An Assessment of the Economic, Environmental and Social Impacts of NSW Agriculture's Wheat Breeding Program

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Economic Research Report No. 17

May 2004

NSW Agriculture

ISSN 1442-9764

ISBN 0 7347 1580 3

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Citation:
Brennan, J.P., Martin, P.J. and Mullen, J.D. (2004), *An Assessment of the Economic, Environmental and Social Impacts of NSW Agriculture's Wheat Breeding Program*, Economic Research Report No. 17, NSW Agriculture, Wagga Wagga.

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Acronyms and Abbreviations Used in This Report

ASW	Australian Standard White
APW	Australian Premium White
AH	Australian Hard
APH	Australian Prime Hard
AWB	Australian Wheat Board
CSIRO	Commonwealth Scientific and Industrial Research Organization
EGA	Enterprise Grains Australia
fob	free on board
FTE	full;-time equivalent
GRDC	Grains Research and Development Corporation
NSW	New South Wales
WWAI	Wagga Wagga Agricultural Institute

Acknowledgments

We would like to acknowledge the assistance and cooperation of a number of people within NSW Agriculture who helped with data and information. In particular, John Oliver and Helen Allen made valuable contributions. We would also like to acknowledge the assistance of Richard Williams of AWB Ltd in supplying some information to allow us to calculate the program's varieties' share of wheat production. Also, we owe a debt to industry representatives who provided confidential information to allow us to estimate the program's share of sales outside the AWB.

Executive Summary

The Wagga wheat breeding program has been operating for over 100 years. In that time, it has released a flow of new wheat varieties for wheat growers in south-eastern Australia. Those varieties have led to increases in both yields and grain quality. The average annual rate of yield improvement in NSW has been 3.2% compared to the average for Australia of 2.4% with a significant proportion of these productivity gains arising from new varieties.

In this analysis, the investment in that program from 1980 to 2003 has been evaluated. Given the lags inherent in wheat breeding investments, the benefits from those investments are being measured from 1993 to 2020. The broad structure of the program has remained relatively stable for most of the period since 1980. The program consists of 2-3 wheat breeders, one breeder-pathologist, and a cereal chemist, with appropriate technical and field support, totaling approximately 15 full-time equivalents per year. The costs of the program have averaged approximately $1.2 million per year over the period.

In assessing the Wagga wheat breeding program it is important to consider how the industry would have developed without the program. The benefits of the program were measured as the difference in returns from improved wheat varieties in NSW over that period and the returns that would have been achieved in the absence of the Wagga breeding program. The assumption used to determine the impact without the Wagga program was that the rate of yield improvement in NSW would have been the same as for the rest of Australia. For quality, without the Wagga program the assumption was that in southern NSW the increase in quality would have been 20% slower, and in the north there would have been no change in the rate of quality improvement.

Not all of those gains from new varieties in NSW are attributable to the Wagga wheat breeding program. Over half of all productivity gains are attributable to technologies other than new varieties and other breeding programs have contributed some of new varieties adopted. Wheat breeding within NSW was estimated to have increased the value of wheat per hectare (incorporating both yield and quality) by approximately 0.50% per year in southern NSW, and by approximately 0.15% per year in northern NSW. The share of the area sown to wheat in NSW of Wagga program varieties over the study period averaged around 46% in southern regions and 11% in northern regions. The benefits were projected into the future on the basis that the varieties released before 2003 will have a significant impact on production until 2013, but from then, these benefits will decline to zero by 2020.

Based on these assumptions, the benefit-cost ratio found in the analysis was 8.4, with an internal rate of return of 16%. The Net Present Value of the total resources used in the program over the period since 1980 was estimated at $321 million. The economic benefits of the breeding program are shared by producers, processors and consumers in the wheat industry, some of whom live overseas. Because Australia is largely a price taker on world wheat markets and because the wheat processing and distribution sector in Australia is generally considered to be competitive, most of the benefits of the wheat breeding program are likely to remain with producers. However these gains are offset by declines in the world price in response to advancing technology throughout the world.

These economic benefits have positive social consequences, largely through their contribution to the incomes of farmers and those who handle and process wheat in regional NSW. Some of

these gains are in the form of new marketing and processing industries around the increasingly specialised industry segments resulting directly from the changes that have occurred in wheat varieties. Perhaps these new skills add to the social capital of towns in the wheat belt of NSW.

