AN ECONOMIC ANALYSIS OF DECISION SUPPORT FOR INFORMED NITROGEN MANAGEMENT: SOIL NITROGEN MINERALISATION TESTS AND ASSESSMENT OF SOIL N CONTRIBUTION TO CROP N REQUIREMENTS

Project 2015/069

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Evaluation completed by AgTrans.

1 Introduction

The following impact assessment has been carried out using the guidelines produced by the Council of Research and Development Corporations (CRRDC, 2018).

2 Background

Fertiliser inputs in the Australian sugarcane industry had traditionally been based on a set of general recommendations which did not adequately account for the different impacts of growing region and soil types on nutrient requirements. Growers had often followed their own approaches to nutrient management, which due to the complexity of determining optimum rates, had the potential to lead to rates of fertiliser usage beyond what is economically or environmentally ideal.

In the past 20 years a more focused approach to understanding and managing the complexity of nutrient management on individual sugarcane soils and farming systems has evolved that has benefitted the Australian sugarcane industry. This new approach recognises the impact that different soils, growing conditions and farming systems have on nutrient requirements. Soil/site-specific fertiliser recommendations were identified as a means of achieving sustainable nutrient management outcomes in in an industry that is affected by fluctuating sugar prices and variable weather conditions.

Development of the approach has been driven by a number of key projects in nutrient management between the years 1999-2017. This investment resulted in the SIX EASY STEPS® program.

At the same time (since the early 2000s) increasing attention was being given to the impacts of climate change and water quality on the sustainability of the Great Barrier Reef (GBR). Sugarcane production has been identified as contributing to a decline in water quality in the GBR catchment area through nutrient and pesticide runoff. This posed a threat to the industry as it was faced with the prospect of reduced access to key fertiliser inputs and loss of social licence to operate. It was thus recognised that sustainable nutrient management required profitable sugarcane production to be achieved in combination with the maintenance of soil fertility and minimisation of off-site effects. This supported the need for updated nutrient management practices.

A range of extension activities, governance programs and smaller research, development and adoption (RD&A) projects have also contributed to the development and use of SIX EASY STEPS®. These activities were funded from numerous sources including Canegrowers, the Australian Cane Farmers Association and the NSW Sugar Milling Cooperative Ltd and were aimed at encouraging industry acceptance and increasing the levels of adoption of nutrient guidelines.

An area of knowledge that had been relatively neglected was the prediction of mineralised nitrogen (N) in the soil before fertiliser application. The then current recognition of this soil N content in SIX EASY STEPS® was based on the soil organic carbon content and included a generalised estimate of this N source.

The current project recognised that this approach would be only approximate, given that widely variable field conditions would have existed in the previous growth period, as well as different trash management histories. Also, zero N applications had not always been included in past trials and the crop-accumulated N in such trials was rarely measured.

The new approach in Project 2015/069 recognised some earlier investment in decision support for assessing soil mineralisation and then set out to develop a more robust indicator of potential in-season mineralisation in different soils and climates.

3 Project Objectives

The overall aim of the project was to develop a site- and soil-specific decision support tool that incorporated soil mineralisation potential and typical seasonal conditions to estimate the contribution of soil N mineralisation to crop N supply.

The specific objectives of the project were:

1) To apply a two-pool N model to N mineralisation data from lab and field incubation experiments undertaken on a range of representative cane soils to establish benchmark N mineralisation rate constants for soils differing in soil organic C levels, texture and clay mineralogy.
2) To correlate model estimates of the active and slow N pools with diagnostic N availability indicators including total organic C, easily oxidisable organic C, total N, C/N ratio, dissolved organic N potentially mineralizable N using aerobic and anaerobic techniques, and MIR spectral fingerprints.
3) To correlate promising diagnostic N availability indicators with the amount of N taken up by N-unfertilised sugarcane under field conditions.
4) To develop and document decision support guidelines to estimate the contribution of soil N mineralisation to the N requirements of a sugarcane crop using the diagnostic N availability indicator validated in this project.
5) To document how the estimate of soil N mineralisation can be incorporated into the SIX EASY STEPS® guidelines for calculating fertiliser N requirement.

