ECONOMIC REVIEW OF THE VICTORIAN OILSEEDS RESEARCH PROGRAM

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Abstract*

During the period 1980-94, the area of canola planted in Victoria expanded from 2,500 hectares to 74,500 hectares, and by 1994 accounted for over 70 per cent of the gross value of production of all oilseeds in the state and 80 per cent of the oilseeds research expenditure. Due to the dominance of Victorian oilseeds production by canola, the quantitative benefit-cost analysis of the oilseeds industry was restricted to this commodity. During the period 1980-94 the yield of canola increased at a mean rate of 3.3 per cent per annum. Ex post (1980-95) and ex ante (1995-98) quantitative benefit-cost analyses of the Victorian canola research program were performed using the linear programming model PRISM. The benefit-cost ratio for the ex post evaluation was found to be 1.6 (that is, for every $1 invested the return was $1.60). This reflects the establishment phase that the industry under went during this period, when expenditures were initially high relative to returns. The ex ante evaluation returned a benefit-cost ratio of 3.0 due to the increased benefits generated by higher yields and the larger area of canola grown in the mid 1990s. The benefit cost ratio for the entire program (1980-98) was predicted to rise to 1.9 by 1998.

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1. Introduction

Since the late 1970s, Australian production of oilseeds has expanded rapidly due to: an increase in world demand reflected in competitive oilseed prices compared with wheat; the recognition of the value of oilseeds in implementing sustainable cropping rotations; and increased expenditure on research to develop high yielding, disease resistant germplasm adapted to the local environment.

Over the 30 year period from 1964 world production of oilseeds increased three-fold to 225,000 kt in 1994[1]. During this period canola production expanded ten-fold to 27,000 kt. This trend is expected to continue over the next decade due to population growth, increased per capita incomes and a greater awareness of the benefits to human health of consuming mono-unsaturated fats. In 1994 Australian farmers grew 558 kt of oilseeds (canola, sunflowers, soybeans, safflowers and linseed/linola) with a gross value of production (GVP) of $220 million. The most significant of these crops was canola which accounted for 59 per cent of total oilseed production and GVP.

The oil obtained by crushing canola seed is used to manufacture margarine and other highly processed food products. The residual meal provides a high protein animal feed suitable for pigs and poultry. Australia is currently a net exporter of canola seed and almost self sufficient in the supply of oil and meal to the domestic market. Canola oil contains less than seven per cent saturated fat and over 90 per cent mono and polyunsaturated fatty acids. The benefits to human health of consuming more mono and polyunsaturated fats and less saturated fat are well documented, and have been shown to reduce the risk of cardiac disease (Edwards, 1995).

The total Victorian production of oilseeds (canola, sunflower, safflower, soybean and linseed/linola) has increased from 3.4 kt in 1983 to 84 kt in 1994. In 1994 Victorian canola production was 74.5 kt (with a GVP of $26.3 million) which accounted for more than 70 per cent of the tonnage and value of Victorian oilseed crops. Victorian production of oilseeds, and especially canola, is expected to continue to expand over the next decade due to the development of improved germplasm, increasing farmer awareness of the value of oilseeds in sustainable crop rotations, competitive prices for oilseeds compared to wheat and increasing world demand for the product.

The aim of this review is to determine the role and economic value of research and extension in the development of the Victorian oilseeds industry. Canola accounts for over 70 per cent of Victorian oilseeds production and GVP, and attracts approximately 80 per cent of the oilseeds research budget. A quantitative benefit-cost analysis of Victorian research into canola is presented in section two of this review.

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[1] Annual prices, yields and areas of wheat, barley, field peas, chick peas and faba beans, and the areas and yields of canola, were taken from the *Commodity Statistical Bulletins 1986-94* and *Australian Commodity Statistics 1995*, both of which were published by the Australian Bureau of Agriculture and Resource Economics (ABARE), GPO Box 1563, Canberra, 2601. The prices of canola were supplied by ABARE (Rees, R. 1996, pers. comm. Sept).

