421.8
Zinc (g/Ha)	0		258.1
Boron (g/Ha)	0	0	0
Molybdenum (g/Ha)	0	0	0
Lime (tonnes/Ha)		4	
Gypsum (tonnes/Ha)		0	
Mill mud/ash (tonnes/Ha)			

Figure 32 – Full nutrient requirement report per block. Average applications and average crop removal information is also supplied.

Fertiliser applied

Edit	Crop	NITROGEN			PHOSPHORUS			POTASSIUM			SULPHUR			COPPER			ZINC		
		Pre*	At*	SD*	Pre	At	SD	Pre	At	SD	Pre	At	SD	Pre	At	SD	Pre	At	SD
	Soybean, Dec-06		16			7			57			12							
	Sugarcane, 07		36			40				99		3							
	Sugarcane, 08			114			27			108									
	Sugarcane, 09			114			27			108									
	Sugarcane, 10			114			27			108									

* Pre = Pre-planting, At = At Planting, SD = Side-Dress. N, P, K, S, Ca, Mg in kg/ha, Cu, Fe, Mn, Zn, B, Mo in g/ha

Figure 33 – Example of records of nutrients applied to crops

Figure 34 – The Fertiliser Recording tool which allows access to drop-down menus covering products, period, dates, rates, placement strategies, etc

NutriCalc enables the generation of reports of nutrient management per block that conform to the requirements of the Queensland Government's Reef Regulations. An example is shown in Figure 35.

The above description has only highlighted the main features of NutriCalc. It is a versatile package with the ability to be integrated with other nutrient and farm management programs. It contains the ability to identify specific farms and blocks, to determine appropriate nutrient management strategies and the cost of fertiliser inputs based on unit prices of nutrients, to select appropriate fertiliser carriers to meet the determined requirements and to record actual nutrient inputs. The useful electronic record-keeping system will enable nutrient/soil fertility trends and economic assessments (as partial net returns) to be calculated at block, farm, catchment and industry scale (especially as more data is entered into the system).

An important future development is the linkage of NutriCalc with *SafeGauge for Nutrients* (as described in Section 6). This development is currently under discussion between BSES, DERM and NCEA. It will enable the risk of run-off or leaching of nutrients to be assessed in terms of specified inputs during various seasonal weather conditions.

NutriCalc was launched at the BSES Field Day in Mackay (May 2011). It will be accessible from mid-June 2011 to all bona-fide sugarcane growers in Australia via the BSES website (following registration to enable allocation of a username and password). Feedback from users will be obtained in due course and communicated to SRDC when appropriate (December 2012).

BSES SIX EASY STEPS NutriCalc NCEA

Records for amendments, ameliorants and fertilisers applied 17-Dec-2009 to 10-Dec-2010

Property and contact details

Contact person: Mr Joe Smith

Company name: JL & PG Smith

Property address

PO Box 111,
Tully, 4854,
QLD, Australia

Farm identification number

Danielle's Hideaway (TUL-1234)
216 Dallachy Road,
Tully, 4854,
QLD, Australia

1. Block (sub-block)	2
2. Crop	
Crop name	Sugarcane, Ratoon 3
Season start date	15-Oct-2010
Area (ha)	2
3. Nutrient management - calculation of optimal rates	
Soil test sample number	021099626
Sample date	01-Nov-2006
Calculated optimum rate of nitrogen (N) (kg/ha)	120
Calculated optimum rate of phosphorus (P) (kg/ha)	30
4. Amendments/ameliorants applied	
No amendment/ameliorant applied.	
5. Fertiliser(s) applied	
1. Product trade name	JP1 (Incitec Pivot)
Nutrient content	N: 19(%) P: 4.5(%)
Application rate (kg/ha, L/ha)	600
Application methods	Subsurface (tyne, coulter and knife)
Nitrogen (N) applied (kg/ha, L/ha)	114
Phosphorus (P) applied (kg/ha, L/ha)	27
Name of person who authorised application	
Date of application	01-Nov-2010
6. Justification for difference between optimum rate and applied rate	
No justification given.	
7. Total nitrogen (N) applied (kg/ha)	114
8. Total phosphorus (P) applied (kg/ha)	27

Figure 35 – Example of a report generated by NutriCalc

10.0 GENERAL CONCLUSIONS

Project BSS268 has been successful in delivering against all the objectives.