4 Cost of Investment for Project 2015/069

Estimates of the total investment by Sugar Research Australia (SRA) and the Department of Environment and Science (DES) for the three-year project are provided in Table B1.

TABLE B1: THE COSTS OF THE INVESTMENT IN PROJECT 2015/069 (NOMINAL $)

YEAR ENDED JUNE	DES	SRA	TOTAL
2016	110,420	163,978	274,398
2017	113,897	139,990	253,887
2018	44,600	97,318	141,918
Total	268,917	401,286	670,203

Sources: (1) Contract between SRA and Queensland Department of Science Information Technology Innovation and the Arts (2) Deed effected between DES and SRA (2015-2020).

4.1 Real Investment and Extension Costs

For purposes of the investment analysis, the investment costs of all parties were expressed in 2019/20-dollar terms using the Implicit Price Deflator for Gross Domestic Product (ABS, 2020). There were expected to be some additional development, communication and extension costs associated with the modified N fertiliser decision aids produced by the project. These costs were recognised via an attribution factor as reported later in Table 7 of the quantitative analysis.

4.2 Program Management and Administration Costs

The cost of managing the investment varied according to the source of funds. Estimates of the cost of administration and management of the investment by SRA and DES were added to the total project costs currently appearing in Table B1. The management cost multipliers used were as follows:

- SRA: 1.10
- DES: 1.10

The multipliers are to accommodate the allocation of indirect Research and Development (R&D) expenditure (management and administrative resources) for each organisation across individual projects. This is to ensure the full costs of R&D funding are included as per the CRRDC Guidelines (CRRDC, 2018). The use of multipliers is an accountability item only and does not mean that any of the DES resources granted to SRA are used by SRA to fund project administration or management costs. The DES multiplier applied is to accommodate the resources DES expends in managing the Deed.

The management and administration costs for Canegrowers and others were assumed to be included already in the contributions appearing in Table B1.

5 Activities

- Representative soil samples (0-20 cm depth) of major soil types for six sugarcane districts (Mackay, Johnstone, Sarina, Herbert, Proserpine and Bundaberg) were selected from the archives of an earlier project.
- The samples were analysed for a number of characteristics including total organic carbon (C), Walkley Black organic C, easily oxidable organic C, total N, C/N ratio dissolved organic N, and Near-infrared and Mid-infrared spectral fingerprints.
- Correlations were estimated for these parameters with mineralizable N to assess their potential as diagnostic indicators.
- A selection of 15 of these soils was chosen for incubation experiments under aerobic conditions to measure net N mineralisation and carbon dioxide emissions.
- The results from these experiments were used in a two pool (active and slow) N model that related pool sizes to the soil properties identified earlier.
- Temporal changes in mineral N were measured over several months in bare plots at three sites by destructively sampling soil cores enclosed in porous plastic sleeves.
- Soil temperature and water content measures were recorded continuously, and the measured rate of N mineralisation compared with model simulations.
- The project interacted with existing programs (Paddock to Reef, Reef Water Quality Science and Action on the Ground programs) where there were plots with zero applied N; soil samples were taken at crop planting/emergence and soil N analyses correlated with crop N uptake at stalk elongation.

6 Outputs

Expected new knowledge:

- Detailed characterisation and benchmarking of the soil N mineralisation potential of major soils in several cane districts.
- Increased understanding of the key soil properties affecting soil N mineralisation rate and quantity in cane soils.

