Variety selection in sugarcane: Assistance from economics and modelling[1]

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Canegrowers in Australia, and probably in other countries as well, have tended to grow well-performing varieties extensively. In the past, single varieties such as Badila, a native cane introduced to Queensland from New Guinea by Henry Tryon in 1895 (Easterby undated, p 16) comprised the majority of cane produced by the whole industry over long periods of time. In more recent times, varieties such as NCo310, Pindar, Q90, Q96, and Q124 were very popular in some areas. NCo310 was the dominant variety grown in south and central Queensland canegrowing areas over a 30-year period from the 1950s until it was replaced, because of its susceptibilty to Fiji disease, by a series of varieties including Q124, Q137, CP44-101, and H56-752. While many of the varieties popular in the sugar industry over its history have been replaced because of susceptibility to disease, in other cases, growers have presumably replaced varieties because they perceived newly released varieties to be more profitable or to have other appealing characteristics. In some relatively infrequent cases, varieties have been replaced because of milling difficulties.

Traxler *et al.* (1995) used a Just-Pope production function to estimate the first two moments of wheat yield from trials in Mexico over the period 1950-1986 and concluded that the substantial increases in yield achieved by wheat breeders during the period of the "green revolution" had been accompanied by higher yield variances. They also noted that the period since the green revolution had been a time of slower increases in mean wheat yields but of relatively rapid improvement in yield stability.

In this paper, another aspect of the mean-variance relationship, relevant to the selection of plant varieties is examined. A simple income measure, rather than yield alone, is suggested as an appropriate variable by which to judge the value of varieties to producers and some limited evidence is presented to support the notion that income stability is important to canegrowers in the selection of varieties for commercial production. It is also proposed that bio-physical modelling might be adopted as a convenient way to assess the expected variance in income between potential commercial varieties as well as expected income. The determination of such information, prior to the release of varieties for commercial production, might prevent some of the unwise choices that canegrowers have made in the past regarding varieties to plant.

Moreton Mill area case study

The varieties selected by growers supplying the Moreton Mill in south Queensland over the past 30 years were studied to reach some understanding of the factors affecting varietal choice.

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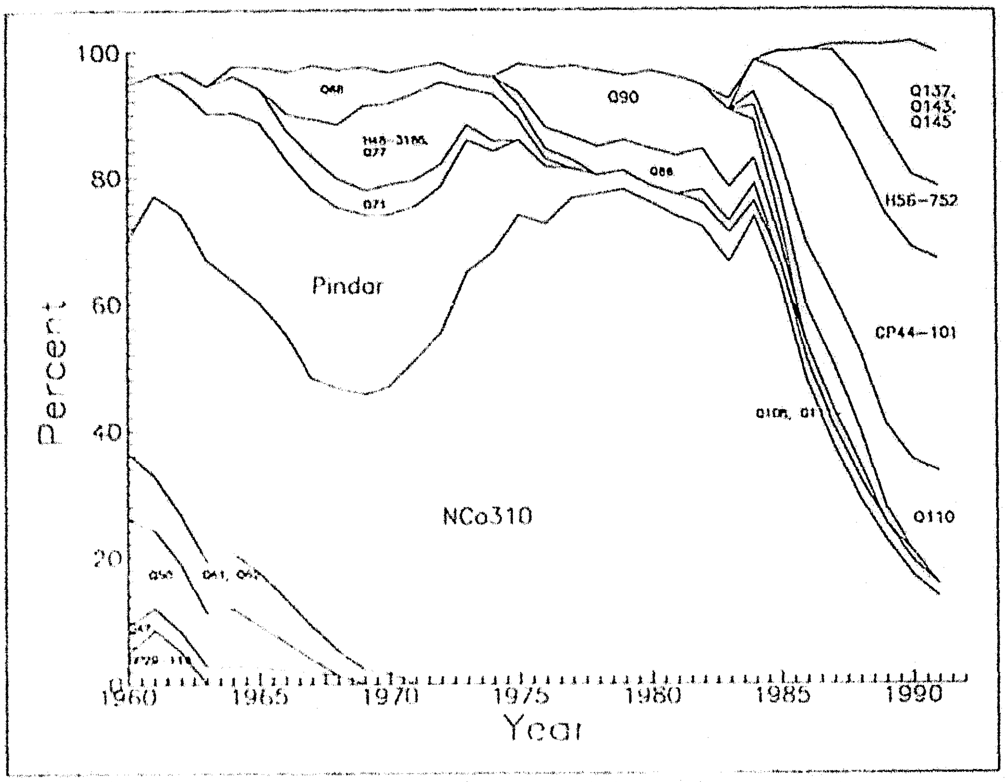

Figure 1: Percentage of cane supply to Moreton Mill supplied by individual varieties, 1960 to 1991.

