ASSESSING FACTORS AFFECTING FARM PRODUCTIVITY: A SUGAR INDUSTRY EXAMPLE

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Abstract

QDPI undertoo a study to identify major factors affecting cane farm productivity in t Bundaberg district. Financial resources available severely limited the nun r of growers who could be interviewed.

A screening m thod, which used detailed crop, soil, and water data was used to identify those characteristics which were related to sugar yield. Two groups of canegrowers were selected - one group who possessed all high yielding characteristics and another who possessed a low yielding characteristics. Fifty-three farms were surveyed.

Farm data collected were used in regression analysis to explain variation in sugar yield within the two groups.

Contributed paper presented to the 38th Annual Conference of the Australian Agricultural Economics Society, Victoria University, Wellington, New Zealand. February 1994.

Introduction

Bundaberg Cane Productivity Committee (BCPC) was formed in 1986 to address a situation of declining farm productivity that was described at that time as "yield decline". Chappell, Poulson and Glasgow (1991) reported on the farm block recording scheme, cell discussion groups, productivity awards and other extension activities, that the BCPC initiated in its first four years. The role, activities and membership of BCPC have further evolved since that time. The appointment of a full-time District Productivity Coordinator in 1992 further increased the effectiveness of BCPC.

A major role of BCPC is to coordinate the local activities of industry organisations concerned with cane productivity and cane farm profitability improvement issues. The organisations now represented within the BCPC structure include Bundaberg Sugar Company, Bundaberg CANEGROWERS, the three Cane Protection and Productivity Boards, Bureau of Sugar Experiment Stations (BSES), Water Resources, QDPI and the Queensland Mechanical Cane Harvesters Association.

In 1990, BCPC initiated a study which had the following objectives:

- to identify factors affecting sugar yields in the Bundaberg district;
- to identify reasons for variation in the levels of farm input use; and
- to examine on-farm factors affecting the profitability of cane growing in the Bundaberg district.

BCPC through the local Farm Financial Counsellor of the QDPI approached QDPI Economic and Financial Services which has experience with industry studies in Queensland and overseas. QDPI agreed to undertake a study which would attempt to identify, from within a complex situation, the major factors affecting productivity and profitability in the Bundaberg area. Operational funding for the study was obtained from the Rural Adjustment Scheme (RAS) via the Queensland Industry Development Corporation (QIDC).

This paper concentrates on the analytical and survey methods employed in the study and discusses the limitations of the methods used and the use of findings for determining research and extension activities in the region.

Study Design

Discussions held by the QDPI study team with members of BCPC, canegrowers and research organisations generated a list of factors that were thought to directly or indirectly influence productivity, viz soil type, lack of grower finance, debt levels, drought conditions, farms too small to support further investment in irrigation, cane varieties, entomological problems, age of grower, frost damage, alternative enterprises diverting resources to the detriment of cane, weed growth, drainage constraints, plant nutrition, soil salinity, topographical constraints and crop cycle length, existing profitability of canegrowing and grower confidence in future of the industry.

Resources available to the study team meant that a maximum of 60 growers could be sampled using personal interviews. This survey instrument was considered essential in view of the scope of the information required from growers including the need for financial information.

Using other (cheaper) survey instruments with a greater coverage eg mail-in survey or a telephone survey of all growers or a large sample of growers, would not have allowed the collection of the scope and detail of data required and may have resulted in unacceptably low response rates and consequent lower precision, and a high incidence of recording errors.

In order to increase the likelihood of identifying the major factors affecting sugar yields in the district with such a small sample, a two stage method was employed which involved an initial screening of the complete farm population and a detailed study of the 'screened' population.

Population screening

Bundaberg Sugar Company had available block recording data (details of block area, fallow area, area harvested according to age of crop and cane variety, tonnes cane harvested and tonnes of sugar harvested) for each grower for the 1989 harvest. This information was combined with farm soil type data for each grower (BSES), and farm water use for the financial year 1988-89 (Water Resources), to compile a comprehensive data base for all growers in the study area.

There were about 830 gazetted cane suppliers in the study area which included the Fairymead, Bingera and Millaquin mill areas. However, some of these were under common management. With the assistance of mill, Cane Protection and Productivity Board and BSES staff these were amalgamated into 514 farming units all operating with the Bundaberg Irrigation Area.

Using the full data set, the following relationship was estimated using regression techniques.

Sugar Yield $= f$ (soil type, Ratoon structure, Cane Variety, Water Use).

The results of the regression analysis are shown in Table 1.