Expected decision support contribution

- Diagnostic indicators and interpretation guidelines for estimating the contribution to crop N requirements of soil N mineralisation for different soils and seasonal conditions; this information can feed directly into the SmartCane Best Management Practices via updating of the SIX EASY STEPS® fertiliser N requirement calculator.
- Updated methods for calculating fertiliser N requirements incorporated into SafeGauge for Nutrients to guide and inform improvements in N use efficiency through practice change.
- Two peer-reviewed journal articles communicating project results were published in Soil Research (Orton et al, 2019; Allen et al, 2019).
- Phil Moody provided an update to the DES Office of GBR at the completion of the project, including an approach for incorporating the information

7 Outcomes

It was expected that the decision support tools developed in the project would be thereafter built into existing N fertiliser decision aids.

For example, it was intended that the information generated in the project will be:

- Used to refine and improve the calculation of N fertiliser requirements in the SIX EASY STEPS® decision aid.
- Incorporated into the budget printout from the decision support tool SafeGauge for Nutrients where the N budget is based on the SIX EASY STEPS® fertiliser calculator, so highlighting whether the planned fertiliser N inputs meet or exceed the N requirement of the crop.

The summary in the final report suggested that decision support options would include:

- Estimating N mineralised over the longer term based upon soil total N content or soil organic C content, and/or
- Adjusting laboratory long-term N mineralisation using temperature and moisture factors to estimate N mineralised in the field over the growing season.

It was further stated that, while these factors “could be generated through simulation models using seasonal forecasting and whole-farm-systems planning, they would require calibration at the site scale. Integration of measured site data (N uptake by the crop at the nil applied N treatment and seasonal soil moisture and temperature parameters) from ongoing trials would assist this”.

Phil Moody advised Diane Allen in early calendar 2020 that the decision support options await opportunity for discussion at the SIX EASY STEPS® advisory committee, pending scheduling of a committee meeting. Also, discussions between Diane Allen and the DES Office of GBR were underway to identify the next steps (Diane Allen, pers comm., October 2020).

Project results were communicated at the Innovative Nitrogen Use in Sugarcane Forum, Cairns, Nov 2018 and at grower forums attended by Phil Moody in 2019. As yet communication material beyond the peer-review publications and final report as ‘rules of thumb’ has not been communicated, although this may have been considered by Phil Moody after project completion (Diane Allen, pers. comm., October 2020)

Pathway to impact:

It was expected that the primary target audience for the decision support tools developed would be sugarcane extension officers and advisers, with the ultimate decision makers being sugarcane growers.

8 Impacts

The potential impact from this project was expected to be an improved efficiency of N fertiliser applications by growers via more accurately estimating existing mineralised N in the soil. This was expected to result in N fertiliser cost savings for some farm areas in some years.

This potential impact referred to above has not been delivered directly by the project to date but could be expected to be delivered in the future. Further, any N fertiliser reduction would contribute also to a reduction in N export off-farm and, potentially, an associated improvement in water quality runoff to the GBR.

A summary of the principal types of likely impacts associated with the outcomes of the project is shown in Table B2.

TABLE B2: CATEGORIES OF PRINCIPAL POTENTIAL IMPACTS FROM THE INVESTMENT

ECONOMIC • Contribution to potentially higher profits for some sugarcane growers from more accurate estimation of existing and plant-usable soil nitrogen, in turn leading to cost savings and increased profits from reduced N application rates on some farm areas under specific conditions.
ENVIRONMENTAL • Potential reduction in export of fertiliser nutrients to off-farm environments, including the GBR.
SOCIAL • Spillover impacts to regional communities from increased sugarcane industry net incomes. • Increased scientific knowledge and understanding of mineralisation processes across a range of sugarcane soils and climatic conditions. • A reduced probability of a future loss in the social licence for sugarcane growing.

8.1 Public versus Private Impacts

The key potential impacts will be private, initially delivered to some sugarcane growers directly or via advisors. Some additional private impacts could be delivered to sugarcane processors via increased cane production.

Public impacts are likely to be in the form of environmental benefits from a reduced level of nitrogen entering public waterways and from regional spillovers from increased grower incomes.