Information presented in Figure 1 shows that NCo310 was the dominant variety planted by Moreton Mill area growers over a 30-year period from 1960 to the early 1990s. About 25 cane varieties have been grown in this mill area over the past 30 years but only 16 of them ever contributed more than five percent of the cane supply to the mill in any one year. A relatively small number of varieties including Q90, H48-3166, and H56-752 contributed a more significant share of the cane supply for a few years before being replaced while a group which included Q61, Q62, Q71, Q86, Q103, and Q111 contributed a little over one percent to the cane supply for a few years and were discarded by growers. With hindsight, it is questionable whether many of these varieties were ever really worth consideration as commercial canes.

Recently, Norton and Lawrence (1995) reported comments by a Central Queensland canegrower who suggested that more attention needed to be paid to the selection and release of cane varieties. This producer was critical of the fact that sugarcane varieties were released without the appropriate information on their likely performance. "*.... they will experiment with a new variety for about ten years and then put it out to trial. They will release it for commercial production and then find out it is no good. So all that money has been wasted and I will not be satisfied until they can get a variety like the one we used to have which produced ratoon crops for ten years. The new varieties they have now have had it after two, three, or four years, which means that you have to replant which is one of the most expensive operations on the farm*" (Norton and Lawrence (1995, p 43).

The opportunity costs to growers and to the mill of planting inferior varieties, in addition to the development costs referred to in the grower's comments above, are substantial and therefore more attention should be paid to selecting varieties that will meet the growers' and the millers' requirements for reasonably long periods of time.

Traxler *et al.* (1995) compared the mean and variance of wheat yield among varieties released by the International Centre for Improvement of Wheat and Maize (CIMMYT) in the Yaquin Valley of Mexico between 1950 and 1985. Presumably, wheatgrowers make variety selections predominantly for economic reasons so that wheat yield is assumed to be an approximate indicator of the difference in economic value between cultivars. While this has been true for many crops in the past, it is becoming increasingly common for quality attributes to be recognised in determining market price. For example, the payment of protein premiums for wheat and barley is becoming increasingly common and in sugarcane, both yield (tonnes of millable stalks per hectare) and sucrose content of the cane (ccs) are used to determine the contribution to farm income from individual cultivars. Thus output may not equate with gross income and there may be cost differences between cultivars to take into account. These may include yield sensitive costs such as harvesting and cartage which are commonly assessed on the basis of tonnage handled.

For sugarcane, the gross margin per hectare net of harvesting costs appears to be an appropriate measure by which to judge the contribution of individual varieties to overall farm profit. In the Australian sugarcane production system, where four or five ratoon crops are commonly harvested from a single planting, is seems that the average gross margin from ratoon cane is a useful indicator of the economic value of individual cultivars.

On the basis of statistical information available from the sugar industry, gross margins net of harvest costs were estimated for each of the varieties that comprised more than one percent of the cane supply to the Moreton Mill for at least three of the past 35 years.

Cane payment formula

The principal components of this gross margin calculation were yield, sucrose content of the cane (estimated empirically by ccs or commercial cane sugar), raw sugar price, and harvest cost. Price, yield, and sucrose content are used in the following empirical formula to determine the value of cane to be paid to mill suppliers:

$$P_c = 0.009*P_s\ (CCS - 4) + 0.328$$

where P_c = price ($ per tonne) paid for cane delivered to the mill pick-up point. The mill usually pays the cost of transport from the growers' siding to the factory.

P_s = price ($ per tonne) received by the mill from the marketing authority (currently the Queensland Sugar Corporation) for sugar of a set quality standard (94 net titre).

The "0.009" term reflected the efficeency of Australian raw sugar milling operations at the time that this formula was devised.