Information from the surveys that were conducted indicated that although some symptoms of inefficient nutrient management were identified in the Australian sugarcane industry, sustainable nutrient management is integral to the sugarcane production system. In the longer-term sustainability means the adoption of best-practice options in order to achieve profitability in combination with environmental responsibility. The SIX EASY STEPS program, which is based on a logical set of principles, is aimed at facilitating the adoption of appropriate nutrient management practices on-farm. It encourages growers to make informed decisions about their nutrient inputs.

The development of a tool such as SCAMP has contributed to easy identification of constraints associated with particular soils found in specific parts of a landscape. This has been particularly useful when developing nutrient and soil management practices that will assist in minimising off-site losses.

The roll-out of the SIX EASY STEPS short course program has been extremely successful in facilitating the use of nutrient management plans on-farm. The importance of this initiative increased substantially with the introduction of the Australian Government's Reef Rescue Program and the Queensland Government's Reef Regulations. In both instances, the SIX EASY STEPS package enabled the industry to be better prepared to meet the challenges set by environmentally-focused government agendas. The one-day SIX EASY STEPS short-course format has proved to be popular amongst growers and has enough technical detail to meet the objective of capacity building in the industry. The range and scale of scientific papers and grower-orientated articles associated with this project has ensured that the SIX EASY STEPS program has had wide coverage. This 'publicity' has contributed markedly to industry acceptance and ownership of the SIX EASY STEPS program.

The government-initiated programs mentioned above are aimed at improving water quality in the Great Barrier Reef lagoon. Developments within this project have contributed in two ways towards this goal - production of vulnerability maps at catchment scale and development of *SafeGauge for Nutrients* as a decision support tool for growers and their advisors. Its eventual linkage to BSES SIX EASY STEPS NutriCalc will be an important step towards raising the awareness of the risks of nutrient losses (run-off and/or leaching) associated with particular nutrient management practices (choice of fertilisers, timing, application rates, etc). This is especially the case when seasonal weather conditions favour the chance of heavy or persistent rainfall events.

The series of replicated participative strip-trials have been most successful in demonstrating the benefits of nutrient inputs according to the SIX EASY STEPS guidelines. In most instances the SIX EASY STEPS inputs resulted in yields comparable to the grower-determined nutrient applications. However partial net returns were often in favour of the SIX EASY STEPS based strategy. Data from small plot experiments also confirmed this trend and demonstrated that the SIX EASY STEPS approach was superior to other available strategies (grower-developed, traditional and N-Replacement). These types of trials also contributed to fine-tuning of the SIX EASY STEPS guidelines.

The calculation of target N-use efficiency factors associated with the SIX EASY STEPS guidelines and actual N-use-efficiency factors using a range of trial data, indicate that the targets are appropriate and that the actual SIX EASY STEPS inputs are approaching those targets. However, environmental conditions and inefficiencies within the soil/plant environment will preclude attainment of identical target and actual N-use efficiency values. Results from the demonstration strip trials and small plot experiments indicated that improvement in N fertiliser-use efficiency cannot occur in isolation from productivity and profitability on farm. The SIX EASY STEPS approach that considers both these aspects is more appropriate than systems aimed at either maximum production (grower-developed inputs) or being overly environmentally focused (N Replacement strategy). In overall terms the SIX EASY STEPS is aimed at sustainable sugar cane production that encompasses best practice management by considering a combination of agronomic, economic, environmental and social benefits.

NutriCalc is an important development that brings together the SIX EASY STEPS guidelines, a mapping interface and a record-keeping system into a powerful web-based nutrient management tool accessible on-line to growers and their advisors for determining appropriate nutrient management strategies for particular blocks and farms. The versatility of the system will enable further developments and add-on improvements (e.g. *SafeGauge for Nutrients*).