8.2 Distribution of Impacts along the Supply Chain

The project is likely to have contributed to direct private productivity/profitability impacts for Australian sugarcane producers through improved NUE driven largely by reduced N fertiliser use/N savings. Secondary productivity/profitability impacts may accrue to the Australian sugarcane milling sector if, in the future, improved NUE on-farm results in increased sugarcane yields and therefore increased cane processing.

8.3 Impacts on other Primary Industries

There are not likely to be any direct impacts to other agricultural industries from the investment.

8.4 Impacts Overseas

There are no overseas impacts expected.

8.5 Match with National, State and SRA Priorities

The Australian Government's Science and Research Priorities and Rural RD&E priorities are reproduced in Table B3. The Project 2015/069 investment could potentially contribute primarily to Rural RD&E Priority 3 and to Science and Research Priorities 1 and 2.

TABLE B3: AUSTRALIAN GOVERNMENT RESEARCH PRIORITIES

AUSTRALIAN GOVERNMENT	
RURAL RD&E PRIORITIES (EST. 2015)	**SCIENCE AND RESEARCH PRIORITIES (EST. 2015)**
1) Advanced technology 2) Biosecurity 3) Soil, water and managing natural resources 4) Adoption of R&D	1) Food 2) Soil and Water 3) Transport 4) Cybersecurity 5) Energy and Resources 6) Manufacturing 7) Environmental Change 8) Health

Sources: DAWR (2015) and OCS (2016)

9 SRA Research Priorities

SRA's key focus areas are presented in Table B4. Project 2015/069 addressed KFAs 2 and 4.

TABLE B4: SRA STRATEGIC FOCUS AREAS AND DESIRED OUTCOMES

KEY FOCUS AREA (KFA)	OUTCOMES
1) Optimally adapted varieties, plant breeding and release	Increased sugarcane yield and commercial cane sugar (CCS)
2) Soil health, nutrient management and environmental sustainability	Better soil health, reduced nutrient losses and improved water quality
3) Pest, disease and weed management	Reduced or avoided yield losses and/or added input costs
4) Farming systems and harvesting	Improved farm input-output efficiencies and profitability
5) Milling efficiency and technology	Optimised production, improved capital u4lisa4on and waste minimisation
6) Product diversification and value adding	Diversified revenue streams and product innovation
7) Knowledge and technology transfer and adoption	Accelerated adoption of new technology and practice change
8) Collaboration and capability development	Enhanced industry and research capability and capacity
9) Organisational effectiveness	Increased investor satisfaction and returns on investment

Source: SRA Strategic Plan (2018)

10 Valuation of Impacts

10.1 Impacts Valued

Of the five major impacts identified in Table B2, only the first economic impact has been valued in this assessment, namely the contribution to higher profits for some sugarcane growers from more accurate estimation of N requirements.

10.2 Other Potential Impacts Identified but not Valued

The other four impacts of the five identified in Table B2 were not valued for the following reasons:

- The potential reduction in export of fertiliser N to off-farm environments, including the GBR, was not valued due to the difficulty of quantifying the reduction and its value on improving GBR health.
- Spillover impacts to regional communities from increased sugarcane industry net incomes was not valued due to the range and diversity of geographic locations involved.
- The increased scientific knowledge and understanding of mineralisation was not valued due to the lack of a clear pathway to additional benefits. However, to some extent, some of the prospective future impact of this knowledge has been valued via the first valued impact.
- A reduced probability of a future loss in the social licence for sugarcane growing was not valued due to the difficulty of identifying any clear linkages between the likely project outcomes and community views and/or government policy.

10.3 Attribution

The counterfactual assumed is that the industry changes that are anticipated would not have taken place without the funding of this project. However, an attribution factor of 25% is applied to the valued impacts due to the project. This is because of the cost of further investment required to confidently deliver appropriate information to growers; this will include further research as well as communication and extension costs required to build grower confidence and assist growers to capture the benefits.