The "CCS - 4" term is used to apportion the proceeds of sugar sales between the grower who supplies the cane and the mill. When the formula was originally devised, it was agreed that the proceeds from raw sugar sales would be divided between growers and millers in proportion to their aggregate capital investments in the industry: approximately 2/3 by growers and 1/3 by millers. The addition of $0.328 to the growers' returns occurred later when it was concluded that capital shares had shifted in the growers' favour. (There has been a more recent adjustment, also to increase the growers' share of the proceeds, in light of changes in both ccs and coefficient of work (indicator of milling efficiency) which has affected the proportion of sugar sales proceeds being paid to growers.

Table 1 summarises information about the main varieties grown at Moreton over the past 30 years.

Many varieties approved for planting at Moreton over the past 30 years have been tried by growers and rejected after a short time as unacceptable. Initially, consider varieties that represented one percent of the cane supply to the mill for less than five years. This includes varieties such as Q62, Q77, Q93, Q103, Q108, Q111 and possibly Q70. Data are not available to show whether Q70 was grown more extensively prior to 1960. None of these varieties had an estimated gross margin per hectare net of harvesting costs as high as NCo310, the most popular variety in the mill area for most of the past 30 years. For those varieties which comprised a more substantial proportion of the cane supply over a 10-year period before being replaced, including H48-3166, Q68, Q86, and Q90, the position was much the same. None of these varieties had gross margins as high as NCo310 and some (Q68) had a much higher variance. They would have been rejected by growers applying either maximum profit or maximum utility criteria through mean-variance rules.

The fate of newer varieties including Q103, Q108, Q110, Q111, H56-752, CP44-101, Q137, and Q143 also appears to be consistent with the application of mean-variance rules by growers to variety selection.

Production of Q103, Q108, and Q111 has already ceased although Q108 and Q111 were first harvested commercially as recently as 1984 and 1987 respectively. Both had mean gross margins lower than NCo310 and comparable variances. Q103 first harvested commercially in 1980, was abandoned as a commercial variety because of processing difficulties, but it had a mean income less than NCo310 and a slightly higher variance so it is likely it would not have met the growers' requirements even if its milling characteristics were acceptable.

CP44-101 is a variety with resistance to Fiji disease that was introduced in 1985 and has replaced NCo310 as the most popular variety in the Moreton Mill area. It appears to have a higher mean income and a higher variance than NCo310 although its expanding percentage of the cane supply confirms its acceptability among growers. CP44-101 reached its highest percentage of the cane supply in 1993 (24 percent). Apparently, the relatively high variance of income associated with this variety was not sufficient to dissuade growers from planting it. H56-752 was introduced about the same time as CP44-101. Initially, it was quite popular among growers because of its high yields but its

Table 1: Summary of variety information (including mean and variance of net revenue after harvesting costs) for varieties grown at Moreton, 1960-1991.

Variety	Period grown	Maximum percentage of cane supply and (year)	Mean yield (t/ha) and (variance)	Mean ccs and (variance)	Estimated gross margin net of harvest cost ($/ha)
CP29-116	1960 only*	na	69.5	14.28+	1 570
Trojan	1961-1962*	4.1(1961)#	64.5	13.29+	1 383
			(4.5)	(0.7)	(8 963)
POJ2878	1961 only*	na	62.3	13.30+	1 242
Q70	1960-1962*	3.2(1961)#	61.4	14.00+	1 338
			(87.3)	(0.4)	(42 276)
Q47	1960-1968*	4.4(1960)#	60.1	13.70+	1 258
			(62.3)	(0.5)	(36 263)
Q50	1960-1967*	16.9(1960)#	67.3	13.60+	1 402
			(47.0)	(0.5)	(41 775)
Q61	1960-1970*	10.6(1960)#	62.0	13.50+	1 266
			(43.1)	(0.9)	(38 297)
Q62	1963-1964	1.5(1964)	66.5	12.80+	1 247
			(21.3)	(0.5)	(47 112)
NCo310	1960-1991	78 (1979)	76.9	13.26	1 519
			(98.0)	(0.58)	(50 954)
Pindar	1960-1991	28.6(1968)	72.5	13.10	1 375
			(110.8)	(0.33)	(56 032)
Q71	1962-1974	5.8(1964)	65.4	13.40	1 326
			(58.6)	(0.8)	(54 054)
H48-3166	1966-1976	13.5(1969)	60.1	13.30	1 202
			(60.2)	(0.8)	(48 119)
Q68	1964-1990	8.5(1967)	73.0	12.97	1 388
			(266.8)	0.96)	(137 647)
Q77	1971-1975	1.8(1972)	63.2	13.20+	1 274
			(8.5)	(0.6)	(21 300)
Q86	1974-1985	6.4(1982)	69.8	12.59	1 257
			40.5	0.36	20 927
Q90	1975-1984	9(1977)	76.9	13.26	1 272
			(98.0)	(0.58)	27 652
Q93	1975-1983	3.2(1977)	69.6	12.90+	1 365
			(109.4)	(0.7)	(36 790)
Q103	1980-1985	7.4(1983)	72.8	12.80	1 358
			(87.1)	(0.7)	(60 678)
Q108	1984-1989	6.0(1986)	58.5	12.48	1 033
			(70.9)	(0.29)	(24 701)
Q110	1984-1991	17.7(1991)	79.7	12.73	1 457
			(78.3)	(0.52)	(21 442)
Q111	1987-1988	2.6(1987)	80.0	12.80	1 483
			(80.6)	(0)	(31 416)
CP44-101	1985-1991	33.6(1991)	81.1	12.98	1 547
			(104.1)	(0.63)	(68 918
H56-752	1986-1991	13.1(1990)	82.0	12.66	1 492
			(43.5)	(0.32)	(26 520)
Q137	1989-1991	13.5(1991)	77.9	13.36	1 559
			(128.9)	(0.42)	(38 835)
Q143	1989-1991	6.5(1991)	73.3	13.59	1 519
			(265.8)	(0.10)	(123 918)
Q145	1991 only	1.4(1991)	84.6	12.45	1 485