2. The Contribution of Research to the Victorian Canola Industry

2.1 Introduction

Canola is a rapeseed derivative with low levels of erucic acid that was a product of the Canadian oilseed breeding program conducted in the 1960s. Canola is a member of the genus *Brassica*, and several species are grown for human consumption. Canola oil for the processed food industry is derived from *B. napus* and *B. campestris*. *B. napus* has larger seeds and greater yield potential than *B. campestris*, but is more susceptible to drought and losses due to seed shattering before and during harvesting. Condiment mustards are manufactured from *B. juncea*, *Sinapus alba* and *B. nigra*. The quantitative benefit-cost analysis presented here is for canola species suitable for oil production, which constitutes at least 95 per cent of the canola grown in Victoria (Salisbury, P. 1996, pers. comm. Sept)

Canadian *B. napus* cultivars such as Target were introduced into Australia in 1968 and grown commercially in 1969 and 1970, with some preliminary success. In 1971 and 1972, the disease blackleg (*Leptosphaeria maculans*) devastated canola crops throughout the country and provided a major setback to the establishment of the industry. The utility of Target and other introduced cultivars was limited by a combination of susceptibility to disease, low yields and oil content, and high levels of erucic acid[2] in the oil and glucosinolates[3] in the meal. These problems were largely the result of the imported germplasm being developed under different environmental constraints than those existing in this country. Breeding and agronomy programs were initiated in Victoria, New South Wales and Western Australia in the mid 1970s to produce locally adapted high yielding cultivars that met Canadian standards for oil and meal composition with increased resistance to blackleg.

The *B. napus* cultivar Marnoo was developed by the Victorian canola breeding program, and released commercially in 1980. Marnoo met Canadian standards for erucic acid and glucosinolates, and had moderate resistance to blackleg, but was still susceptible to seed shattering during harvest.

Since 1980, the Victorian canola research program has concentrated on increasing the yield and oil content of canola varieties, minimising the adverse effects of disease, overcoming losses from seed shattering, controlling pests and weeds, and developing new speciality varieties. The average yield of canola grown in Victoria has increased by 62.5 per cent (equivalent to 3.3 per cent per annum) since 1980, while the oil content has been increased by approximately three per percentage points. The adverse effects on yield of blackleg have been decreased through selective breeding for resistance and the development of management strategies to minimise the incidence of the disease. While blackleg still remains a problem for canola growers, the advances made by scientists over the last decade have decreased yield losses to acceptable levels. Losses from seed shattering during harvesting have been decreased by windrowing prior to the operation, and continuing research at the University of Melbourne aims to breed canola varieties less susceptible to shattering. Pre-emergent sprays have been used to combat red-legged earth mites. These advances have been made through an integrated research program combining breeding, agronomy, plant physiology and extension services. Current research is aimed at further increasing the yield and oil content of canola, increasing blackleg resistance and triazine tolerance, development of a range of maturity types (especially early maturing types for low rainfall areas) and developing new speciality varieties including those suitable for the manufacture of condiment mustards and industrial oils.

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[2] High levels of erucic acid in oil have been associated with heart tissue degeneration in laboratory animals.

[3] High levels of glucosinolates in the meal can cause reduced growth in stock fed on canola meal based supplements.

Since 1980, eight canola varieties and two high erucic acid varieties (for industrial oils) have been released from the Victorian breeding program. These varieties and the associated improvements over previous varieties are listed in appendix 1. The improvements in yield and composition of canola are the result of agronomy and breeding; however it is beyond the scope of this review to apportion benefits between these sub-programs. In the proceeding quantitative benefit-cost analysis it is assumed that the program managers apportion the available resources in an optimal manner to maximise the benefits derived from research.