This project has enabled further development and validation of the SIX EASY STEPS package. It has resulted in a number of important outputs and outcomes consistent with the philosophy of sustainable sugarcane production. It also provided a unique opportunity to promote and accelerate the adoption best-practice nutrient management across the Australian sugarcane industry.

11.0 OUTPUTS

This project, in association with linked investigations and initiatives, has led to a number of enhancements to the original SIX EASY STEPS program. These enhancements (Figure 36) can be divided into either "capacity building" or "decision support" outputs. As indicated earlier the strategic importance of the SIX EASY STEPS program increased substantially with the introduction of the Reef Regulations and the Reef Rescue Program. Importantly, further enhancements and/or refinements to the SIX EASY STEPS package will continue through initiatives led by BSES (Nutrient management for new farming systems) and DERM (Sugarcane Soil Nutrient Management Program).

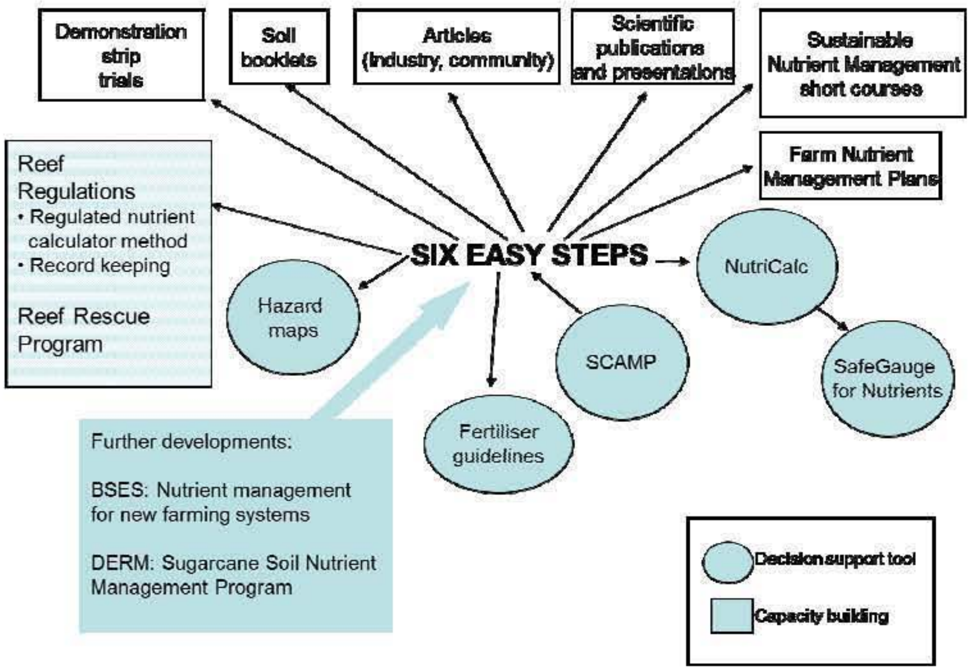


Figure 36 – The SIX EASY STEPS is central to many capacity building and decision support enhancements

Specific outputs include:

- SIX EASY STEPS workbooks that continue to be used during the short-courses presentations. These are regional/district specific and are regularly updated. As participants retain these after attending a course, they serve as a useful reference (for growers and their advisors).
- Soil reference booklets that have been developed and printed for several regions (Herbert, Proserpine, Johnstone and Bundaberg). Booklets are currently being developed for Mackay, Plane Creek, Tully and New South Wales (with funding from sources other than SRDC).