relatively low ccs has resulted in a low mean income. H56-752 reached a peak of 13 percent of the cane supply in 1990 and has since declined in popularity, presumably because of its lower income (and lower variance) than comparable varieties such as NCo310, Q111, and CP44-101.

Q137 is another variety that reached its maximum percentage in 1993 when it comprised 19 percent of the cane crushed. It has a high income estimate and a low variance but this was based on only three year's results. Q137 appears to have similar income characteristics to CP44-101 but both varieties have been replaced in recent years by several new ones including CP51-21, Q141, Q143, Q145, Q146 and Q148. All of these varieties rose quickly to around five percent of the cane supply in the period after 1992.

Varieties grown at Moreton over the past 30 years are presented in a mean-variance diagram in Figure 2.

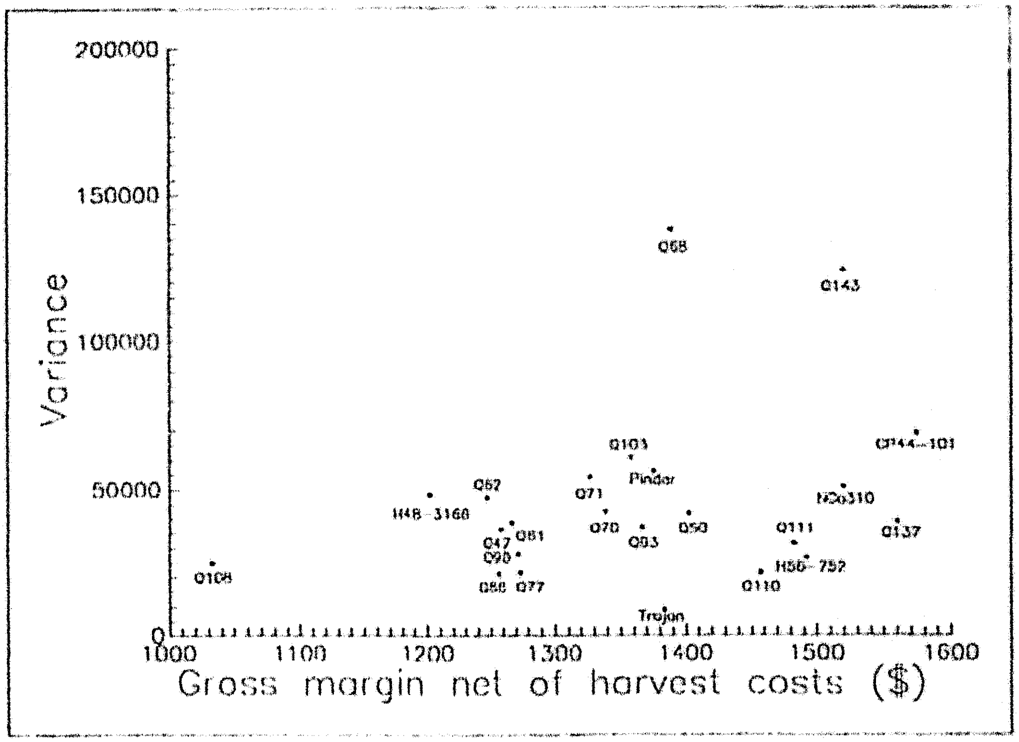

Figure 2: Varieties grown at Moreton displayed in a mean-variance diagram.