2.2 Methods

The quantitative benefit-cost analysis of the Victorian canola research program was performed using PRISM-Wimmera (Profitable Resource Integration, Southern MIDAS, developed for the Wimmera region of Victoria). PRISM was developed from a joint research program between the Victorian Department of Natural Resources and Environment and the New South Wales Department of Agriculture, and supported by the Grains Research and Development Corporation. PRISM was developed from MIDAS (Model of an Integrated Dryland Agricultural System) produced by the Western Australian Department of Agriculture in the early 1980s (Kingwell and Pannell 1987). PRISM-Wimmera was developed by the Victorian Department of Natural Resources and Environment to be representative of a mixed farming enterprise in the Wimmera region. PRISM-Wimmera is a linear programming model which optimises on-farm profit for a mixed sheep and cropping enterprise. The model chooses the optimal combination of wheat, barley, canola, field peas, chick peas, faba beans, pasture and fallow to maximise the profit over a three year period for a 1,000 hectare farm. The model considers the paddock history and the relative costs and prices of each activity in determining the most profitable mix of crops and pasture over the three year period[4]. The constraints on crop areas and paddock histories used in the model are contained in Tables 1 and 2 respectively. It is necessary to constrain the maximum area allowable for each activity as the linear programming model maximises profit over three years, without considering sustainability or risk management when generating the solution. Constraining the area available for each activity forces the model to choose a mixed enterprise which is more likely to reflect current risk management and sustainable agriculture strategies employed by farmers. The majority of Victorian canola production occurs in the Wimmera-Mallee regions in north western Victoria, and in the analysis it is assumed that the results generated by PRISM-Wimmera (hereafter referred to as the PRISM model) will be indicative of the returns in other regions. For this reason state average crop yields were used for the analysis.

Table 1: Crop Constraints

Activity	Area (ha)
Canola	200
Wheat	400
Barley	240
Field peas	100
Chick peas	250
Faba beans	200
Pasture	333
Fallow	333

Table 2: Paddock Histories

Activities Year 1	Year 2	Area (ha)
Fallow	Wheat	200
Pasture	Wheat	200
Wheat	Pasture	200
Wheat	Fallow	200
Barley	Pasture	100
Pasture	Barley	100

[4] For a full description of the PRISM model contact Kate O'Brien at the Victorian Institute of Dryland Agriculture, Private Bag 260, Horsham, 3401.

The annual (state average) yield and unit value of canola, wheat, barley, field peas, chick peas and faba beans used for the analysis are contained in Table 4. Regression analysis of the yield and unit value of each crop was performed over the period 1980 to 1995. The analyses revealed statistically significant increases in the nominal price of canola (p-value<0.01), chick peas (p-value<0.01) and faba beans (p-value<0.01) over the period. The nominal prices of wheat, barley and field peas remained constant during this period. Regression analysis showed that the yield of canola increased by 62.5 per cent (p-value=0.02) between 1980 and 1995, while all other crops maintained a constant yield over this period. The prices and yields used in the analyses presented in this paper were derived from regression models when a statistically significant relationship existed, and where no significant relationship was evident, mean values were used. Observed prices and yields were not used, as short run variations in these values may distort the benefits achieved by productivity increases.

To determine the returns to research during the period 1980-95 it was necessary to apportion the total increase in the operating cash surplus between the effects of changing relative prices and increased productivity. To achieve this, the PRISM model was run using 1980 prices and yields to establish a baseline for the analysis. The model was then run using 1980 yields and 1995 prices to determine the effect of changing relative prices on the optimal enterprise mix and profit. A third run was performed using 1995 prices and yields to determine the increase in profit generated by the increase in canola yields since 1980. As canola was the only crop to experience an increase in yield over this period the difference in profit between the second run (1980 yields and 1995 prices) and the third run (1995 prices and yields) can be attributed to the productivity gains in growing canola.

The yields and prices used in the benefit-cost analysis are listed in Table 3. The prices per tonne of wheat and barley were set at $173 and $134 respectively, which represent the mean values for the period 1980 to 1995. The price of field peas, chick peas and faba beans were set at an arbitrary value of $10 in 1980, as very little of these commodities were grown during this time and no price data was available. The 1980 price of canola was set at the value predicted by the regression model of $239. The 1995 prices of canola ($347), faba beans ($227) and chick peas ($569) were set at the values predicted by the respective regression models. The 1995 price of field peas ($237) represents the mean value for the period. The price of wool was held constant throughout the analysis at an arbitrary value of 500 cents per kilogram. The yields of wheat, barley, field peas, chick peas and faba beans were set at the mean values over 1980 to 1995. The canola yields of 0.8 tonnes per hectare in 1980 and 1.3 tonnes per hectare in 1995 were derived from the regression model. The cost of producing each commodity was held constant at the default (1995) values contained in the model.

