AN ECONOMIC ANALYSIS OF SPATIALLY EXPLICIT ESTIMATION OF ACHIEVABLE YIELD POTENTIAL – AN IMPROVED BASIS FOR FERTILIZER MANAGEMENT

Project 2015/070

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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

A previous large 7-year project (SRA Project CSE 022) had made a significant contribution towards development of zonal management capability in the Australian sugarcane industry. CSE 022 provided:

- An important 'reality check' on yield monitoring developments that were underway in the industry at the time of project commencement (2009), by identifying inaccuracies in the yield maps being produced by the industry.
- Considerable progress in developing yield mapping and zonal management equipment, processes and protocols for the industry.
- Exposure to growers of the nature of variability of land resources, the need for growers to manage farm inputs spatially, and an increased industry awareness and capacity to adopt spatial management technologies to increase profitability and maintain sustainable production into the future.

Effective use of precision agriculture (PA) addresses inherent variability in sugarcane areas by delivering efficient rates of inputs (e.g. fertiliser) to segments of sugarcane areas. However, current fertiliser rate applications are generally based on SIX EASY STEPS® (SES) protocols that rely on yield potential estimated at a much broader regional scale and do not address differences in rainfall and soil types within regions.

A large Herbert Cane Productivity Services Ltd (HCPSL) effort, focused on yield monitoring and mapping in the Herbert Region, had generated a valuable database of georeferenced yield data. Analysis of such data could address yield variation at different spatial scales and, along with the results of other projects (e.g. SRA project 2014/028, SRDC Project DPI 021), potentially provide information to deliver potential benefits via improved application of PA methods.

The current project (SRA 2015/070) set out to re-analyse the data collected by HCPSL and generate robust multi-year yield maps to be generated for areas within sugarcane fields, whole fields or blocks, farms, and subdistricts. The results of such analyses were seen as having significant implications for PA and delivering efficient inputs to sugarcane production for use in applications such as SES.

3 Project Objectives

The original objectives of the project included:

- In partnership with HCPSL, select data from a small number of harvester groups in the HCPSL database which:
  - used the TechAgro/Solinftec yield monitor during the yield monitoring project,
  - represent contrasting Herbert soils,
  - represent differing annual rainfall, and
  - have good mill records of harvest events.
- Re-analyse these data to enable robust yield maps to be produced at the block, farm and group scale along with estimates of the yield variation measured by the data at these scales.
- Identify management zones, as appropriate, at the within block scale and the magnitude of yield differences between these.
- Use the results to generate estimates of yield potential (YP) at these different scales, the associated recommended nitrogen (N) rates (based on SIX EASY STEPS®) and use these to quantify the error associated with regional estimates of YP for all years for which data are available and the consequences of this error for N management.
- Produce a protocol for scale appropriate YP estimation based on the methods here, for implementation in other districts, including documentation of data input requirements.

However, the main focus of the project turned out to be on within-district yield variation, due to data availability and inconsistency at the within-farm and within-block scales.

4 Cost of Investment for Project 2015/070

Estimates of the total investment for the three-year project by SRA, DES, and CSIRO/ HCPSL are provided in Table C1.

TABLE C1: THE COSTS OF THE INVESTMENT IN PROJECT 2015/070 (NOMINAL $)

YEAR ENDED JUNE	DES	SRA	CSIRO AND HCPSL	TOTAL
2016	29,106	17,112	97,184	143,402
2017	89,321	52,510	100,294	242,125
2018	14,464	8,503	0	22,967
Total	132,891	78,125	197,478	408,494

Sources: (1) Contract between SRA and CSIRO; (2) Deed effected between Queensland Department of Environment and Science and Sugar Research Australia (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 no additional extension costs associated with the project. The project was undertaken in close cooperation with the HCPSL so a pathway to adoption of the project findings was already established by the project investment.

4.2 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 all parties were added to the total project costs currently appearing in Table C1. The management cost multipliers used were as follows:

- SRA: 1.10
- DES: 1.10

The multipliers are to accommodate the allocation of indirect 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 multipliers for CSIRO/HPSCL were set at 1.0 as it was assumed management and administrative costs were already included in the Table C1 figures.