- Fourteen scientific papers that were prepared and presented at conferences (ASSCT, ISSCT and Soils 2008). These papers provide comprehensive coverage of the developments that have occurred within this project.
- A series of 50 articles that were written for the Australian Canegrower magazine.
- Soil test interpretation guidelines that were developed for all cane-growing areas from Maryborough northward. Laminated interpretation charts are regularly updated and distributed as required.
- Templates and guidance for developing nutrient management plans
- A web-based nutrient advisory and record-keeping system badged as BSES SIX EASY STEPS NutriCalc
- A series of replicated demonstration strip-trials that have illustrated the advantages of using the SIX EASY STEPS for determining nutrient inputs to blocks of sugarcane

12.0 INTELLECTUAL PROPERTY AND CONFIDENTIALITY

If commercial opportunities arise with the potential to create adoption of this project's intellectual property, then the terms and conditions of releasing information would be developed between the researchers' organisations, SRDC and commercial partners. Aspects of this project that have the potential IP are:

- The framework used to develop the SIX EASY STEPS
- Delivery of the SIX EASY STEPS package
- The SIX EASY STEPS nutrient management guidelines and interpretation charts
- The web-based BSES SIX EASY STEPS NutriCalc

13.0 ENVIRONMENTAL AND SOCIAL IMPACTS

Use of the outputs from this project will either deliver, or have the potential to deliver, a number of positive environmental and social impacts. These include:

- More precise nutrient applications customised to soil properties
- Improved nutrient use efficiency and less offsite movement
- Improved productivity (tonnes sugar/ha)
- Reduced input costs
- Enhanced profitability
- Improved water quality
- More balanced nutrition
- Enhanced positive community perception of the sugar industry as good custodians of the land, water and reef

14.0 EXPECTED OUTCOMES

The following is a list of expected outcomes from this project:

- Improved understanding by growers of their soils, nutrient availability and best practice nutrient management
- Greater precision in application of nutrients customised to soil types and properties
- Better balance of nutrients in soil
- Improved soil health
- Improved nutrient-use efficiency and reduced off-site movement
- Improved productivity in terms of tonnes sugar per hectare (TSH)
- Improved profitability, particularly as a result of reduced input costs
- Improved water quality
- Enhanced community perception of the sugarcane industry's fertilising and soil management practices
- Empowerment of growers to be better informed about their soils, soil fertility and nutrient management practices
- Greater confidence amongst growers when interacting with government, environmental and scientific groups
- More positive attitudes by government who can see growers are being proactive about managing their soils and protecting their environment

15.0 FUTURE RESEARCH NEEDS AND RECOMMENDATIONS

A number of future research needs have been identified as a result of activities within BSS268 and/or due to discussions amongst the project team. These include:

- Adjusting district yield potential (DYP) for seasonal climatic conditions
  Background: The SIX EASY STEPS N guidelines are based on a combination of DYP and a soil-N mineralisation index. The DYP is determined from the best possible yield averaged over all soil types within a district and is defined as the estimated highest average annual yield (EHAADY) multiplied by a factor of 1.2. Existing mechanisms within the SIX EASY STEPS program already allow for alternative base-line N application rates for sub-districts or farms (where annual average yields consistently exceed or consistently produce lower yields that the estimated DYP values). However, seasonal climatic conditions (e.g. forecast wet or dry seasons) are currently not accounted for when determining appropriate N application rates for specific districts.
- Mitigation strategies for denitrification.
  Background: Denitrification losses can occur under certain conditions (water-logged soils in the presence of organic matter). Although the SIX EASY STEPS recognises such losses and high-lights guidelines for minimising denitrification, it may not account for all such losses when these are severe. Mitigation strategies are therefore needed for such circumstances.
- Glasshouse screening of potential commercial varieties for nutrient-use efficiency.
  Background: This will provide important information for inclusion into QCANESelect™. Such investigations could cover N- and P-use efficiency (e.g. mycorrhizal dependence and effect of background soil P on mycorrhizae).

- Decision support tool for assessing risks of denitrification.
  Background:
  A number of factors influence the occurrence and extent of denitrification. Given the potential contribution of denitrification to greenhouse gas emissions, it is in the interest of the sugarcane industry to minimise such losses. A decision-support tool that aids growers to assess the risk and extent of denitrification and then presents some alternative on-farm management strategies could easily be linked to NurtriCalc.