There has been an increase in estimated gross margin after harvesting costs over time, similar to the observation made by Traxler *et al.* (1995) that more recently-released cultivars were higher-yielding than the earlier releases confirming the positive effects of plant breeding and varietal improvement. Some of the yield improvement is due to increased levels of inputs used in the production process and possibly to some substitution between inputs as well. With few exceptions, the variance in income associated with these varieties appears to be of similar magnitude which may not be surprising given that year-to-year variations in weather and other environmental effects have an important impact on cane and sugar yields over time.

From the figure, it appears that the mean-variance frontier which separates acceptable from unacceptable varieties among those currently being used by growers in the Moreton Mill area might be represented by a line drawn approximately through the points representing Q110, H56-752, Q111, NCo310, and CP44-101. The decisions taken by growers in this mill area on which varieties to plant appear to be consistent with the mean-variance decision rule. At any one time, they have mostly chosen varieties which gave them a relatively high mean income net of harvesting costs combined with a modest variance. One could possibly argue that while their decisions are consistent with maximising utility through the application of mean-variance rules, they are not inconsistent with application of a profit maximising criteria but when considered in the light of other information about the nature of canegrowers' decision-making, then the conclusion that the decision-makers are risk averse is favoured.

The conclusion that growers choose varieties according to mean-variance rules is consistent with their risk averse behaviour in many other aspects of their farm businesses and confirms earlier observations (Wegener *et al.* (1992) that varieties with higher mean incomes and lower income variances were chosen by growers at Tully. In that case, separate yield and ccs figures were available for plant and ratoon crops and the analysis suggested that growers placed more emphasis on ratoon crop results than plant cane. The popularity of varieties was consistent with their being chosen according to the mean and variance of the ratoon crop income, although this was not always consistent with plant cane results. This conclusion is understandable in a production system where the area of ratoon cane harvested each year is three or four times the area of plant cane.

The growers' choice of varieties appears to be consistent with that expected by rational, risk averse decision-makers, although the hypothesis is not easy to evaluate because the set of varieties used by growers in each mill area is always changing over time. There tends to be adequate information about long-standing varieties such as NCo310 to test the assertion but there is always much less information available about varieties that are popular on a short-term basis.

The estimate of income variance in this case was based on average annual yields of cane for each variety supplied to the mill. While there is undoubtedly some inaccuracy associated with individual yield estimates, it is believed that the aggregate estimates are quite relaible. However, in compiling the average figures, the considerable block-to-block variation in cane yield that exists in any year is eliminated from the dataset and the variance includes only the year-to-year variation in average cane yields for the mill area and may not represent the extent of the variability in income from a variety faced by an individual grower. The availability of a better database of yield information for individual varieties, as was available in the earlier example from Tully, would enable better estimates of the mean income, and the variance for individual varieties, to be calculated.

While it appears that canegrowers' decisions on which variety to plant have been consistent with mean-variance rules, they assume that the income measure on which the decision is based is normally distributed and that the decision-makers are risk averse. Other decision-making procedures such as generalised stochastic dominance analysis or stochastic dominance with respect to a function, could allow the risk preferences of individual canegrowers to be taken into account and allow more efficient choices to be made.

Income distributions for main varieties

Long series of average annual yield observations for commercial cane varieties were available for two varieties, NCo310 and Pindar. Both varieties were harvested at Moreton in each of 32 years from 1960 although Pindar was a minor variety comprising 1-2 percent of the total cane supply for some of those years. Information on the normality of the estimated distributions for the main varieties grown in the Moreton Mill area since 1960 is contained in Table 2. Distributions for 18 varieties, grown for periods of six to 32 years were analysed using the SAS UNIVARIATE procedure (Allen 1982).