5 Activities

- The project was focused on the Herbert River district and explored finer-scale alternatives to the use of district YP as inputs to the use of SES.
- Data for exploring these alternatives included spatial analysis of mill records over seven seasons, as well as spatial data and yield maps collected using yield monitors.
- Differences in maximum YP by zone, block, farm and harvester groups across a number of years were estimated from the data, wherever possible.
- Differences between maximum YP at these different scales and the district YP as used in SES were examined.
- Measures of how fertiliser N management may differ if zone, block, farm or district YP were estimated.
- An important aspect of project activity was the provision of the factory and other data held by Wilmar Sugar.
- A protocol was developed for the determination of such spatial differences that could be applied in other sugarcane growing districts.

6 Outputs

- It was found that the use of a district YP is inappropriate for determining N fertiliser application levels; this was because it was found that potential yield is highly spatially variable at the within-district scale; further, the patterns of yield variation are highly stable from year to year in the Herbert River district.
- Hence, the use of location-specific estimates of YP, such as the block YP, should be used in preference to district YP as is currently the case. Such a practice change could lead to a significant saving in N fertiliser costs and a reduction in the quantity of N exported off-site.
- A block YP derived from a map of the maximum yield of first ratoon achieved over the seven seasons was suggested.
- Also, growers with access to yield mapping could readily adopt a similar means of estimating YP at the within-farm or within-field scale.
- In addition, further location-specific refinement of the application of SES was suggested as possible, with access to data on soil carbon content derived from regional soil surveys or local soil testing.
- The spatial protocols developed in the project could be applied in other sugarcane growing regions in order to maximise N use efficiency.
- A number of journal publications and other communication messages were produced, including industry publications, videos and addresses at industry forums.

- The project team also was in close communication with Wilmar Sugar who control all milling operations in the Herbert. In addition, the project was presented on two occasions to workshop meetings convened by the Queensland Department of Environment and Heritage Protection, both of which were attended by the Canegrowers organisation.
- The project and the findings were presented to the 2017 (Cairns) conference of the Australian Society of Sugar Cane Technologists (ASSCT) and the paper was awarded the ASSCT President's Medal – Research.

7 Outcomes

- The project data have revealed that the 'productivity zones' used by HCPSL for agronomic advice and extension did not equate to the actual regional productivity zones (Rob Bramley, pers. comm., 2018).
- The principal potential industry outcome of the project investment has been that some growers in the Herbert River district could change from using a district YP for their N fertiliser decisions to one of a block YP, or a subdistrict YP.
- However, there is no hard evidence available currently to demonstrate that the project has resulted in changed spatial N strategies by growers with either using subdistrict productivity maps or farm level zonal/block information (Lawrence di Bella, pers. comm., 2018, and confirmed in 2020.)
- One of the issues affecting the use of the subdistrict yield maps was a legal dispute between HCPSL and Wilmar Sugar as to who owns the data.
- The dispute has now been resolved in part and growers now have access to the subdistrict yield maps on request (Lawrence di Bella, pers. comm., 2020).
- HCPSL has modified its productivity zones accordingly; however, new SRA research undertaken by Dr Danielle Skocaj may modify these zones further (Lawrence di Bella, pers. comm., 2020).
- The first outcome has been some adoption of subdistrict yield maps; zonal data is now gaining some use in some parts of the district, especially in areas where there are sodic and saline soils (Lawrence di Bella, pers. comm., 2020).
- The use of the HCPSL Dual EM (an electromagnetic sensor) is driving this (Lawrence di Bella, pers. comm., 2020); this has allowed the local industry to map soils and aid the implementation of PA practices.
- A further potential outcome is that the spatial protocols developed in Project 2015/070 may be adopted in other sugarcane growing regions in order to maximise N use efficiency.

8 Impacts

The potential impact from this project was originally expected to be improved efficiency of nitrogen fertiliser management in the Herbert sugarcane region. This could be delivered by:

- N fertiliser cost savings for some farm areas
- Increased sugarcane yields for some farm areas

However, there is no evidence of N fertiliser cost savings to date but there has been some potential sugarcane yield increases on some farms that have adopted new systems approaches (Lawrence di Bella, pers. comm., 2020).