Table 1 Results of regression analysis using full data set

Explanatory variable	Coefficient	T-value*
Constant	5.03	5.48
Soil type - GR	2.48	3.74
GE	2.41	3.50
GA	2.20	3.25
AP	2.07	3.15
AC	1.44	2.16
AB	1.41	2.03
PR	2.26	3.17
PG	1.49	2.04
PLANTPC	0.04	4.18
RAT123PC	0.02	2.74
RAT4PC	0.02	2.08
CP44PC	0.01	2.45
MLPERHA	0.97	4.90
MLPERHASQ	-0.94	2.91

* If the t-value exceeds 2, the coefficient is significant at the 95% level.

Overall F 10.46
Adjusted R^2 .21
(Refer appendix 1 for definitions of the explanatory variables)

The model explained only 21% of the variability in sugar yields in the district. The subsequent task therefore was to identify factors, other than those already analysed, which would improve the explanatory power of the estimated model using a sample of only 60 growers.

On the basis of the regression result reported in Table 1 it is possible to identify those farm characteristics which are related to high yields and those which are related to low yields. For example, soil types of GR, GE, GA, AP are associated with high yields, whereas AC, AB, PG and PS are more conducive to low yields. Similarly, farms which planted higher proportions of cane variety CP44 achieved higher yields than other farms. Consequently, two groups of farms were selected from the population: the expected high yield group and the expected low yield group. The characteristics and the selection values for the two groups are show in Table 2.

Table 2 Characteristics used to select farm groups[1]

Characteristic	Expected high yield group	Expected low yield group
Predominant soil type	GR, GE, GA or AP	AC, AB, PS, PG or PR@
Plant cane percentage	Greater than 15% of area harvested	Less than 15% of area harvested
Variety of cane	Greater than 25% of area harvested was CP44	Less than 25% of area harvested was CP44
Ratoon cane percentage	Greater than 55% of area harvested was 1st, 2nd or 3rd ratoon	Less than 55 percent of area harvested was 1st, 2nd, 3rd ratoon

@ Soil type PR was included in the list of poor soils even though the regression results presented in Table 1 indicate that it is superior to AP and GA soils. An analysis of soil type data showed that only a small number of farms had PR type soils, which could effect the validity of this regression result. Therefore, it was decided to adopt the BSES classification of this soil type.

To be eligible as either an expected high or expected low yielder a farm had to possess all of the identified characteristics for the specific group. Consequently a total of only 49 expected high yielders and 42 expected low yielders were identified from the population of 514.
Thus the population for sampling was reduced from the original 514 farms to 91 farms as a result of the screening method employed. The two groups are referred to as *expected* high and *expected* low yield groups because, as expected, even though farms in either group possessed *all* the required attributes for that group, there was still significant variability in sugar yields. It was this variability within the two groups that we then attempted to explain.

By "screening" the population into groups which have similar combinations of known characteristics i.e. characteristics associated with high or low yields, the chances of identifying other yield related characteristics for a given sample size are improved. Removing known sources of variability from the sample facilitates the identification of other

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1 Note that even though water application had the major effect on yield, water use was not used as a screening variable. This was done for the following reasons:

- as the level of water use has the major effect on yield, the interest was in knowing why water use varied among farms which did not differ in soil types, percentage ratoons etc. Restricting the sample of (say) expected low yielders to include low water users and conversely the sample of expected high yielders to high water users would have resulted in little variation in water use within each sample, making analysis of likely reasons for variation in water use difficult;
- water use data were felt to be not as reliable as the other data in the regression analysis; and
- water used on non sugar activities could not be identified separately.

possible sources of variability. If no data were available on the characteristics used to select farms then a much larger sample would have been required to achieve the results obtained. In this instance such a sample size would have exceeded the resources available to the study.

Small sample investigation

The second stage of the study involved a detailed investigation of a sample of the screened population of 91 farms. A significant number of factors, which had been identified in earlier discussions, had yet to be examined. These included:

- percentage of income from cane production (non-specialist cane growers may concentrate their farming effort on non-cane crops, such as vegetables, to the detriment of their cane crops);
- irrigation capacity (Other things being equal, a farmer's capacity to apply a given amount of water in a shorter period may increase yield. The extent to which yield improvements can be achieved is dependent upon soil characteristics, particularly water holding capacity, and crop water requirements);
- level of nitrogen application on ratoon crops;
- level of weed control (by mechanical and/or chemical means);
- type of irrigation used (it was suggested that use of flood irrigation may be more effective in wetting the soil than use of travelling irrigators due to problems of wind drift etc);
- debt levels (it was suggested that high debt levels may be associated with lower expenditure on farm inputs and hence lower yields);
- profitability of cane growing; and
- personal characteristics of the farm manager.