The data in the table show that few of these distributions could be judged "normal". About the same number of distributions were positively as were negatively skewed and most distributions were kurtotic. However, these conclusions were almost always based on a small number of observations. All of the distributions, except those for NCo310 and Pindar, were based on 12 or fewer observations so that more credibility should be placed on information from varieties grown for longer periods. There was a 0.32 and 0.37 probability respectively that the income distributions for NCo310 and Pindar were normally distributed. Therefore the conclusion that the distributions for income from cane varieties will be skewed when they are largely determined by weather conditions, which themselves are represented by skewed distribtions of rainfall, temperature, and radiation, seems reasonable in the majority of cases.

Table 2: Normality of estimated income distributions for varieties grown at Moreton, 1960-1991.

Variety	Years of data	Mean income	Variance	Skewness	Kurtosis
NCo310	32	1 202	50 954	0.08	0.73
Pindar	32	1 520	56 032	0.22	0.35
H48-3166	11	1 375	48 119	0.14	0.26
Q47	9	1 258	36 264	0.14	0.35
Q50	8	1 402	41 775	-0.51	-0.92
Q61	11	1 266	38 298	-0.02	-0.02
Q68	21	1 366	78 608	-0.01	0.02
Q70	3	1 338	42 276	0.47	0.63
Q77	4	1 274	21 300	0.16	0.26
Q86	12	1 285	22 551	-0.13	-0.45
Q90	10	1 273	27 652	-0.76	-1.82
Q93	8	1 308	36 748	3.37	7.13
Q100	3	1 302	12 993	-0.52	-0.70
Q103	6	1 358	60 678	0.57	0.92
Q108	6	1 033	24 701	0.42	0.89
Q110	8	1 457	21 442	-0.70	-1.26
Q111	2	1 483	31 416	0.01	0.01
CP44-101	7	1 547	68 918	-0.29	-0.68
H56-752	6	1 492	26 520	-0.20	-0.36
Q137	3	1 560	38 805	0.56	0.76
Q143	3	1 519	123 918	-0.33	-0.44
Q145	1	1 485	na	na	na

Variety comparisons using stochastic dominance analysis

The income distributions for varieties grown at Moreton over the past 30 years were analysed using stochastic dominance software provided by Goh *et al.* (1989). Two sets of analyses were conducted - one for a group of older varieties and another for a group of more recently released varieties. The results are presented in Figures 3 and 4.