In environmental terms, the wheat breeding program itself is not likely to have major impacts, since the wheat industry would have been very similar whether or not there was a Wagga breeding program. However, to the extent that improved productivity from the Wagga program's varieties has allowed an expansion of the wheat industry, there could be some negative environmental consequences of the breeding program, such as those arising from the clearing of land, increased cultivation and increased use of herbicides. On the other hand, the high levels of disease resistance developed and maintained has meant that wheat production is not associated with large-scale fungicide use, and hence the danger of chemical contamination of the environment is less than it would have been without the resistance developed in this program. Some of these environmental impacts affect the costs and incomes of wheat farmers and hence are reflected in economic benefits and some spill over to the broader community and have not been valued here.

It is not clear that these social and environmental impacts would be much different without the Wagga breeding program, except through the extent to which the Wagga program has allowed the wheat industry in NSW to develop more than it otherwise would have. Without the Wagga program the slower gains in yield and quality would also be associated with some social and environmental impacts, and it is the difference that is critical in evaluating the Wagga program.

The costs of this program have been met partly by the NSW taxpayers through NSW Agriculture and partly by the grains industry through levies from the Grains Research and Development Corporation (GRDC). The recent introduction of variety royalty payments ("end-point royalties") has not yet led to significant funding, but may be expected to do so in the future. The nature of the outputs of plant breeding programs is that there are large economic benefits that flow directly to producers, processors and consumers in the industry. However the social and environmental impacts on the broader community, while not explicitly valued here, are considered to be small relative to economic benefits and relative to some other programs of NSW Agriculture that have been evaluated.

Hence it is appropriate that the industry, though GRDC levies and royalties on production, has increasingly funded the operations of the wheat breeding program. Recent institutional changes for the wheat breeding program have made it even more commercially-based for the future and less reliant on government funding.

The new institutional arrangements for wheat breeding programs and the strengthening role of the private sector in supplying varieties traditionally supplied by the public sector mean that the place of public wheat breeding programs is being re-assessed. A key question is whether publicly-operated programs, can offer some additional benefits either to the industry or to the community, which would not result from the complete privatisation of the wheat breeding sector. While those issues have not been addressed directly in this analysis, the results indicate that past investments in public wheat breeding program at Wagga have certainly been a productive use of public funds over the past 20 years or so.

1 Introduction

There has been a long history within NSW Agriculture of evaluating the returns from investment in specific research and development (R&D) projects. These evaluations were often used to support industry funding submissions and focused on the economic benefits from changes in farm productivity.

In 2003, NSW Agriculture began a more systematic process of evaluating the economic, social and environmental impacts of major programs of investment in research, extension and education. Five areas of investment were selected for evaluation of their economic, environmental and social impacts in 2003:

- an assessment of NSW Agriculture's wheat breeding program;
- an assessment of NSW Agriculture's advisory programs in water use efficiency;
- an assessment of net feed efficiency breeding research in beef cattle;
- an assessment of research and extension in conservation farming;
- an assessment of research and extension in annual weeds (*Vulpia*) in pastures.

This report presents the results of one of these initial evaluations conducted in 2003.

NSW Agriculture currently invests about $100m per year in research, extension and education activities making it the largest provider of research and development services within the NSW government sector. The opportunity cost of this investment is the benefit to the people of NSW were these resources used in other areas such as health and education. Hence it is important that NSW Agriculture can demonstrate that it uses these resources in ways that enhance the welfare of the people of NSW.

This suite of evaluations is designed to assess the economic, social and environmental impacts of some key areas of investment by NSW Agriculture. It is anticipated that each year another set of investment areas will be evaluated, so that a significant proportion of the Department's portfolio will be evaluated on a regular basis. This evaluation process serves a number of purposes. The first is an external requirement for accountability in the way NSW Agriculture uses the scientific resources in its care. This evaluation process can also be used within NSW Agriculture to assist in allocating resources to areas likely to have high payoffs and to assist in designing research and extension projects that have clearly defined objectives consistent with the role of a public institution like NSW Agriculture. Working through this formal benefit cost framework gives those involved – economists, research and advisory officers and managers - a greater appreciation of the paths by which, and the extent to which, research and extension activities are likely to have an impact at the farm level and hence lead to better projects. Part of this process is a greater understanding of other trends in the industry and of the extent to which "the market" is failing to deliver outcomes sought by the industry or by the community.

We would like to be able to value all economic, environmental and social impacts and relate these to the investments made, but generally we are only successful in valuing some of these impacts because of:

- uncertainty about the technology on farm production both now and in the future;
- uncertainty about environmental and social impacts both now and in the future;
- uncertainty about the value of environmental and social resources both now and in the future;
- limited resources to undertake these evaluations.