A comprehensive survey questionnaire was developed after lengthy discussions with local BSES and QDPI staff and some preliminary trial interviews. A questionnaire, some 80 pages in length, was generated by this process. Sections dealt with included: farm identification, land use, cane planting in 1990-91 where information was not available from the block recording database, capital equipment, livestock and fixed capital assets, labour, cultivation/harvesting system, fallow preparation, planting, plant and ratoon cane cultivation, fertiliser use, chemical weed control, other chemical crop protection product usage, harvesting costs, irrigation method, water use, electricity tariff, farmer's perceptions regarding irrigation and crop yield, debt levels, costs and returns, farmer's age, education and experience, farm succession and the farmer's perceptions of the industry's future.

The period analysed comprised the "sugar years" 1989, 1990 and 1991, corresponding (approximately) to the financial years 1988-89, 1989-90 and 1990-91. Where appropriate, sugar returns and harvesting costs were taken back one year to match costs with returns from a particular season's crop. In Bundaberg, the 1991 year was considered to be a severe drought, the 1990 year had only slightly better rainfall and 1989 was a year of average rainfall and better sugar and small crop prices.

QDPI Economic and Financial Services staff from Brisbane conducted the lengthy (2 to 5 hour) interviews which were arranged and programmed by local staff at a rate of two per day per interviewer. All but one of the participating growers made their tax returns available as a source of financial information. Yield, crop class and variety information for each of the three years was obtained from the Bundaberg Sugar Company block recording database. Water use data was obtained from Water Resources.

Within the expected high yield population of 49 farms, 26 growers were interviewed, while 27 growers were interviewed for the expected low yield group of 42 farms, giving a total sample of 53 farms.

Analysis of the large amount of data collected during the survey mainly involved computing correlation coefficients for all hypothesised variables and sugar yields. Regression analysis was then performed using those variables which were found to be correlated. Correlation matrices were also used to assess the extent of multicollinearity in the models estimated. The incidence of multicollinearity is often a significant problem in this type of analysis. The extent of multicollinearity was not found to be significant in the final model estimated.

Results

A preliminary multi-variate analysis was carried out on the total sample of 52 growers (one cane grower was unable to provide three years of financial data and was excluded from the analysis). However, it was subsequently decided to restrict the regression analysis to 'specialist' cane farms. A specialist cane farm was one which, over the three year survey period, showed cane receipts greater than 85 percent of total farm cash receipts. By restricting the analysis to specialist growers, estimates of water use on cane could be improved as it was difficult to estimate water use on cane crops on non-specialist farms. The results of the analysis are shown in Table 3.

Table 3 Results of regression analysis using small sample data

Factor	Coefficient	t-value*
Constant	-6.15	1.54
Autumn plant cane as a % of cane area harvested	0.058	3.12
Type of irrigation (non-flood=0, flood=1)	0.90	2.79
Days between irrigations	-0.15	4.11
Ratoon nitrogen application rate (kg ha^{-1})	0.027	4.74
Soil type (poor soil=0, good soil=1)	0.94	2.86
Water (effective rainfall + irrigation) ($MLha^{-1}$)	2.66	3.48
$Water^2$	-0.102	2.67

* If the t-value exceeds 2, the coefficient is significant at the 95% level.

Overall F 37.7
Adjusted R^2 0.67

Autumn plant cane

Due to the greater crop age (16 to 20 months from planting to harvest), the autumn plant crop class is the highest yielding in the Bundaberg area. It was no surprise to find that a higher proportion of autumn plant cane led to higher yields per harvested hectare.

Soil type

BSES staff allocated a major soil type classification to each farm. Red volcanic, red and yellow podsolic, red and yellow earth and alluvial soils were classified as good soils while solodic, soloth, sand, and gleyed podsolic soils were grouped as poor soils. As expected, the soil coefficient indicated that good soils produced 0.94 t sugar ha^{-1} more than the poor soils.

Ratoon nitrogen rate

The ratoon nitrogen rate coefficient equates to 27 kg sugar for each additional kg of nitrogen applied over the range of application rates contained within the data set. The average fertiliser nitrogen rate applied by the 53 growers was 153 kg ha^{-1} which is just below the BSES recommendation of 160 kg ha^{-1}.

Flood irrigation

Farms that were flood irrigated had yields 0.9 t sugar ha^{-1} higher than those that were irrigated with water winches.

Days between irrigations

Sugar yield decreased by 0.15 t ha^{-1} for each additional day between irrigations.

Water (effective rainfall + irrigation)

The linear response to irrigation expressed in the multiple regression is a very high at 2.66 t sugar per ML which should not be considered alone but in conjunction with the $water^2$ factor which has a negative coefficient.