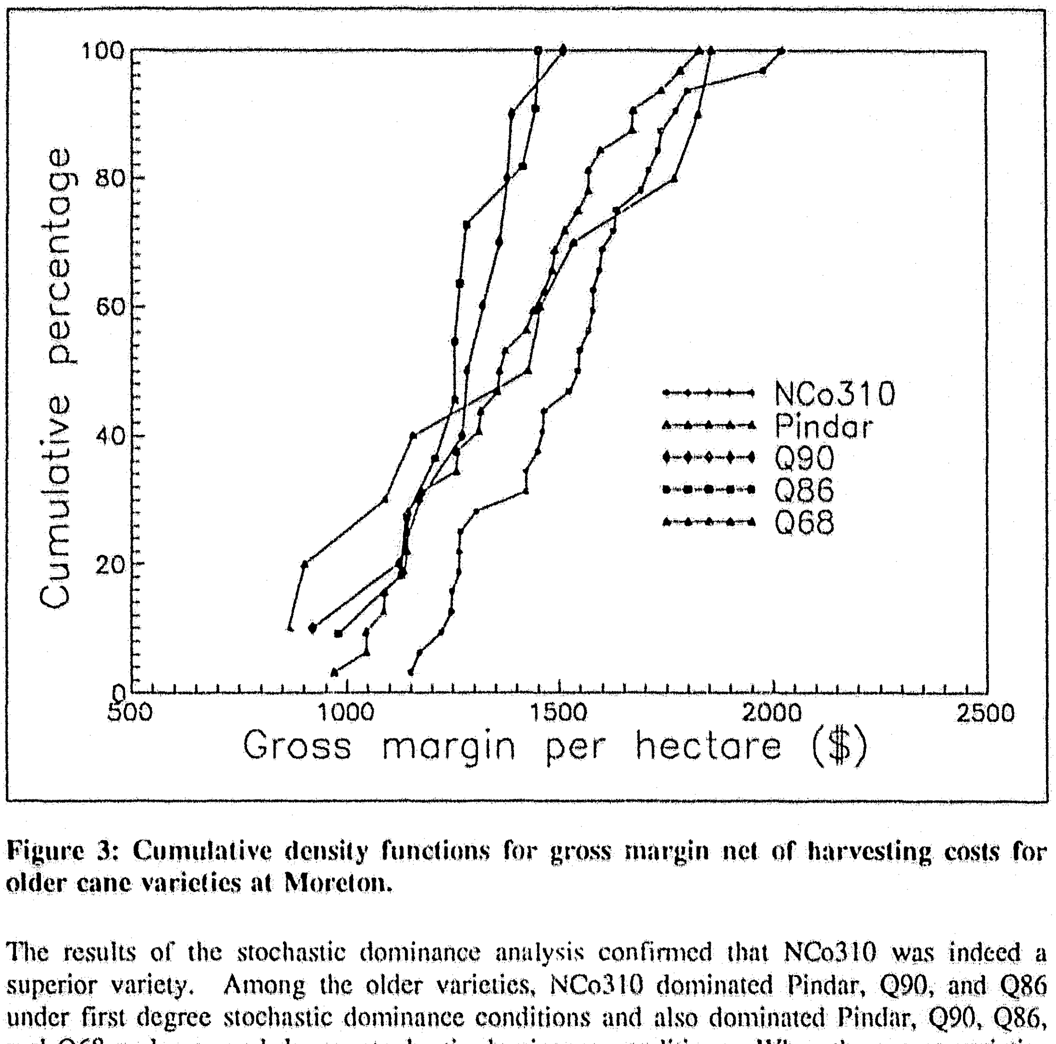

Figure 3: Cumulative density functions for gross margin net of harvesting costs for older cane varieties at Moreton.

The results of the stochastic dominance analysis confirmed that NCo310 was indeed a superior variety. Among the older varieties, NCo310 dominated Pindar, Q90, and Q86 under first degree stochastic dominance conditions and also dominated Pindar, Q90, Q86, and Q68 under second degree stochastic dominance conditions. When the newer varieties were compared, NCo310, H56-752, Q110, and CP44-101 formed a risk efficient set that dominated Q108 by both first and second degree stochastic dominance. This analysis therefore gave results that were consistent with observed behaviour by growers who are assumed mostly to be risk averse and who would therefore make decisions consistent with second degree stochastic dominance rules.

There were several obvious deficiencies in the conduct of these analyses. Firstly, there was an unequal number of observations from most varieties in the dataset. Only two varieties, NCo310 and Pindar, were grown throughout the whole period of the analysis: all other varieties were grown for shorter periods. This means that different factors may have been influencing the outcome and contributing to the yield and income differences between varieties. Ideally, comparisons between varieties should be made on the basis of identical time periods when stochastic inputs were the same. Also, the same crop classes should be harvested at exactly the same dates in the season to synchronise the carry-over effects on yield from earlier seasons, and prodution data should be drawn from consistent production areas. Also, the same population of decision-makers should be involved since