10.4 Summary of Assumptions for Impact Valuation

The specific assumptions used in the impact valuation are provided in Table B5.

TABLE B5: SUMMARY OF ASSUMPTIONS FOR VALUING INVESTMENT IN PROJECT 2015/069

VARIABLE	ASSUMPTION	SOURCE
GENERAL		
Total Australian sugarcane area	377,000 ha	Average of past two years (2017/18 and 2018/19) (Canegrowers Annual Report, 2018/19)
Farm gate value of elemental N	$1.23 per kg	Based on urea price of $565 per tonne @46% N
Average sugarcane yield	86 tonnes per ha	Based on 2017-18 and 2018-19 years (ABARES, 2020)
Existing nitrogen fertiliser average usage	160 kg per ha	Analyst assumption
BENEFIT 1: ESTIMATE OF N COST SAVINGS MADE BY FUTURE USE OF INFORMATION ON N MINERALISATION		
Maximum sugarcane area making use of information	10%	Analyst assumptions
Nitrogen savings effected	15%	
Year of initial adoption	2024	Allows for further investment in validating and communicating
Year of maximum adoption	2028	Assumes a four-year adoption period
RISK FACTORS AND ATTRIBUTION		
Probability of Output	100%	Analyst assumption: project outputs already exist
Probability of Outcome (Usage)	75%	Analyst assumption that refers to the probability that the adoption rates above are realised

Probability of Impact (given usage)	75%	Analyst assumption that refers to the probability that the impacts assumed above will occur, given adoption occurs
Attribution to investment in Project 2015/069	25%	Analyst assumption: allows for the additional development, communication and extension costs required to assist growers capture the benefits

10.5 Results

All past costs and benefits were expressed in 2019/20-dollar terms using the Implicit Price Deflator for Gross Domestic Product (ABS, 2020). All benefits after 2019/20 were expressed in 2019/20-dollar terms. All costs and benefits were discounted to 2019/20 using a discount rate of 5%. A Re-investment rate of 5% was used for estimating the Modified Internal Rate of Return (MIRR). The base analysis used the best estimates of each variable, notwithstanding a high level of uncertainty for many of the estimates. All analyses ran for a period of 30 years after the last year of investment (2019/20).

The investment criteria are reported for the total investment, the SRA investment, and the DES investment in Table B6, Table B7 and Table B8.

TABLE B6: INVESTMENT CRITERIA FOR TOTAL INVESTMENT (DISCOUNT RATE 5%)

INVESTMENT CRITERIA	YEARS FROM LAST YEAR OF INVESTMENT						
	0	5	10	15	20	25	30
Present value of benefits ($m)	0.00	0.00	0.34	0.80	1.16	1.44	1.66
Present value of costs ($m)	0.94	0.94	0.94	0.94	0.94	0.94	0.94
Net present value ($m	-0.94	-0.94	-0.60	-0.14	0.22	0.50	0.72
Benefit-cost ratio	0.00	0.00	0.36	0.85	1.24	1.54	1.77
Internal rate of return (IRR) (%)	negative	negative	negative	3.66	6.57	7.87	8.69
Modified IRR (%)	negative	negative	negative	3.73	6.25	6.98	7.17

TABLE B7: INVESTMENT CRITERIA FOR SRA INVESTMENT (DISCOUNT RATE 5%)