Our approach has been to first describe qualitatively the economic, social and environmental impacts of the actual or proposed investment. We also describe the rationale for government investment from a market failure viewpoint which seeks to identify the characteristics of the investment resulting in farmers individually or collectively under-investing in the areas under consideration. We examine the share of public and private funding in the investment and compare this to a qualitative assessment of whether the benefits from the investment flow largely to farmers or largely to the community.

We then attempt to quantify as many impacts as practicable to arrive at the common measures of economic performance such as a benefit cost ratio. There are insights to be gained from persevering with an empirical benefit cost analysis even under uncertain scenarios. A key step is to identify not only the expected impact of the investment on an industry, the "with technology" scenario, but just as importantly, how the industry would continue to develop without the investment by NSW Agriculture, the "without technology" scenario. Rarely is the "without technology" scenario a no-change scenario because there are usually other sources of similar technologies leading to ongoing productivity growth. This quantitative approach also gives an indication of the relative importance of key parameters such as the rate and extent of adoption of technology, the on-farm impacts, and the size of the investment and its time path.

In assessing the "with" and "without" technology scenarios, key outputs from research and extension activities and communication strategies are described to give credence to claims about the contribution of NSW Agriculture and to assumptions about the rate and extent of adoption of the technology.

In the case of wheat breeding, we are evaluating all activity within NSW Agriculture directed at breeding, evaluating, assessing and developing new bread wheat varieties for farmers. These activities are based at the Wagga Wagga Agricultural Institute, although in the past there was also input to the program from the Temora Agricultural Research and Advisory Station. The NSW Agriculture durum wheat breeding program at Tamworth is a separate activity and has not been included in this evaluation.

2 Wheat Breeding in NSW Agriculture

2.1 Public Sector Wheat Breeding

NSW Agriculture has a long history of involvement in wheat breeding, dating back to its origins in the late Nineteenth Century and the work of William Farrer. From that time, there has been a wheat breeding program at Wagga Wagga, involving collaborative efforts between wheat breeders, cereal chemists and plant pathologists. Since 1952, these researchers have been located at the Wagga Wagga Agricultural Institute (WWAI).

Until recently, all scientific wheat breeding in Australia was carried out in the public sector, largely because of the nature of the varieties produced. As a self-pollinating crop, wheat seed retained from one harvest can be used as seed for the next season's crop. In the past, that meant that a breeder could only recoup costs through the sale of the initial quantity of seed. Given that farmers traditionally purchased only small quantities of the seed of new varieties and built up supplies through farmer-retained seed, this made it virtually impossible for private breeders to receive recompense for their breeding costs, and so the wheat breeding programs were established in the public sector.

Each State Department of Agriculture established its own breeding program. In NSW, the University of Sydney also established a breeding program in Narrabri, focusing on developing wheat varieties for the north of the state. Prior to 1993, there was also a bread wheat breeding program in Tamworth, but in recent years this has been replaced by a program dedicated to durum wheat breeding.

In the 1980s, a hybrid wheat breeding program was established by a commercial company. In 1985, that company developed a high-yielding open-pollinated variety that they were unable to capture the benefits from in any meaningful way, and so it was simply released as a public variety *Vulcan*. In addition, the Commonwealth Scientific and Industrial Research Organization (CSIRO) developed a wheat breeding program in the late 1970s, aiming at producing high-yielding long-season wheat varieties for the high rainfall areas such as the tablelands. Several varieties have been released from that program, all of them feed quality and most of them red wheats that are not favoured by the majority of producers in the main wheat belt. In 2002, the CSIRO program jointly released with NSW Agriculture the early maturing spring variety *Drysdale* for the main wheat belt.

Wheat breeding has long been supported by the levies placed on growers, and the matching Commonwealth Government payments, through the Grains Research and Development Corporation (GRDC) and it predecessors (for example, see Brennan and Mullen 2000). Thus, farmers were able to act collectively to fund the public-sector wheat breeding programs. With the introduction of Plant Variety and Plant Breeders' Rights in the 1980s, breeders were able to have more control over returns from the use of their varieties through seed royalties. However, with the recent introduction of "end-point royalties", whereby all wheat sold or delivered for sale can be subject to a royalty payment, the incentives for private breeding programs have changed sharply. Private-sector breeding programs are now able to obtain income from the production of their varieties, and hence to take up breeding on a sound commercial basis[1].