Table 3: Prices and Yields[a] Used in The Benefit-Cost Analysis

Crop	Prices ($/t)			Yields (t/ha)		
	1980	1995	1998	1980	1995	1998
Canola	239	347	370	0.84	1.30	1.44
Wheat	173	173	173	1.79	1.83	2.03
Barley	134	134	134	1.70	1.57	1.56
Field peas	10	237	237	1.25	1.27	1.17
Chick peas	10	473	568	1.34	1.33	1.34
Faba beans	10	236	252	1.16	1.16	1.23

(a) Yields are generated by the PRISM model using the formula: Yield = Transpiration x Transpiration Efficiency x Weed and Disease Index x Nitrogen Index. Variations in the yields of wheat, barley, field peas, chick peas and faba beans are due to the agronomic effects of preceding crops.

The PRISM model was also used to estimate the returns to research that could be expected over the next three year period (1995-98). Future prices for canola, chick peas and faba beans were predicted using the regression models derived from historical data. The expected yield increase for canola over this period was determined using the regression model used in the previous analysis. All other prices and yields were held constant at their mean values. The model was run using 1995 yields and 1998 prices to determine the effect of changing relative prices on the optimal enterprise mix and profit. The model was then run using 1998 prices and yields with the difference in profit between the two runs again attributable to the productivity gains in growing canola. The results are summarised in Table 5.

Results

Using 1980 prices and yields, PRISM predicted the optimal enterprise mix to consist of wheat, barley, field peas and pasture for sheep (Table 5). The model grew 90 hectares of field peas in year one despite the price being set at only $10. This reflects the rotational benefits and stock (sheep) feed value of a legume crop in the selecting the most profitable enterprise mix over the three year period. The operating cash surplus was $33,998 over three years.

In the second run of the model, the grains prices were changed to 1995 values (with all yields left at the 1980 values) to determine the effect of changing relative prices on the optimal enterprise mix. Under these conditions canola, chick peas and faba beans entered the rotation and the total area of cereals and pasture decreased. The operating cash surplus increased to $466,804.

Finally the yield of canola was increased from the 1980 value of 0.8 tonnes per hectare to the 1995 value of 1.3 tonnes per hectare (with all other yields remaining at average values). Under these conditions the area of canola and pasture was increased and the total area of cereal crops decreased further. The operating cash surplus also increased to $549,723. The benefit derived from increasing the yield of canola is the difference between the operating cash surplus in the final run and that obtained in the second run, which is $82,923 over the three year period (or $27,640 per annum).

For the benefit-cost analysis it was assumed that the canola yield and the resulting cash surplus increased linearly from 1980 to 1995. As 1980 was the base year for the analysis it was assumed that the additional operating cash surplus was zero in this year and increased linearly (by $1,843 per annum) to reach the 1995 value of $27,640. The additional cash surplus is generated for a 1,000 hectare farm growing 200 hectares of canola per annum. To calculate the total benefits in each year the benefit per farm was applied to the actual area of canola grown in Victoria during that year. The results are summarised in Table 6.

The total benefits derived from increases in the yield of canola over the period 1980-95 were calculated to be $26,772,702 (1995 $). In this analysis it is assumed that all of these benefits have been due to the research and extension work of the Victorian oilseeds program and that net spillovers between the research programs of other states and Victoria are zero. The assumption of zero net spillovers was made as no data was available on seed sales by state and variety, and anecdotal evidence suggested that both spillovers in and out of Victoria have occurred.