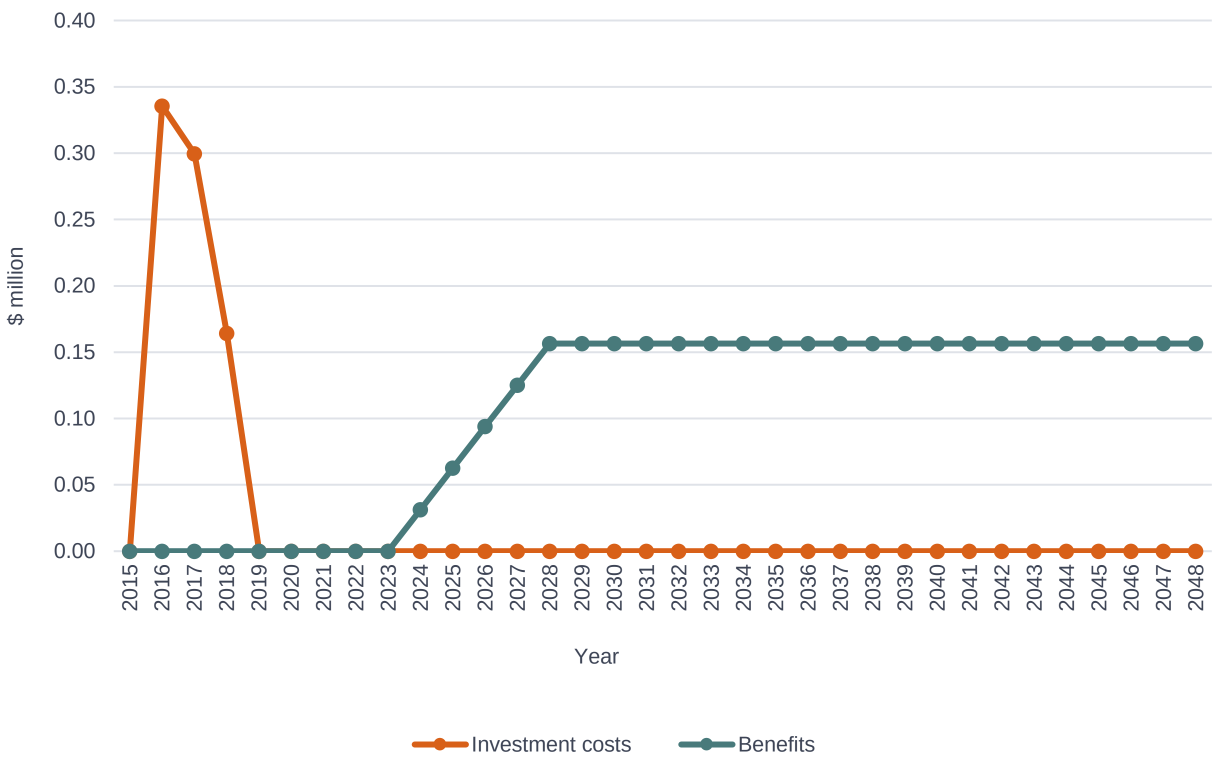
INVESTMENT CRITERIA	YEARS FROM LAST YEAR OF INVESTMENT						
	0	5	10	15	20	25	30
Present value of benefits ($m)	0.00	0.00	0.20	0.48	0.69	0.86	0.99
Present value of costs ($m)	0.24	0.56	0.56	0.56	0.56	0.56	0.56
Net present value ($m)	-0.24	-0.56	-0.36	-0.08	0.13	0.30	0.43
Benefit-cost ratio	0.00	0.00	0.36	0.85	1.24	1.54	1.78
Internal rate of return (IRR) (%)	negative	negative	negative	3.67	6.58	7.88	8.70
Modified IRR (%)	negative	negative	negative	3.74	6.25	6.99	7.18

TABLE B8: INVESTMENT CRITERIA FOR DES INVESTMENT (DISCOUNT RATE 5%)

INVESTMENT CRITERIA	YEARS FROM LAST YEAR OF INVESTMENT						
	0	5	10	15	20	25	30
Present value of benefits ($m)	0.00	0.00	0.14	0.32	0.46	0.58	0.67
Present value of costs ($m)	0.16	0.38	0.38	0.38	0.38	0.38	0.38
Net present value ($m)	-0.16	-0.38	-0.24	-0.06	0.09	0.20	0.29
Benefit-cost ratio	0.00	0.00	0.36	0.85	1.23	1.54	1.77
Internal rate of return (IRR) (%)	negative	negative	negative	3.65	6.55	7.84	8.50
Modified IRR (%)	negative	negative	negative	3.71	6.23	6.97	7.15

The annual cash flow of undiscounted benefits and costs for the total investment are shown in Figure B1.