[1] End-point royalties have been used for new wheat varieties released since about 2000, so that older varieties do not receive any such royalty.

As a result of these changed circumstances, and prompted by major changes to the GRDC funding of breeding programs, public wheat breeding programs have become more commercially oriented and are acting increasingly like private sector breeders.
In 2002, NSW Agriculture formed a joint venture with the GRDC, the Department of Primary Industries Queensland and the Western Australia Department of Agriculture to form Enterprise Grains Australia (EGA), which aims to breed varieties for the whole of Australia. At the same time, the private hybrid-wheat breeding program has also merged with the University of Sydney program, as Sun-Prime Seeds, while CSIRO has set up Graingene with other commercial partners to produce varieties for the main wheat belt. In addition, other private sector breeders entered the market.

The full implications of these recent changes are unclear, particularly in relation to the extent to which wheat breeding programs can become self-funding in the foreseeable future. The long lags in variety adoption and usage mean that for the next 20 years or so varieties that do not have end-point royalties will still have significant market share. As a result, it is difficult to predict the extent to which those royalties will enable breeding programs to be self-funding in the near future.

Another important issue for wheat breeding programs is the development of the new breeding technologies, particularly the use of biotechnology. In recognition of the importance of the use of molecular biology and genetic markers, NSW Agriculture has recently built a new biotechnology laboratory at WWAI, and has made a key investment in these new technologies. They are likely to have important impacts on the efficiency of the breeding process, particularly through the use of genetic markers in selection for important characteristics. With the recent investments, NSW Agriculture is in a strong position to incorporate those advances into its breeding program, although they have had little impact on the varieties released to date.

The key issue now for the continuation of the Wagga wheat breeding program, as part of EGA, is whether there is a need for public wheat breeding programs in the future. Until very recent years, the market share of varieties developed by the private sector has been extremely low (less than 5%), though with the recent commercial success of the variety *H45* it reached 10% of the production in NSW in 2001. Thus, public sector varieties have retained overwhelming dominance of NSW wheat production to date.

2.2 Objectives of the Wagga Wheat Breeding Program

The objectives of the NSW Agriculture breeding program are improved yield, disease resistance, quality, acid soils tolerance and diversity of sowing time. Historically, the effort has been specifically targeted at wheat growers in central and southern NSW. This regional focus has changed in the past few years and varieties are now targeted at the whole of the Australian wheat belt. The target environments include high-rainfall and low rainfall regions, as well as the acid-soils areas. The varieties are aimed to suit a wide range of sowing times from mid-April to the end of June. There is also selection for high quality winter varieties suited to grazing and recovery for grain production after grazing.

The disease resistance breeding objectives are determined by the economic importance of the disease, the existence of useable resistance and having an effective screening procedure. The diseases for which breeding for resistance is conducted are, in priority order: stripe rust, stem rust, leaf rust, Septoria tritici blotch and flag smut.

A wide range of quality types are selected, which include both hard and soft grained cultivars. The quality types include Prime Hard and Australian Hard varieties for export, Australian Hard varieties suited to the production of domestic pan bread (using a rapid dough process not used overseas), soft grained noodle wheat suited for the domestic and export industries, and speciality wheats such as Prime Soft wheat.

2.3 Inputs to Wheat Breeding in NSW Agriculture

The structure of the NSW Agriculture wheat breeding program at Wagga has been relatively stable over much of the past 20 years. The program consists of 2-3 wheat breeders, one breeder-pathologist, and a cereal chemist, although much of the input of some of these officers has been towards research rather than towards breeding (Table 2.1). The extent of the breeding resources at the Professional Officer level has averaged 3.5 full-time equivalents (FTE) per year, declining from 4.0 in the 1980s to 1.9 FTE in 2003. There have been on average 4.7 FTE Technical Officers, and 7.2 FTE Technical Assistants, with both tending to increase slightly as the Professional Officer input has declined. Overall, in the period since 1980 there were an average of 15.3 FTEs in the wheat breeding program, with the figure in 2003 marginally lower at 14.5 per year.