- Rapid soil test for potential mineralisable N, P and S.
  Background:
  The SIX EASY STEPS N guidelines are based on the combined concepts of DYPand and a soil N mineralisation index. The N mineralisation index uses organic C as the basis for a pedo-transfer function for determining an appropriate N mineralisation class for soil samples from commercial cane blocks. The N mineralisation classes were determined from results of laboratory incubation (30°C for two weeks) of samples collected from soil reference sites across the industry. Surrogate organic C determinations are necessary because incubation is not possible on samples submitted for testing to commercial laboratories for nutrient advice. We also know that P and S are mineralised from soil organic matter. A rapid test that estimates the amount of mineralisable N, P and S would add greatly to soil testing capability and the grower community that is dependent on soil analyses for determining nutrient inputs per block.

- Validate *SafeGauge for Nutrients.*
  Background
  SafeGauge for Nutrients is currently based on processes and trends developed from general scientific principles and expert opinion. Specifically conducted field trials and results of monitoring sites are necessary to validate the outputs relating to the risk of run-off and deep-drainage for both N and P.

- Risk averse nutrient application strategies for solid and liquid fertilisers.
  Background
  A range of solid and liquid fertilisers is available to growers throughout the industry. The risk of gaseous, leaching and run-off losses associated with the majority of these products has not been quantified. The development of guidelines detailing appropriate nutrient management strategies for a range of products would help minimise potential losses and result in improved sugarcane profitability and environmental benefits.

- N rate strip-trials to validate the N fertiliser use efficiency factors.
  Background
  Target N fertiliser-use efficiencies have been developed for various strategies within the SIX EASY STEPS process. Although actual efficiencies have been determined from many recent trials conducted in various districts, additional series of replicated strip-trials will add greatly to current data and information.

- Bioavailability of N, P, K, S, Ca, Mg and Si from mill by-products.
  Background
  Mill by-products are known to be variable in composition. However, although total chemical analysis is possible, the nutrient bioavailability can only be assumed. These two issues necessitate a series of pot experiments to determine the release of nutrients and how much is available for uptake by sugarcane in relation to a range of application rates. This type of investigation could cover composted mill by-products.

- N and K nutrient accumulation patterns for maximising biomass (to use as a nutrient budget approach).
  Background

Any future use of sugarcane for biofuels necessitates maximum biomass production per hectare. This change from maximising sugar production will need modifications to the sugarcane farming system, including nutrient management. Several options will need to be investigated especially if crops are grown in close-row configurations and/or harvests occur more than one per year. One possible strategy would involve a nutrient budget approach.

- Diagnostic soil test for assessing starter P requirements for micro-propagated plantlets.
  Background
  Micro-propagated plantlets may form the basis of commercial planting (at least in seed cane plots) in the future. Phosphorus is recognised as an important nutrient that stimulates root growth. In conventional planting systems, the billets or whole-stick cane contain a certain amount of P that probably satisfies the initial need of the emerging plant. Micro-propagated plants do not contain this reserve. A diagnostic soil test for assessing plant available P at this critical growth stage will improve the viability of this type of technology.

- Critical indicator leaf levels (N, P, K, S, Ca and Mg) for new and high biomass varieties.
  Background
  General third-leaf nutrient critical values exist for sugarcane. These are based on internationally recognised norms. Evidence from overseas suggests that critical leaf values can differ according to genotype. Little work has been done in assessing the critical third-leaf nutrient values for recently released Q varieties. In addition, the validity of such values will become more important if sugarcane is grown for biomass production because the adequacy of nutrients inputs will need closer scrutiny.

- Review of appropriate diagnostic soil tests for reserve K and conduct K depletion trials.
  Background
  Routine soil test for potassium involve determining exchangeable K and Nitric K (to estimate the non-exchangeable availably K). With ongoing crop production and a trend to utilising soil K reserves, there is a need to review Nitric K as an appropriate diagnostic method. Investigations relating to the depletion of available K reserves with time are needed to ensure sustainable sugarcane production into the future.