There is also the possibility that that changes in spatial variation of N application may be used to increase sugarcane yields in high performing areas that have been identified as performing well above the district average. However, limited change has occurred in these areas largely due to the potential increased N leading to commercial cane sugar (CCS) decreases.

A summary of the principal types of impacts or potential impacts associated with the outcomes of the project is shown in Table C2.

TABLE C2: CATEGORIES OF PRINCIPAL POTENTIAL IMPACTS FROM THE INVESTMENT

ECONOMIC • Potential for higher profits for Herbert sugarcane growers from spatial management-driven N fertiliser rate applications • Increased sugarcane yields and increased profits for some farm areas that have applied new systems approaches. • Contribution to an increased use of PA used for other purposes in the Herbert cane growing district. • Potential development of improved spatial management of N fertiliser in other sugarcane growing districts.
ENVIRONMENTAL • Nil
SOCIAL • Spillover impacts to regional communities from increased sugar industry net incomes.

8.1 Public versus Private Impacts

The key potential impacts will be private, initially delivered to some sugarcane growers in the Herbert, and potentially in the future in other districts. Some additional impacts could be delivered to sugarcane factories via increased cane production.

Public impacts are likely to be minimal 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 increased sugarcane yields from spatial management-driven N practices.

Higher sugarcane yields also may lead to secondary productivity/profitability impacts for the Australian sugarcane milling sector through increased cane processing. However, such impacts have not yet eventuated. Further, quantification of impacts to the milling sector will depend not only on the increased yields (where realised by growers) but also on the value of any additional bagasse to the individual factory. This value depends on the bagasse balance in the factory and the capacity of the factory to generate additional steam and electricity above its own internal demand (Kent, 2007).

8.3 Impacts on other Primary Industries

There are not likely to be any direct impacts to other agricultural industries from the investment. Manufacturers of PA equipment may benefit if the project results in increased investment in PA by Herbert district growers and potentially by canegrowers in other districts.

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 C3. The Project 2015/070 investment could potentially contribute primarily to Rural RD&E Priority 3 and 4 and to Science and Research Priorities 1 and 2.

TABLE C3: 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	5) Food 6) Soil and Water 7) Transport 8) Cybersecurity 9) Energy and Resources 10) Manufacturing 11) Environmental Change 12) Health

Sources: DAWR (2015) and OCS (2016)

9 SRA Research Priorities

SRA's key focus areas are presented in Table C4. Project 2015/070 addressed KFAs 2 and 4, with some contribution to KFA 7.

TABLE C4: SRA STRATEGIC FOCUS AREAS AND DESIRED OUTCOMES

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

Source: SRA Strategic Plan (2018)

10 Valuation of Impacts

10.1 Counterfactual

The counterfactual assumed is that the industry changes anticipated would not have taken place without the funding of this project.

10.2 Impact Valued

Of the five impacts and potential impacts identified in Table C2, only one impact has been valued in this assessment:

- Increased sugarcane yields for some farm areas that have applied new spatial systems approaches.

10.3 Other Potential Impacts Identified but not Valued

- Potential cost savings and increased profits from reduced N application rates applied to some farm areas from both subdistrict yield maps as well as from within block or within farm scales. Any N fertiliser reduction is expected to be firstly driven by the subdistrict yield maps and, secondly, within farms when a more robust and readily commercially available approach to yield mapping on farm is readily available (Rob Bramley, pers. comm., 2018).
- The reduction in export of fertiliser nutrients to off-farm environments; this potential impact will be delivered when, and if, the N fertiliser reduction occurs.
- An increased use of PA in the Herbert cane growing district.
- The potential development of improved spatial management of N fertiliser in other sugarcane growing districts.
- An increased level of regional income spillovers.

The first two impacts above were not valued due to a lack of current evidence of a linkage between the project investment and any reduction in N fertiliser usage. The other three impacts of the five above were not valued due to the difficulty of making sound linkage assumptions between the project and the impact, as well as time and resource limitations.

