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Economic evaluation of sugarcane harvesting best practice (HBP)

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Abstract Mechanical sugarcane harvesting is commonly undertaken at ground speeds that exceed the cleaning capacity of modern harvesters, which is likely to increase extraneous matter (EM) levels in the cane supply. To attempt to reduce the higher EM levels, operators typically increase extractor fan speeds above recommendations, resulting in unintended cane loss. Past research indicates that using harvesting best practice (HBP) settings can minimise cane loss and stool damage. These benefits would increase grower revenue and be an incentive for growers to request harvesting contractors operate using HBP settings. Reduced ground speeds would, however, increase harvesting time and generate higher costs per hectare. The key issue remains as to whether the increased grower revenues outweigh the additional harvesting costs. Nine replicated and randomised trials undertaken by Sugar Research Australia in 2017 compared harvesting performance when using both conventional and HBP settings through identifying production and grower revenue differences. Detailed information was collected from each harvesting operation to identify harvesting costs under both conventional practice and HBP. This allowed the net benefit for the grower and harvesting operation from using HBP settings to be determined. On average over the nine trials, recommended harvesting settings generated more grower revenue than the added harvesting costs from reducing ground speeds and generated a net economic benefit of $163/ha (or $1.97/t). The trials show that, while growers would need to pay additional compensation for cane harvested using HBP settings, the compensation would be less than the additional revenue they received, increasing overall grower profitability.

Key words Harvesting best practice, profitability, cane loss, economics, harvesting costs

INTRODUCTION

Cane loss, sugar loss and stool damage due to mechanical harvesting practices are widespread problems for the Australian sugarcane industry. Sugarcane harvesters are frequently operating at high ground speeds, delivering an excessive amount of cane and extraneous matter (EM) to the harvester feed train. This in turn overloads the cleaning capacity of the harvester and increases the EM level of the cane being supplied (Whiteing *et al.* 2002; Sugar Research Australia 2014). To offset this problem, it is common practice for operators to increase the primary extractor-fan speed in order to extract more EM. However, this results in cane billets being removed unintentionally from the cane supply. These cane losses go unnoticed as they are not visible to the operator or grower, given that the lost cane is broken down by the extractor fan.

Research has identified that using HBP settings can minimise cane loss and stool damage, increasing the amount of revenue obtained by growers and the wider industry. However, using HBP settings generally entails reducing ground speeds below those commonly used by industry, which increases the amount of time spent harvesting and, in turn, increases harvesting costs per hectare. The key issue for growers and industry is how these higher revenues compare against the additional harvesting costs, and whether there is sufficient benefit to encourage HBP adoption.

Past research has examined the additional revenue obtainable by adopting HBP (Agnew *et al.* 2002; Sugar Research Australia 2014), and previous models have been developed to estimate changes in harvesting costs (Ridge and Powell 1998; Antony *et al.* 2003; Sandell and Prestwidge 2004). However, there has been limited research that has evaluated the full harvesting cost implications (e.g. the full array of costs including depreciation, R&M, fuel, etc.) of HBP adoption on a broad scale (across multiple sites) using detailed harvesting cost information specific to each harvesting contractor (Nothard *et al.* 2019).

Here, we build upon this methodology by quantifying both the harvesting costs and additional revenue from nine replicated harvesting trials to evaluate the net economic benefit from using harvester ground and fan speeds recommended (based on HBP) by Sugar Research Australia Limited (SRA).

MATERIALS AND METHODS

To calculate the additional revenue from using HBP settings, we use data from nine replicated (and randomised) harvesting trials undertaken by SRA during the 2017 harvesting season in the Southern, Central and North Queensland sugarcane growing regions. The harvesting trials compared up to four different ground and fan speed settings, but we focus on the two key settings: (1) the harvesting contractor's standard settings, and; (2) the settings recommended by SRA based on past research findings into HBP. The two settings not examined in detail were not considered commercially practical and were: (1) more aggressive settings than the contactor's chosen settings, and; (2) a control treatment with low ground and fan speeds. For each of the nine trials, production results were collected from the respective mills to determine yields and commercial cane sugar (CCS) levels for the contractor's standard settings along with the recommended settings. These cane yields and CCS results were then used along with the cane-payment formula, respective mill constant and five-year average sugar price ($424/t) to calculate grower revenue, from which levies were subtracted.

For each of the nine trials, detailed harvesting and haulage costs were collected from the contractor that undertook the trial to evaluate the harvesting costs for the harvester settings recommended by SRA and the contractor's standard harvester settings (Nothard *et al.* 2019). Harvesting contractors provided detailed information for the cost analysis including: in-season and pre-season wages; harvester and haulout depreciation and interest; repairs and maintenance costs; fuel costs; overhead costs; and district allowances. This information was then used to model the costs for each harvester setting to determine the total difference in costs. Nothard *et al.* (2019) provided a complete breakdown of these costs and identify marginal cost changes with a shift to HBP settings. Both the harvesting trials and harvesting cost evaluations formed part of a project titled 'Enhancing the sugar industry value chain by addressing mechanical harvest losses through research, technology and adoption', which received funding from the Australian Government's 'Rural Research and Development (R&D) for Profit' program.