We prioritised these research needs by rating our assessment of attractiveness and feasibility according to a scale of ‘1’ (low) to ‘3’ (high). An overall priority rating was determined by multiplying the two ratings (Table 37).

Table 37 – Future research needs rated according to attractiveness and feasibility (1 = low; 3 = high)

Identified research need	Attractiveness	Feasibility	Overall
Adjusting DYP for seasonal climatic conditions	3	3	9
Mitigation strategies for denitrification	3	3	9
Glasshouse screening of varieties for nutrient-use efficiency	3	3	9
Decision support tool for assessing risks of denitrification	3	2	6
Rapid soil test for potentially mineralisable N, P and S	3	2	6
Validate SafeGauge for Nutrients	3	2	6
Risk averse application strategies for solid and liquid fertilisers	3	2	6
N rate strip trials to validate N fertiliser-use efficiency factors	2	2	4
Bioavailability of N, P, K, S, Ca, Mg and Si from mill by-products	2	2	4
N and K accumulation patterns for maximising biomass	2	2	4
Diagnostic soil test for assessing starter P requirement for micro-propagated plantlets	1	3	3
Critical indicator leaf concentrations for N, P, K, S, Ca and Mg for new varieties and for high biomass varieties	1	3	3
Review appropriate soil tests for reserve K	1	2	2

16.0 PUBLICATIONS ARISING FROM THE PROJECT

A relatively large number of publications have resulted from this project. These have included refereed technical papers and more industry-focused articles.

16.1 Technical papers (in chronological order)

Schroeder BL, Wood AW, Moody PW, Panitz JH, Agnew JR, Sluggett RJ Salter B (2006) Delivering nutrient management guidelines to growers in the Central Region of the Australian sugar industry. *Proceedings of the Australian Society of Sugar Cane Technologists* **28**, 142-154.

Schroeder BL, Wood, AW, Moody PW and Panitz JH (2006) Sustainable nutrient management – delivering the message to the Australian sugar industry. *Proceedings of the South African Sugar Technologists Association* **75**, 14pp CD-ROM.

Schroeder BL, Hubert JW, Hubert C, Hubert FG, Panitz JH, Wood AW, Moody PW (2007) Recognising differences in soil type to guide nutrient inputs on-farm – a case study from Bundaberg. *Proceedings of the Australian Society of Sugar Cane Technologists* **29**, 138-148.

Moody PW, Blogg D, Legrand J, Schroeder BL and Wood AW (2008) 'SCAMP' and SafeGauge for Nutrients': Two new decision support tools for minimising off-site movement of nutrients. *Proceedings of the Australian Society of Sugar Cane Technologists* **30**, 276-284.

Salter B, Schroeder BL Wood AW, Panitz JH and Park G (2008) Use of replicated strip-trials for demonstrating the effectiveness of different nutrient management strategies for sugarcane. *Proceedings of the Australian Society of Sugar Cane Technologists* **30**, 361.

Schroeder BL, Wood AW, Moody PW, Panitz JH (2008) A comparison of different approaches for deriving nitrogen application rates using trial data from Macknade. *Proceedings of the Australian Society of Sugar Cane Technologists* **30**, 359-360.

Wood AW, Schroeder BL, Hurney AP, Salter B, Panitz (2008) Research aimed at enhancing nitrogen management guidelines for the SIX EASY STEPS program. *Proceedings of the Australian Society of Sugar Cane Technologists* **30**, 362-363.

Wood AW, Schroeder BL and Moody PW (2008) Development of soil-specific guidelines for nutrient management in the Australian sugar industry. *Soils 2008 Conference*, Massey University, Palmerston North, New Zealand, 2 pp (CD-ROM). (Appendix 13)

Schroeder BL, Wood AW, Panitz JH, Salter B and Moody PW (2008) The "SIX EASY STEPS" as a delivery mechanism for best practice nutrient management in the Australian sugar industry. *Soils 2008 Conference*, Massey University, Palmerston North, New Zealand, 2 pp. (Appendix 14)

Schroeder BL, Wood AW, Park G, Panitz JH, Stewart RL (2009) Validating the 'SIX EASY STEPS' nutrient management guidelines in the Johnstone catchment. *Proceedings of the Australian Society of Sugar Cane Technologists* **31**, 177-185.