Table 4: Victorian State Average Yields and Australian Average Prices for Canola, Wheat, Barley, Field peas, Chick Peas and Faba Beans (1980-95)

	CANOLA		WHEAT		BARLEY		FIELD PEAS		CHICK PEAS		FABA BEANS	
YEAR	Yield (t/ha)	Price ($)	Yield (t/ha)	Price ($)	Yield (t/ha)	Price ($)	Yield (t/ha)	Price ($)	Yield (t/ha)	Price ($)	Yield (t/ha)	Price ($)
1980-81	0.82	259	1.77	155	1.38	141						
1981-82	0.93	230	1.87	156	1.46	111						
1982-83	0.32	239	0.30	176	0.27	158	0.50	256				
1983-84	0.98	291	2.46	164	1.88	131	1.35	188	1.75	178	1.00	178
1984-85	1.01	303	1.75	172	1.31	132	1.02	190	0.68	145	0.50	145
1985-86	1.13	276	1.49	167	1.22	120	1.00	190	1.10	191	0.12	191
1986-87	1.19	241	2.05	147	1.67	112	1.69	187	2.00	188	2.00	188
1987-88	1.10	269	1.83	163	1.45	122	1.09	257	1.02	224	1.24	224
1988-89	1.23	352	1.87	204	1.56	146	1.19	245	1.27	224	1.63	224
1989-90	1.30	305	2.09	201	1.79	145	1.28	253	1.56	446	1.00	224
1990-91	0.90	285	1.64	132	1.41	120	0.80	268	0.63	357	1.00	218
1991-92	1.20	283	1.73	199	1.68	133	1.09	238	1.26	294	0.83	213
1992-93	1.30	319	2.53	179	2.02	137	1.41	258	1.63	376	1.08	217
1993-94	1.60	354	2.59	174	2.17	120	1.46	245	1.38	400	1.22	224
1994-95	0.90	392	1.07	212	0.79	184	0.41	303	0.28	569	0.47	227
p-value[a]	0.02	<0.01	0.41	0.08	0.25	0.36	0.96	0.13	0.40	<0.01	0.99	<0.01

(a) The p-value indicates the statistical significance of the x-coefficient of the linear regression models generated for the yield and price for each commodity. P-value = 0.05 was used as the critical value for the regression analyses (a p-value < 0.05 indicates a significant change in the variable over the period 1980-95, whereas a p-value > 0.05 is indicative of a constant value for the period).

Table 5: Summary of The Results Generated by The PRISM Model

	CANOLA Area (ha)	WHEAT Area (ha)	BARLEY Area (ha)	FIELD PEAS Area (ha)	CHICK PEAS Area (ha)	FABA BEANS Area (ha)	PASTURE Area (ha)
1980 yield & 1980 price							
Year 1	-	200	25	90	-	-	314
Year 2	-	300	-	-	-	-	318
Year 3	-	400	240	-	-	-	318
Operating cash surplus[a]	$33,998						
1980 yield & 1995 price							
Year 1	190	10	240	100	250	150	-
Year 2	-	110	190	100	250	200	150
Year 3	-	400	50	100	250	200	-
Operating cash surplus	$466,804						
1995 yield & 1995 price							
Year 1	200	-	222	100	250	150	65
Year 2	200	52	110	100	250	200	88
Year 3	200	250	-	100	250	200	-
Operating cash surplus	$49,723						
1995 yield & 1998 price							
Year 1	200	-	222	100	250	150	65
Year 2	200	14	186	100	250	200	50
Year 3	200	250	-	100	250	200	-
Operating cash surplus	$673,075						
1998 yield & 1998 price							
Year 1	200	-	222	100	250	150	65
Year 2	200	14	186	100	250	200	50
Year 3	200	250	-	100	250	200	-
Operating cash surplus	$701,441						