We evaluate the net economic benefit from using HBP settings instead of the contractor's standard settings at the nine trial sites. It is calculated by subtracting the difference in harvesting costs from the difference in grower revenue (net benefit = Δ grower revenue – Δ harvesting costs). The net benefit is confined to the grower and harvesting operation and only considers changes in grower revenue and harvesting and transport costs up to the siding or pad (including levies and allowances). Our analysis does not consider the benefits and costs for the whole supply chain (e.g. mill).

RESULTS

Table 1 shows the difference in ground speeds, primary extractor-fan speeds and elevator pour rates between the contractor's standard harvester settings and the recommended settings for each of the nine trials. On average across the nine trials, average ground and primary extractor fan speeds were 1 km/h and 69 rpm lower for the recommended practice.

Table 2 shows the cane yields and grower revenue obtained by each setting together with the corresponding harvesting costs. Harvested yields, grower revenue and harvesting costs were higher for the recommended treatment at every site except for South 2.

Table 3 highlights the differences in cane yield, grower revenue and harvesting costs and shows the overall net economic benefit to growers and harvesting operations. On average across the nine trial sites, harvested cane yield was 6 t cane/ha higher (+6.7%) when using the recommended settings instead of the harvesting contractor's standard settings. Furthermore, grower revenue increased by between –$109/ha and $627/ha amongst the trials and was on average $224/ha higher. Harvesting costs also consistently increased amongst the trials by between $11/ha and $101/ha with an average increase of $61/ha. Subtracting the additional harvesting costs from the additional grower revenue gave an average net economic benefit of $163/ha or $1.97/t of cane from using the recommended harvesting settings. Over the nine trials, the net benefit ranged between –$138/ha and $572/ha or –$1.10 and $8.19 per tonne.

Table 1. Target and average ground speeds, fan speeds and elevator pour rates for the standard and recommended settings.

Trial	Standard harvester settings				Recommended harvester settings			
	Ground speed		Fan	Pour	Ground speed		Fan	Pour
	Target, km/h	Average*, km/h	speed, rpm	rate, t/hr	Target, km/h	Average*, km/h	speed, rpm	rate, t/hr
South 1	6.5	5	700	102	4	3.7	700	82
South 2	5	4.6	800	105	4	3.9	700	88
South 3	7	6.1	850	87	5	4.9	700	76
South 4	6.5	5.7	800	106	5	4.7	700	91
Central 1	5	4.7	830	79	4	3.8	700	76
North 1	5	4.8	720	87	4	4	680	78
North 2	6	5.7	700	84	4.5	4.6	700	73
North 3	5.5	3.9	700	75	5.5	3.9	600	78
North 4	6	5.6	700	103	4	4	700	75
Average	5.8	5.2	756	92	4.4	4.2	687	80

* Actual average harvester ground speed measured with GPS.

Table 2. Mean harvested cane yields, grower revenue and harvesting costs for the standard (Stand.) and recommended (Recom.) settings.

Trial	Mean harvested cane yield, t cane/ha		Mean grower revenue*, $/ha		Harvesting costs**, $/ha	
	Stand.	Recom.	Stand.	Recom.	Stand.	Recom.
South 1	110	121	$3,823	$4,157	$791	$892
South 2	125	124	$4,312	$4,203	$887	$916
South 3	80	86	$2,794	$3,034	$604	$676
South 4	114	118	$4,573	$4,727	$756	$806
Central 1	70	83	$2,859	$3,486	$589	$644
North 1	97	103	$3,785	$3,996	$979	$1,049
North 2	90	98	$2,964	$3,275	$838	$907
North 3	101	106	$3,842	$3,996	$864	$875
North 4	97	97	$4,120	$4,212	$717	$812
Average	98	104	$3,675	$3,899	$781	$842

* Less levies, ** Total harvesting costs less allowances.

Table 3. Observed differences in mean harvested cane yield, grower revenue and harvesting costs and the net benefit from using recommended harvesting settings.

Trial	Additional cane yield, t/ha	Additional grower revenue, $/ha	Additional harvesting costs, $/ha	Additional grower revenue less harvesting costs (net benefit)	
				$/ha	$/t cane
South 1	10.8	$334	$101	$233	$2.11
South 2	–0.9	–$109	$29	–$138	–$1.10
South 3	6.6	$241	$72	$169	$2.12
South 4	3.9	$153	$50	$104	$0.91
Central 1	13	$627	$54	$572	$8.19
North 1	6.8	$212	$70	$141	$1.46
North 2	8.1	$311	$69	$242	$2.69
North 3	5.1	$155	$11	$144	$1.43
North 4	0.2	$92	$95	–$3	–$0.04
Average	6.0	$224	$61	$163	$1.97

DISCUSSION

The additional cane yield harvested when using the recommended settings at the nine trial sites indicates that lower ground speeds (–1 km/h), fan speeds (–69 rpm) and pour rates (–12 t/hr) reduced sugar loss and increased the amount of cane being delivered to the mill. Grower revenue increased on average by $224/ha when using the recommended settings. These grower-revenue findings correspond fairly well but are slightly higher than results from all the harvesting trials undertaken in 2017 as part of the project. Results from an analysis of all the trials identified that using recommended settings delivered a statistically significant reduction in sugar loss and increase in harvested cane yield of 5 t cane/ha (5.4%) and grower revenue of $220/ha (5.9%) (Patane *et al.* 2019).