Schroeder BL, Hurney AP, Wood AW, Moody PW, Calcino DV, Cameron T (2009) Alternative nitrogen management strategies for sugarcane production in Australia: The essence of what they mean. *Proceedings of the Australian Society of Sugar Cane Technologists* **31**, 93-103.

Schroeder BL, Hurney AP, Wood AW, Moody PW, Allsopp PG (2010) Concepts and value of the nitrogen guidelines contained in the Australian sugar industry's 'SIX EASY STEPS' nutrient management program. *Proceedings of the International Society of Sugar Cane Technologists* **27**, 13pp CD-ROM.

Wood AW, Schroeder BL, Dwyer R (2010) Opportunities for improving the efficiency of use of nitrogen fertiliser in the Australian sugar industry. *Proceedings of the Australian Society of Sugar Cane Technologists* **31**, 221-233 (Appendix 12).

Calcino DV, Schroeder BL, Hurney AP (2010) Extension and adoption of the 'SIX EASY STEPS' nutrient management program in sugarcane production in North Queensland. *Proceedings of the International Society of Sugar Cane Technologists* **27**, 10pp CD-ROM.

16.2 Industry-focused articles (in chronological order)

Regular nutrient management article have been published in the *Australian Canegrower* (Table 38). In each article it was noted that the SIX EASY STEPS program forms part of the nutrient management initiative involving BSES Limited, CSR Ltd (now Sucrogen) and Queensland DERM. It was further indicated that the SIX EASY STEPS is supported by CANEGROWERS and receives funding from SRDC, Queensland DPI&F (now DEEDI) and the Australian Department of the Environment, Water, Heritage and the Arts.

Table 38 – Nutrient management articles published in the *Australian Canegrower* August 2007 to July 2009

Issue	Title
13 August 2007	Nutrient management series - part 1
27 August 2007	*Nutrient management series - part 2
10 September 2007	Nutrient management series - part 3
24 September 2007	Nutrient management series - part 4
8 October 2007	Nutrient management series - part 5
22 October 2007	Nutrient management series - part 6
5 November 2007	Managing soil properties for nutrient management
19 November 2007	Soil texture and nutrient management
3 December 2007	Soil structure and nutrient management
17 December 2007	*Managing soil sequence in the landscape
21 January 2008	Knowing our soil chemical properties
4 February 2008	Managing nutrient processes and losses
18 February 2008	Minimising nitrogen losses from production
3 March 2008	Knowing and understanding phosphorus
17 March 2008	Understanding and managing potassium
31 March 2008	Balanced nutrition needed in sugarcane production
14 April 2008	Applying nutrients to ensure cost effective production
28 April 2008	Unnecessary nutrient applications impact profitability
12 May 2008	Don't apply one nutrient at the expense of another
26 May 2008	*Regular soil testing a part of balanced nutrition
9 June 2008	Collecting soil samples for sugarcane production
23 June 2008	Adopting soil-specific nutrient management guidelines
7 July 2008	Using yield potential to determine your N requirement
21 July 2008	Calculating nitrogen from legume crops
4 August 2008	Different yield potential and guidelines for the Burdekin
18 August 2008	N contribution that needs to be taken into account
1 September 2008	Adjusting N rates after small crop production
15 September 2008	Phosphorus is an important nutrient in plant growth
29 September 2008	Sources of phosphorus
13 October 2008	*Potassium helps cane growth
27 October 2008	Mill by-products as sources of potassium
10 November 2008	Sulphur plays important role in plant growth
24 November 2008	Lime neutralises soil acidity and add calcium
8 December 2008	Managing magnesium essential for plant growth
22 December 2008	High levels of sodium can adversely affect soil
12 January 2009	Micro-nutrients in sugarcane production
26 January 2009	Silicon guidelines for nutrient management
9 February 2009	Determining nutrient requirements for cane
23 February 2009	How a soil test report determines nutrient requirements
9 March 2009	What determines the phosphorus requirement?
23 March 2009	Using leaf analysis for nutrient management
6 April 2009	Collecting leaf samples for analysis
20 April 2009	Interpreting leaf analysis results
4 May 2009	Keep good nutrient management records
18 May 2009	What is a nutrient management plan?
1 June 2009	Developing a nutrient management plan
15 June 2009	Will a nutrient management plan have positive results?
29 June 2009	How to develop a soil sampling program for my farm
13 July 2009	How to develop a leaf sampling program for my farm
27 July 2009	*SIX EASY STEPS nutrient management completed