(a) Operating cash surplus is the total cash surplus over the three year period

Table 6: Benefit-Cost Analysis of The Victorian Canola Research Program

YEAR	AREA (ha)	COSTS ($)	BENEFITS[b] ($ per farm)	BENEFITS ($)	VALUE OF PRODUCTION ($)
1980-81	2,500	342,144[a]	1,843	23,033	1,135,384
1981-82	3,800	620,212[a]	3,685	70,020	1,575,377
1982-83	3,800	842,496[a]	5,528	105,031	510,103
1983-84	4,300	1,051,018	7,371	158,467	2,013,806
1984-85	8,600	1,244,823	9,213	396,169	4,095,246
1985-86	21,800	1,396,711	11,056	1,205,089	9,891,891
1986-87	18,100	1,491,342	12,899	1,167,315	7,047,545
1987-88	21,000	1,483,112	14,471	1,547,821	7,853,281
1988-89	13,300	1,318,102	16,584	1,102,823	6,691,663
1989-90	12,400	1,228,470	18,426	1,142,440	5,393,510
1990-91	10,200	1,021,455[a]	20,269	1,033,724	2,783,784
1991-92	23,000	991,638[a]	22,112	2,542,849	8,068,218
1992-93	18,500	845,729	23,954	2,215,780	7,836,247
1993-94	29,200	1,304,716	25,797	3,766,365	16,706,401
1994-95	74,500	1,337,370	27,640	10,295,776	26,283,600
PV		16,519,338		26,772,702	107,886,056
NPV	10,253,364				
BCR	1.6				
1995-96	100,000[c]	1,300,000[a]	9,455	4,377,469	51,001,667
1996-97	95,000[c]	1,300,000[a]	9,455	3,850,551	49,543,450
1997-98	95,000[c]	1,300,000[a]	9,455	3,565,326	50,498,833
PV		20,419,338		38,566,048	258,930,006
NPV	18,146,710				
BCR	1.9				

(a) Estimated by the authors as no data were available. All costs are in 1995 dollars.

(b) Benefits per farm are based on the notional 1,000 hectare farm in the PRISM model. It was assumed the yield increase of 62.5 per cent between 1980 and 1995 occurred linearly at a rate of 3.3 per cent per annum, and the resulting benefits grew at the same rate. To determine the total benefits, the benefit per farm was then multiplied by the equivalent number of notional farms needed to grow the actual amount of canola produced in Victoria in that year. The benefits for the period 1980-95 are expressed in constant 1995 dollars (1995 $). A discount rate of eight per cent was used to calculate the benefits for the period 1995-98.

(c) ABARE estimates from the Australian Crop Report, June, 1996.

The cost of the Victorian oilseeds research program includes all State, Commonwealth and GRDC funding to the Department of Natural Resources and Environment. The research expenditure per annum is listed in Table 6. The benefit cost analysis was performed over the period 1980-95. Although the research program started in the mid 1970s no records exist detailing expenditures before 1983-84, and expenditures before 1980 are considered to be minimal (Salisbury, P. 1996, pers. comm. Sept.). The total amount spent during the period 1980-95 was $16,519,338 (1995 $). The resultant benefit-cost ratio (BCR) for the Victorian canola program over the period 1980-95 was calculated to be 1.6 (that is, for every $1 invested in research, the value of the benefits derived has been $1.60). From Table 6 it can be seen that in the initial years of the research program the costs exceeded the benefits by a factor of 10. Throughout the 1980s the benefits increased as the yield and area of canola increased. By the 1990s the benefits derived from the research program exceeded the costs, and the BCR was greater than unity. This reflects the establishment of the canola industry during this period and the role of the research program in developing a profitable enterprise.

A forward looking benefit-cost analysis was also performed using the PRISM model to estimate the returns to research over the period 1995-98. In this analysis the prices of wheat, barley, field peas and wool were held constant at the mean values used previously. The yields of wheat, barley, field peas, chick peas and faba beans were also held constant at their mean values. The 1998 prices for canola, chick peas and faba beans were predicted using the linear regression models generated for the previous analysis. The analysis assumed that the yield of canola continued to increase at 3.3 per cent per annum and ABARE predictions of the area of canola planted in each year were used to determine the total benefits. The costs of the research program were assumed to remain constant in real terms over the next three years. The net present value of the returns from research over the period 1995-98 was calculated to be $11.8 million compared with research expenditure of $3.9 million (Table 6). This represents a BCR[5] of 3.0 for the Victorian canola research program over the period 1995-98. The increase in benefits relative to costs during 1995-98 raised the benefit-cost ratio for the entire period (1990-98) to 1.9 (compared to the value of 1.6 obtained for the period 1980-95).