Across the nine trials that we examined, harvesting costs increased by an average of $61/ha due to reduced ground speeds and longer harvesting times per hectare. The higher harvesting costs per hectare were driven by increased harvester and haulout depreciation costs, fuel costs and in-season wages. Interestingly, due to the reduced cane loss and increased tonnages of cane delivered per hectare, average harvesting costs per tonne increased only marginally. Nothard *et al.* (2019) identified that harvesting costs per tonne increased on average by 10 c/t across the nine trials but this figure jumped to 21 c/t when analysed using a 5.4% yield improvement[1] for each trial. Importantly, per tonne costs varied considerably among trials due to the difference in yield improvements (–0.7% to 18.6%).

On average, our findings identified that using the recommended settings generated more grower revenue than the added harvesting costs from reducing ground speeds. The net economic benefit was $163/ha across the nine trials on average. The net benefit was also calculated for a control and aggressive treatment. The control had both lower ground and fan speed settings than those recommended, and the aggressive treatment had higher ground and fan speed settings than standard practice. While producing satisfactory revenue, the control treatment had substantially higher harvesting costs that outweighed the additional revenue and ended up delivering $261/ha less than the recommended settings overall. In contrast, the aggressive treatment had slightly lower harvesting costs and much lower mean revenue and ended up providing $257/ha less than the recommended treatment overall. These findings confirm that these settings are not commercially practical.

Patane *et al.* (2019) extrapolated the findings from all 2017 trials in the harvesting project across the whole Australian green-cane harvested area. They estimated that full industry-wide adoption of recommended settings could potentially increase grower revenue by $57.5 million annually. The additional harvesting costs that we examined were also extrapolated across the total green-cane harvested area, which estimated that full adoption of recommended settings might increase harvesting costs by $17.2 million annually. Subtracting the additional harvesting costs and levies from the additional grower revenue would deliver an annual net benefit of $39.3 million ($140/ha or $1.70/t). This dollar per hectare figure was less than the $163/ha for the nine trials that we calculated, largely due to the latter's higher average cane yield improvement. Notably, industry benefit did not include revenue that the additional cane would generate for mills (around $28 million); however, the additional transport, milling and logistics costs, including potential investments into bin fleets, were unknown so the net miller benefit could not be established.

The sugar price strongly influenced the size of the net benefit obtained from using the recommended settings. While the net benefit mentioned above was calculated using the five-year average sugar price of $424/t, Table 4 shows the benefit at a range of sugar prices. At lower sugar prices, the net benefit is lower, while higher sugar prices generate higher net benefits.

Table 4. Grower net benefit from using the recommended harvesting settings at different sugar prices.

Sugar price ($/t)	$350	$390	$424	$430	$470	$510
Net benefit ($million)	$29.4	$34.8	$39.3	$40.1	$45.5	$50.8

These results suggest that broader scale adoption of the recommended settings would increase industry profitability considerably and improve the sustainability of sugarcane farming. Focusing future research on determining where the largest gains from HBP adoption are (particular cultivars, field conditions, crop presentation for harvest, etc.) would help inform extension activities so that these areas could be targeted in the

[1] Analysis of all harvesting trials completed in 2017 identified a 5.4% yield increase (Patane *et al.* 2019), which was applied to all nine harvesting cost evaluations. Results indicated a 21 c/t increase in harvesting costs on average.

short term to maximise industry gains. Our economic analysis did not take into account the expected beneficial effect of reduced ground speeds on ratoon yields and crop cycle length, which would also likely increase grower revenue.

CONCLUSIONS

We compared the profitability of harvesting using the contractor's standard harvester settings and settings recommended by SRA (based on HBP). Our analysis drew upon production data from nine different trial sites to calculate grower revenue along with detailed information collected from each harvesting operation to identify harvesting costs. The grower revenue and harvesting cost information were then used to evaluate the net economic benefit from using the recommended harvesting settings instead of the standard settings.

On average over the nine trials, using the recommended harvesting settings generated more grower revenue than the added harvesting costs from reducing ground speeds and generated a net economic benefit of $163/ha (or $1.97/t). Two other treatments examining both lower and higher ground and fan speeds were evaluated but neither proved as profitable as the recommended or standard settings. Extrapolating the harvesting costs across the total green-cane harvested area and subtracting these from the grower revenue findings from Patane *et al.* (2019) indicates that full adoption of recommended settings could potentially generate a net benefit of $39.3 million. However, this net benefit does not include the value to the milling sector and is strongly influenced by the sugar price. These findings suggest that broader scale adoption of the recommended settings would increase industry profitability considerably.

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