10.4 Attribution

As noted earlier, other projects have contributed to the impacts assumed to be delivered by SRA Project 2015/070; such projects include SRA Project CSE 002, SRA Project 2014/028, and SRDC Project DPI 021. As it is difficult to develop specific contributions to these enabling investments, their contributions have been acknowledged by the application of an attribution factor of 75% to the impact valued in the assessment of 2015/070.

10.5 Summary of Assumptions

A summary of the key assumptions made is shown in Table C5.

TABLE C5: SUMMARY OF ASSUMPTIONS

VARIABLE	ASSUMPTION	SOURCE
GENERAL		
Total sugarcane area in Herbert River Mill Region	57,061 ha	Average of past two years (Canegrowers Annual Report, 2018/19)
District yield potential	120 tonnes cane per ha	SRA Nutrient Management Guidelines for Herbert District (SRA,2018)
BENEFIT 1: INCREASED SUGARCANE YIELD		
Additional sugarcane yield produced	20%	Analyst assumption

Estimated maximum proportion of Herbert cane area using yield mapping and zonal management	20%	Analyst assumption: assumed to be a function of the proportion of growers adopting some form of yield mapping and improved zonal management and the average area on each farm to which the zonal management applies
Marginal value of additional sugarcane after harvesting costs and transport	$26 per tonne	Analyst assumption
Year of first adoption due to project	2019	
Maximum year of adoption	2021	
RISK FACTORS		
Probability of Output	100%	Analyst assumption: project outputs already exist
Probability of Outcome (Usage)	90%	Analyst assumption; some form of zonal systems management by a small proportion of Herbert River canegrowers
Probability of Impact	100%	Analyst assumption given usage by a small proportion of growers, yield impact is already being demonstrated (Lawrence di Bella, pers. comm., 2020)
ATTRIBUTION		
Past projects	25%	Analyst assumption
Current project	75%	

10.6 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 2017/18 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 (2017/18).

The investment criteria are reported for the total investment, the SRA investment, and the DES investment in Table C6, Table C7 and Table C8.

TABLE C6: 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 ($m)	0.00	0.15	0.30	0.42	0.51	0.58	0.64
Present value of costs ($m)	0.57	0.57	0.57	0.57	0.57	0.57	0.57
Net present value ($m)	-0.57	-0.42	-0.27	-0.16	-0.06	0.01	0.07
Benefit-cost ratio	0.00	0.26	0.52	0.73	0.89	1.02	1.11
Internal rate of return (IRR) (%)	negative	negative	negative	1.48	3.89	5.13	5.83
Modified IRR (%)	negative	negative	negative	1.67	3.84	4.85	5.16

TABLE C7: INVESTMENT CRITERIA FOR SRA INVESTMENT (DISCOUNT RATE 5%)