This analysis does not seek to project benefits from previous and current research beyond 1998, but indicates the magnitude of the benefits that can be expected to flow from the research over the three year period 1995-98. The benefits were not projected beyond 1998 as the yield of canola may not continue to grow at 3.3 per cent per annum for an extended period of time. It is recommended that a similar analysis is conducted in 1998 to compare the magnitude of the benefits predicted in this paper with the actual achievements of the canola research program. This approach would allow the progress of the research program to be mapped throughout the 1990s, and would provide management with valuable information to assist in the allocation of marginal funding between programs.

Sensitivity analysis was performed using the PRISM model to determine the minimum productivity gains required over the period 1995-98 to produce total benefits equal to the research expenditure for the three years. The results of the analysis are presented in Table 7 and show that the historical annual yield increase of 3.3 per cent per annum would need to decrease to one per cent per annum to reduce the BCR[5] below one.

Table 7: Sensitivity Analysis

Annual yield increase (%)	BCR[5]
3.3	3.0
2.5	2.3
1.7	1.5
1.3	1.1
0.9	0.8

[5] The BCR ratio presented here represents the ratio of the benefits from research realised during the period 1995-98 to the research expenditure in that period. This will include benefits that have come from previous research and excludes benefits that may flow in future years from current research.

2.3 Conclusion

The PRISM model provides a tool that allows rigorous and rapid benefit-cost analyses of grains research. Previous benefit-cost analyses, performed using less sophisticated methods, tended to overstate the value of grains research as substitution effects were not accounted for and individual project evaluations resulted in benefits being counted more than once. The PRISM model is a whole farm model that can be used to be predict the net increase in profit brought about through productivity gains. When productivity gains result in one crop being substituted for another the benefit gained is the difference in the profitability between the two crops net of any effects (positive or negative) on the yield of subsequent crops. There are also rotational constraints that affect the degree of substitution that can occur. These factors are accounted for by PRISM and can result in substantially lower estimates of the benefits from research than would be generated by less sophisticated methods. Productivity gains are usually the result of the combined efforts of several sub-programs or research projects. Ex ante benefit-cost analysis of these individual projects often results in further over estimation of the returns to research as the benefits from the entire program are assigned to each project. This analysis makes no attempt to ascribe proportional benefits to individual projects or sub-programs but presents a rigorous analysis of the returns to the Victorian canola research program. The BCR ratio for the period 1980-95 was found to be 1.6, which represents good returns to investment in for a developing industry. The BCR for the period 1980-98 was found to be 1.9, which indicates that the returns from research will continue to increase over the next three years.

The PRISM model is suitable for the evaluation of other crop breeding programs and the effects of technological change on the profitability of mixed cropping and sheep enterprises. However, it is not an appropriate tool for answering questions regarding the sustainability of these enterprises, as the model considers only a short period of time when generating the optimal mix of crops and pastures. To answer long term questions regarding agricultural sustainability, time path analysis, optimal control methods or a dynamic programming approach should be used.

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Appendix One: New Varieties Generated by The Victorian Canola Research Program (1980-95)

Year	Variety released	Benefits
1980	Marnoo	Canola quality - meets international standards for oil quality and content.
1984	Tatyoon	Canola quality Blackleg resistance Increased yield
1988	Nindoo	Canola quality Increased blackleg resistance Increased yield
	Taparoo	Canola quality Early maturing Increased yield
1993	Dunkeld	Canola quality with increased oil (3%) and protein the meal (1%) Increased yield
	Siren	Triazine resistant
	Rainbow	Increased yield Increased blackleg
1995	Hemola 7 & 9	High erucic acid - for industrial oil
	Karoo	Triazine resistant Increased yield Early maturity

Source: Salisbury, P. 1996, pers. comm. Nov. 6.