FIGURE B1: ANNUAL CASH FLOW OF UNDISCOUNTED BENEFITS AND COSTS



10.6 Sensitivity Analyses

Sensitivity analyses were carried out for two variables and results are reported in Table B9 and Table B10. The sensitivity analyses were performed on the total investment using a 5% discount rate (with the exception of Table B9) with benefits taken over the 30-year period. All other parameters were held at their base values.

Table B9 shows there is a moderately high sensitivity to the discount rate, due to the long period of benefits assumed and the time period between the investment and the benefits.

TABLE B9: SENSITIVITY TO DISCOUNT RATE (TOTAL INVESTMENT, 30 YEARS)

CRITERION	DISCOUNT RATE		
	0%	BASE (5%)	10%
Present value of benefits ($m)	3.60	1.66	0.87
Present value of costs ($m)	0.80	0.94	1.09
Net present value ($m)	2.80	0.72	-0.22
Benefit-cost ratio	4.50	1.77	0.80

Table B10 provides the sensitivity of the investment criteria to the assumed attribution of Project 2015/069 to the impact assumed. The results show a high sensitivity to this assumption that indirectly represents the time and resources likely to be required to deliver the impact assumed from the knowledge produced in Project 2015/069. The attribution factor for the investment to break even was 14.1%.

TABLE B10: SENSITIVITY TO ATTRIBUTION OF THE IMPACT TO PROJECT 2015/069 (TOTAL INVESTMENT, 5% DISCOUNT RATE, 30 YEARS)

CRITERION	ASSUMED ATTRIBUTION OF IMPACT TO PROJECT 2015/069		
	PESSIMISTIC (12.5%)	BASE (25%)	OPTIMISTIC (50%)
Present value of benefits ($m)	0.83	1.66	3.32
Present value of costs ($m)	0.94	0.94	0.94
Net present value ($m)	-0.11	0.72	2.38
Benefit-cost ratio	0.89	1.77	3.55

11 Conclusions

The project is likely to have contributed to direct private productivity/profitability impacts for Australian sugarcane producers through improved NUE driven largely by reduced N fertiliser use/N savings. Secondary productivity/profitability impacts may accrue to the Australian sugarcane milling sector if, in the future, improved NUE on-farm results in increased sugarcane yields and therefore increased cane processing.

Given the assumptions made, the investment criteria estimated for total investment in the project of $0.94 million (present value of costs) were positive with an expected present value of benefits of $1.66 million, an expected net present value estimated at $0.72 million and an expected benefit-cost ratio of 1.77 to 1. The internal rate of return was estimated at 8.7% and the modified internal rate of return at 7.2%.

For the SRA investment, the investment of $0.56 million provided an expected present value of benefits of $0.99 million with rates of return similar to those for the total investment. For the DES investment, the investment of $0.38 million gave an expected present value of benefits of $0.67 million and expected rates of return similar to those for the total investment.

All investment criteria were estimated using a discount rate of 5% and with benefits estimated over 30 years from the final year of investment.

The quantitative analysis relied on assumptions regarding the contribution of the project outputs to decision support options that could become available to growers in the future. While best-bet estimates for the likely future usage and impacts have been made, there is still considerable linkage development required to translate the project findings to the individual site scale. This has been allowed for in the economic analysis by an attribution factor that assumes there will still be further investment and time required to capture the potential benefits emanating from the project.

Also, as described earlier, four impacts of the project investment that were identified were not valued in the monetary analysis. Hence, the magnitude of the investment criteria estimated and reported are likely to be underestimated.

12 Acknowledgments

Diane Allen, Landscape Sciences, Department of Environment and Science, Queensland Government

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