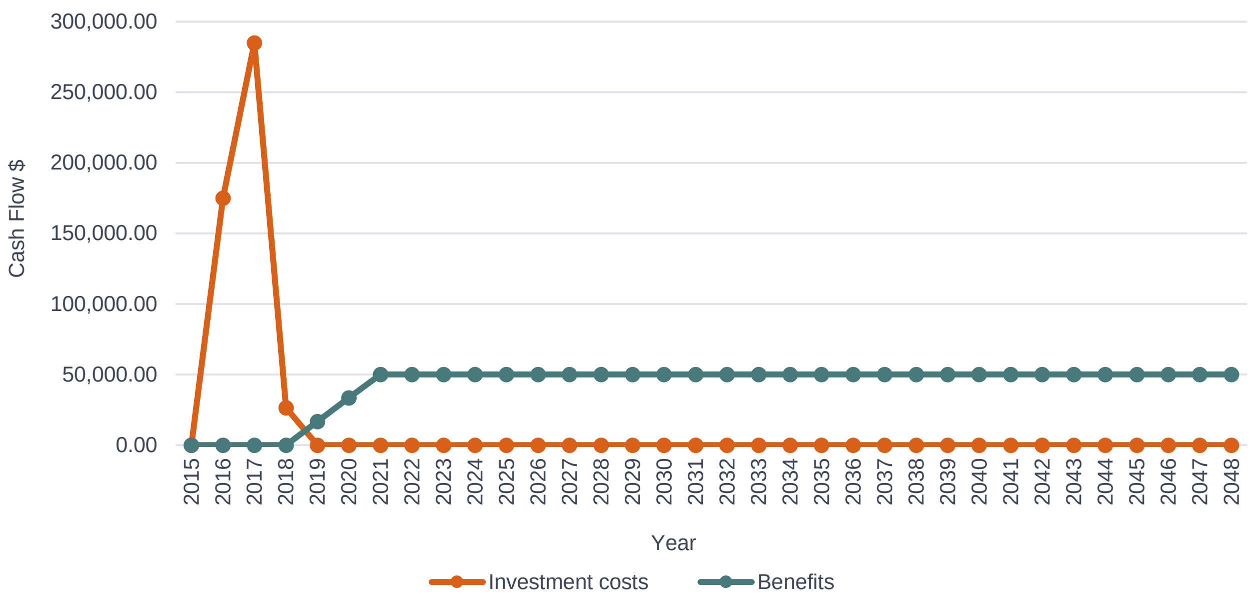
INVESTMENT CRITERIA	YEARS FROM LAST YEAR OF INVESTMENT						
	0	5	10	15	20	25	30
Present value of benefits ($m)	0.00	0.03	0.06	0.08	0.10	0.11	0.12
Present value of costs ($m)	0.03	0.11	0.11	0.11	0.11	0.11	0.11
Net present value ($m)	-0.03	-0.08	-0.05	-0.03	-0.01	0.00	0.01
Benefit-cost ratio	0.00	0.26	0.53	0.74	0.90	1.02	1.12
Internal rate of return (IRR) (%)	negative	negative	negative	1.51	3.96	5.21	5.92
Modified IRR (%)	negative	negative	negative	2.56	4.37	5.20	5.42

TABLE C8: 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 ($m)	0.00	0.05	0.10	0.13	0.16	0.19	0.21
Present value of costs ($m)	0.04	0.18	0.18	0.18	0.18	0.18	0.18
Net present value ($m)	-0.04	-0.13	-0.09	-0.05	-0.02	0.00	0.02
Benefit-cost ratio	0.00	0.26	0.53	0.74	0.90	1.02	1.12
Internal rate of return (IRR) (%)	negative	negative	negative	1.51	3.96	5.21	5.92
Modified IRR (%)	negative	negative	negative	2.56	4.37	5.20	5.44

The annual cash flow of undiscounted benefits and costs for the total investment are shown in Figure C1.

FIGURE C1: ANNUAL CASH FLOW OF UNDISCOUNTED BENEFITS AND COSTS



10.7 Sensitivity Analyses

Sensitivity analyses were carried out for several variables and results are reported in Table C9 and Table C10. All sensitivity analyses were performed on the total investment using a 5% discount rate (with the exception of Table C9) with benefits taken over the 30-year period. All other parameters were held at their base values.

Table C9 shows there is a high sensitivity to the discount rate, partly due to the long period of benefits assumed.

TABLE C9: SENSITIVITY TO DISCOUNT RATE (TOTAL INVESTMENT, 30 YEARS)

CRITERION	DISCOUNT RATE		
	0%	BASE (5%)	10%
Present value of benefits ($m)	1.16	0.64	0.41
Present value of costs ($m)	0.49	0.57	0.67
Net present value ($m)	0.67	0.07	-0.25
Benefit-cost ratio	2.39	1.11	0.62

Table C10 provides the sensitivity of the investment criteria to the assumed yield increase assumed for some growers.