$Water^2$

This factor was included to generate a water response curve similar in shape to that recorded in earlier trials. This and the previous factor (Water) need to be considered together when interpreting the relationship between sugar yield and water use. The two water factors explained over 50 percent of the total yield variability.

Table 3 shows that the factors included in the model explain 67% of the variability in sugar yields. When compared with the 21% achieved using the larger population data set reported in Table 1, it suggests that the benefits of screening the population and subjecting the screened population to a more detailed analysis were substantial. What we cannot conclude however, is that the screening of the population into the two roughly homogeneous groups using detailed available data, would have out-performed some other sampling procedure eg simple or stratified random sampling. Nevertheless, we contend that, for a given sample size, the use of available information to minimise the sources of variability within a sample will almost certainly provide more precise estimates than a simple random sample and more than likely give greater precision than a stratified random sample. The issue is therefore an economic one - whether the additional costs of data collection, manipulation and analysis associated with the method described above are less than the costs associated with the use of less precise estimates which are likely to result from an alternate sampling approach.

Limitations

There are two limitations associated with the methods employed in the study and the use of the study's findings. The first results from the use of regression analysis to identify yield related factors using a small sample, and the second concerns the use of the results of such analysis to determine future research and extension activities.

With regard to the first limitation it must be remembered that there could well be other factors, in addition to those presented in Table 3 that affect yield eg cane variety, extent of green cane harvesting, timing of irrigation applications etc. Because of the small number of observations and the lack of 'spread' of values for some variables, important characteristics may not be identified. Also the values of the co-efficient or degree of influence of the explanatory variables on yield are only estimates based on the number of observations. A larger number of observations may result in a 'better' estimate. Finally a significant relationship between yield and (say) type of irrigation used may mask a more fundamental relationship between yield and an unidentified characteristic. It could be that it is not whether a farmer uses flood irrigation that is really important. There could be other characteristics possessed by flood irrigators (but not identified) which result in higher yields. Flood irrigators may be the 'better farmers' who, on average, have selected flood irrigation. This type of limitation can be overcome by increasing the sample size and expanding the range of information collected. Both of these approaches will increase the cost of the research which is often not possible given a fixed research budget.

The second limitation pertains to the application of the results of the analysis for extension and research. While the multiple regression analysis identified six major factors affecting sugar yields, with water the predominant factor, it does not necessarily follow that research and extension should focus on these factors. For example, growers cannot alter the soil type on their farms. Similarly the finding that an increase in the proportion of autumn plant cane led to higher yields does not necessarily mean that all or most growers should be encouraged to increase the crop area under autumn plant. Farm profitability may be reduced as the area under autumn plant cane requires a preceding fallow period reducing the area available for harvest. However by firstly identifying factors affecting farm productivity and then determinating the profit-maximising levels of input use, a comparison of actual and calculated profit maximising levels of input use can be made. Reasons for differences between these levels of input use can then be explored and, where relevant, used to identify possible research and extension activities.

In the Bundaberg study information was collected from growers in the sample as part of the study in an attempt to ascertain reasons for variation in water use form the "optimum". This followed from the initial regression analysis which showed water use as the major influence on yield.

The BCPC has used the findings of the study to produce an activity plan for future research and extension in the district. The Committee has decided to concentrate on activities to improve irrigation use. A central theme of "Irrigation efficiency means profitability" has been adopted for research and extension activities over the next couple of years. The emphasis on irrigation is based on the determination of optimal irrigation application rates in the district using the water use coefficients presented in Table 3, net grower returns during the study period and the cost of applying irrigation water. This analysis showed that, on average over the study period, irrigators applied 1.8 ML/ha less than the profit maximising level. In addition, it has been found that the irrigation response function obtained by the study differs markedly from that obtained from irrigation trials conducted by the BSES in Bundaberg. This has led the BCPC to place a high priority on future research and extension activities aimed at improving irrigation efficiency and improving irrigation application techniques.

Appendix 1: Description of variables used in large sample regression analysis

Variable		Description
Sugar Yield		Tonnes of sugar per hectare harvested
Soil types -	GR	Good - Red volcanic
	GE	- Red & Yellow earths
	GA	- Alluvials
	AP	Average- Red and yellow podsolics
	AC	- Clays
	AB	- Black and brown sands
	PR	Poor - Sands
	PG	- Gleyed podsolics
	PS	- Residual solodics, soloths
PLANTPC		Percent of cane area harvested made up of plant cane
RAT123PC		Percent of cane area harvested made up of first, second and third ratoon cane
RAT4PC		Percent of cane area harvested made up of fourth ratoon cane
CP44PC		Percent of cane area harvested planted to cane variety CP44
MLPERHA		Megalitres of irrigation water per hectare harvested
MLPERHASQ		$MLPERHA^2$

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