* Shown as examples in Appendices 16 – 20.

17.0 ACKNOWLEDGMENTS

The follow BSES staff members were heavily involved in conducting the series of field trials associated with this project. Their ongoing input and dedication is acknowledged with thanks:

- Innisfail: Glen Park (Ingham)
- Burdekin: Jayson Dowie (Burdekin)
- Mackay / Plane Creek: Dr Barry Salter and Jason Perna (Mackay)
- Bundaberg: John Panitz and Phil Netz (Bundaberg)
- Tully: Alan Hurney and Danielle Skocaj

Thanks are also due to:

- The growers who have been participating in the field trials associated with this project
- BSES staff including David Calcino, Alan Hurney, Danielle Skocaj, Marian Davis, Ryan Matthews, Barry Salter, Jason Perna, Peter Muller, John Agnew (MAPS) and John Panitz for their enthusiastic participation in presenting the SIX EASY STEPS short-courses and promoting the use of the SIX EASY STEPS principles in nutrient management planning
- Craig Baillie (NCEA/USQ) for the positive interaction in setting-up the sub-contract with NCEA/USQ for developing NutriCalc, and for the useful initial discussions about the format and capability of the system
- Lidya Agustina (NCEA/USQ) for her patience and dedication in developing and fine-tuning the computer-coding and programming of the NutriCalc system
- John Panitz (BSES Limited) for the many hours spent testing and refining NurtiCalc inputs and outputs
- The group of extension officers, researchers and growers who volunteered to road-test the draft version of NutriCalc

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19.0 LIST OF APPENDICES

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Appendix 3: Schroeder BL, Hurney AP, Wood AW, Moody PW, Allsopp PG (2010) Concepts and value of the nitrogen guidelines contained in the Australian sugar industry's 'SIX EASY STEPS' nutrient management program. *Proceedings of the International Society of Sugar Cane Technologists* **27**, 13pp CD-ROM.

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Appendix 11: Schroeder BL, Hurney AP, Wood AW, Moody PW, Calcino DV, Cameron T (2009) Alternative nitrogen management strategies for sugarcane production in Australia: The essence of what they mean. *Proceedings of the Australian Society of Sugar Cane Technologists* **31**, 93-103.

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Appendix 15: SCAMP: A Decision Support System for Sustainable Management of Sugarcane Soils (Moody PW, Schroeder BL, Wood, AW and Legrand J) - Advanced Draft.

Appendix 16: Nutrient management series – Part 2, *Australian Canegrower*, 27 August 2007

Appendix 17: Nutrient management – Managing soil sequence in the landscape, *Australian Canegrower*, 17 December 2007.

Appendix 18: Nutrient management – Regular soil testing a part of balanced nutrition, *Australian Canegrower*, 26 May 2008.

Appendix 19: Nutrient management – Potassium helps cane growth, *Australian Canegrower*, 13 October 2008.

Appendix 20: Nutrient management – SIX EASY STEPS nutrient management completed, *Australian Canegrower*, 27 July 2009.

Appendix 21: Example of a SIX EASY STEPS short-course workbook.

Appendix 22: Example of a PowerPoint presentation used during a SIX EASY STEPS short-course.