TABLE C10: SENSITIVITY TO SUGARCANE YIELD INCREASE ASSUMED FOR ADOPTING GROWERS (TOTAL INVESTMENT, 5% DISCOUNT RATE, 30 YEARS)

CRITERION	MAXIMUM YIELD INCREASE ASSUMED FOR ADOPTING GROWERS		
	PESSIMISTIC (15%)	BASE (20%)	OPTIMISTIC (25%)
Present value of benefits ($m)	0.48	0.64	0.80
Present value of costs ($m)	0.57	0.57	0.57
Net present value ($m)	-0.09	0.07	0.22
Benefit-cost ratio	0.84	1.11	1.39

11 Conclusions

The project is likely to have contributed to direct private productivity/profitability impacts for Australian sugarcane producers through increased sugarcane yields from spatial management-driven N practices. Higher sugarcane yields also may lead to secondary productivity/profitability impacts for the Australian sugarcane milling sector through increased cane processing. However, such impacts have not yet eventuated. Further, quantification of impacts to the milling sector will depend not only on the increased yields (where realised by growers) but also on the value of bagasse.

Given the assumptions made, the investment criteria estimated for total investment in the project of $0.57 million (present value of costs) were positive with an expected present value of benefits of $0.64 million, an expected net present value estimated at $0.07 million and an expected benefit-cost ratio of 1.11 to 1. The internal rate of return was estimated at 5.9% and the modified internal rate of return at 5.4%.

For the SRA investment, the investment of $0.11 million provided an expected present value of benefits estimate of $0.12 million and an expected benefit-cost ratio of 1.12 to 1 with rates of return similar to those for the total investment,

For the DES investment, the investment of $0.18 million gave an expected present value of benefits of $0.21 million and an expected benefit-cost ratio of 1.12 to 1, again with 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.

As several impacts identified were not valued, the magnitude of the investment criteria estimated and reported are likely to be underestimates. In addition, the project has contributed to future projects that are likely to further improve precision management of inputs by growers.

12 Acknowledgments

Rob Bramley, Senior Principal Research Scientist, CSIRO

Lawrence di Bella, Manager, Herbert Cane Productivity Services Limited

Michael O'Shea, Sugar Research Australia

13 References

Australian Bureau of Statistics. (2020, September 2). 5206.0 – Australian National Accounts: National Income, Expenditure and Product, Jun 2020. Table 5. Expenditure on Gross Domestic Product (GDP), Implicit price deflators. Retrieved from Australian Bureau of Statistics: https://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/5206.0Jun%202020?OpenDocument

Bramley R (2017) Final Report for Project 2015/070, Accessed August 2018 at https://elibrary.sugarresearch.com.au/handle/11079/16862

Canegrowers Annual Report. (2018/19). Retrieved from: http://www.canegrowers.com.au/icms_docs/310857_canegrowers-annual-report-2018-19.pdf

Council of Rural Research and Development Corporations (CRRDC). (2018). Cross-RDC Impact Assessment Program: Guidelines. Canberra: Council of Rural Research and Development Corporations. Retrieved from http://www.ruralrdc.com.au/wp-content/uploads/2018/08/201804_RDC-IA-Guidelines-V.2.pdf

DAWR 2015, Rural Research and Development Priorities, Department of Agriculture and Water Resources, Canberra, ACT, accessed January 2016, http://www.agriculture.gov.au/ag-farm-food/innovation/priorities

Kent, Geoffrey (2007) The value of bagasse to an Australian raw sugar factory. In Bruce, R. C. (Ed.) 29th Annual Conference of the Australian Society of Sugar Cane Technologists, 8-11 May 2007, Cairns, Queensland, Australia.

OCS 2016, Science and Research Priorities, Office of the Chief Scientist, Department of Industry, Innovation and Science, Canberra, accessed 02 Nov 16, http://science.gov.au/scienceGov/ScienceAndResearchPriorities/Pages/default.aspx

SRA (2017) SRA Strategic Plan 2017/18 − 2021/22 Accessed August 2018 at: https://sugarresearch.com.au/wp-content/uploads/2017/09/Strategic-Plan-2017-_FINAL.pdf

SRA (2018) SRA Nutrient Management Guidelines for Herbert District, Accessed August 2018 at https://sugarresearch.com.au/wp-content/uploads/2017/02/SIX-EASY-STEPS-Nutrient-Guidelines-for-HERBERT.pdf

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