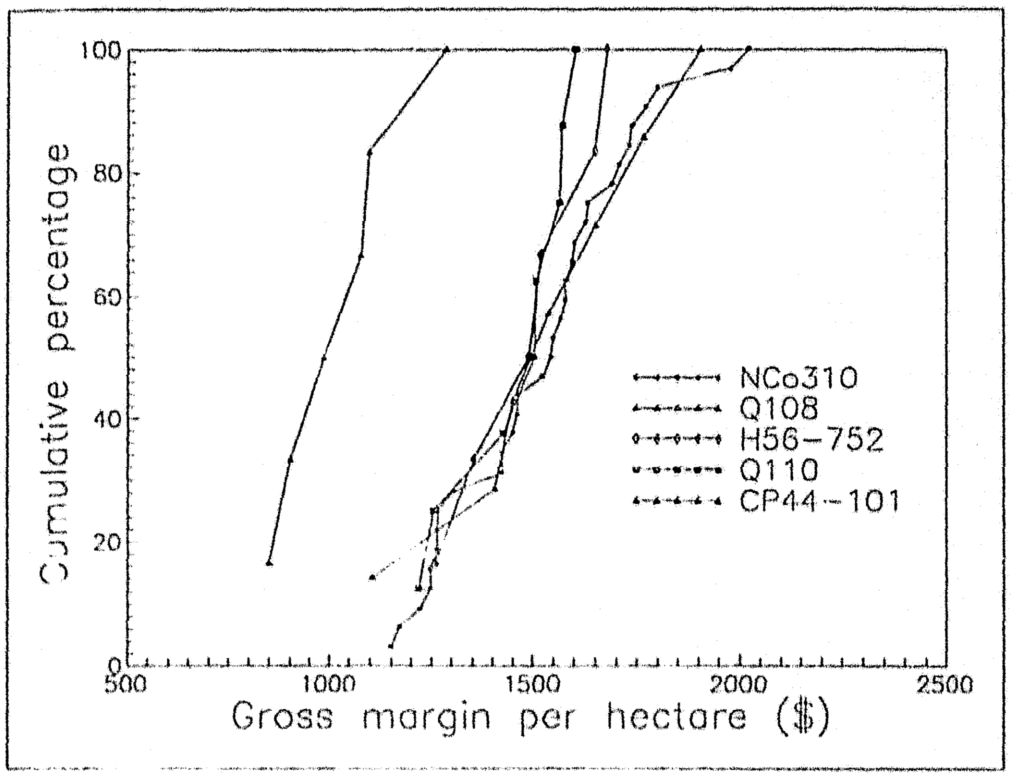

Figure 4: Cumulative density function for gross margin net of harvesting costs for current varieties at Moreton.

the assumption is being made that the attitude of the group to risk is constant. Unfortunately, these conditions do not apply with commercial variety information.

The short series of actual data on which the income distributions for individual varieties were based constitutes a serious problem for variety analysis. Two possible ways to overcome the problem involve simulation, either by using a general simulation procedure as is available with the *@Risk* program (Palisade Corporation 1992) or by using a biophysical simulation model that can simulate differences between varieties. In the first case, acceptable results depend on selecting the correct type of distribution and appropriate starting values for the simulation. Some pertinent comments on selecting appropriate distributions for decision variables were made by Gbur and Collins (1989). Where a biophysical simulation model is used, success depends on the model being sufficiently sensitive to generate differences in yield in accordance with the variability of weather inputs and other stochastic information.

Thus there is a convincing case for adapting an appropriate model for the purpose of variety assessment. A method for discriminating, either in a mean-variance or stochastic dominance framework, between varieties that are acceptable to growers and those that are not, is needed to assist canegrowers make this difficult choice.

If more information about the risk attitudes of the decision-makers was available, more use could be made of the sophisticated decision methods that are available. The capabilities of stochastic dominance with repect to a function could be used to separate the varieties likely to be preferred by various groups of decision-makers in accordance with their risk preferences.

References

Allen, A., (ed.) 1982. *SAS users' guide: Basics, 1982 edition.* SAS Insitute, Inc. Cary, North Carolina, 923 pp.

Easterby, H.T., undated. *The Australian Sugar Industry: An historical review*, Frederick Phillips, Government Printer, Brisbane, 226 pp.

Gbur, E.E., and Collins, R.A., 1989. "A small-sample comparison of estimators on the EU-MGF approach to decision making", *American Journal of Agricultural Economics*, Vol. 71, pp 202-210.

Goh, S., Shih, C-C., Cochran, M.J., and Raskin, R., 1989. "A generalised stochastic dominance program for the IBM PC", *Southern Journal of Agricultural Economics*, Vol. 21, pp 175-182.

Norton, J., and Lawrence, G., 1995. "Farmers and scientists: Views on agrobiotechnologies", *Agricultural Science: The Journal of the Australian Institute of Agricultural Science* (New Series), Vol. 8, pp 39-42.

Palisade Corporation, 1992. *@Risk: Risk analysis and simulation add-in for Lotus 1-2-3*, Palisade Corporation, New Field, New York.

Traxler, G., Falk-Zapelda, J., Ortiz-Monasterio, R., and Sayre, K., 1995. "Production risk and the evolution of varietal technology", *American Journal of Agricultural Economics*, Vol. 77, pp 1-7.

Wegener, M.K., Bruce, D., and Fuelling, T.G., 1992. "Application of geographic information systems software for productivity evaluation", pp 99-106 in B.T. Egan (ed.) *Proceedings of Australian Society of Sugar Cane Technologists conference*, Mackay, 28 April-1 May 1992. Australian Society of Sugar Cane Technologists, Brisbane.