Table 2.1: Labour Inputs to Wheat Breeding Program
(Full-time equivalents)

Year	Total PO[a]	Total TO[a]	Total TA[a]	Total FA[a]	Total
1980	4.00	4.50	6.00	0.75	15.25
1981	4.00	4.50	6.00	0.75	15.25
1982	4.00	4.50	6.00	0.75	15.25
1983	4.00	4.50	6.00	0.75	15.25
1984	4.00	4.50	6.00	0.75	15.25
1985	4.00	4.50	6.00	0.75	15.25
1986	4.00	4.50	6.00	0.75	15.25
1987	4.00	4.50	6.00	0.75	15.25
1988	4.00	4.50	6.00	0.75	15.25
1989	4.00	4.50	6.00	0.75	15.25
1990	4.00	4.50	6.00	0.75	15.25
1991	4.00	4.50	6.00	0.75	15.25
1992	4.00	4.50	6.00	0.75	15.25
1993	4.00	4.50	6.00	0.75	15.25
1994	3.50	5.00	7.00	0.75	16.25
1995	3.50	5.00	7.00	0.75	16.25
1996	3.50	5.00	7.00	0.75	16.25
1997	2.50	5.00	7.00	0.75	15.25
1998	2.50	5.00	7.00	0.75	15.25
1999	2.50	5.00	7.00	0.75	15.25
2000	2.50	5.00	7.00	0.75	15.25
2001	2.90	4.90	6.90	0.75	15.45
2002	2.40	4.90	6.90	0.75	14.95
2003	1.90	4.90	6.90	0.75	14.45

a PO Professional Officer; TO Technical Officer; TA Technical Assistant; FA Field Assistant

The total costs of the program include salary and wages costs for these labour inputs, the on-costs associated with those salaries, the operating costs involved in the program, and capital costs. Using current salary rates for typical grades as at September 2003[2], with on-costs of 23%, the composition of the total labour costs over the period since 1980 is shown in Table 2.2. The annual labour costs over the period have averaged $928,000 (in real 2002 dollars), but have been lower than that average since 1997[3]. The approach used here assumes no change in the real cost of labour used in wheat breeding over the period of the analysis. If there has been an increase in real costs over that time, this approach will overstate the labour costs accordingly.

Table 2.2: Annual Costs of Wheat Breeding Program

	Total Labour *($'000)*	**Total Operating** *($'000)*	**Total Direct** *($'000)*	**Capital** *($'000)*	**Total** *($'000)*
1980	941[a]	92[a]	1,033	100[a]	1,133
1981	941[a]	92[a]	1,033	100[a]	1,133
1982	941[a]	92[a]	1,033	100[a]	1,133
1983	941[a]	92[a]	1,033	100[a]	1,133
1984	941[a]	92[a]	1,033	100[a]	1,133
1985	941[a]	92[a]	1,033	100[a]	1,133
1986	941[a]	92[a]	1,033	100[a]	1,133
1987	941[a]	92[a]	1,033	100[a]	1,133
1988	941[a]	92[a]	1,033	100[a]	1,133
1989	941[a]	92[a]	1,033	100[a]	1,133
1990	941[a]	92[a]	1,033	100[a]	1,133
1991	941[a]	92[a]	1,033	100[a]	1,133
1992	941[a]	92[a]	1,033	100[a]	1,133
1993	941	118	1,058	100[a]	1,158
1994	976	117	1,094	100[a]	1,194
1995	976	120	1,096	100[a]	1,196
1996	976	125	1,101	100[a]	1,201
1997	892	130	1,022	100[a]	1,122
1998	892	197	1,089	100[a]	1,189
1999	892	205	1,096	100[a]	1,196
2000	892	227	1,119	100[a]	1,219
2001	914	189	1,104	100[a]	1,204
2002	872	184	1,056	100[a]	1,156
2003	830	228	1,058	100[a]	1,158
Mean 80-03	***928***	***126***	***1,055***	***100***	***1,155***

a Estimated

[2] Professional Officer $68,968; Technical Officer $52,827; Technical Assistant and Field Assistant $37,221.

[3] Departmental overhead costs are not included in the labour costs, on the basis that those aggregate overheads would be the same whether or not there was a Wagga wheat breeding program. Thus, the marginal value of those overheads would be zero for the labour associated with the Wagga breeding program.

The operating costs in the program involve the chemicals and machinery operating costs for field work, materials used for seed packaging and storage, laboratory running costs, travel costs, etc. The total operating costs have averaged $126,000 (in real 2002 dollars), but have been higher in recent years than during the 1980s. Travel funds from Consolidated Revenue have declined in recent years. However, other operating costs have generally increased throughout the period (Table 2.2). Given the sunk cost nature of the capital such as land and buildings used in the program and the low level on new capital expenditure, annual capital costs are relatively low at an estimated $100,000. This includes expenditure on items such as glasshouses, machinery, plant and equipment. The total costs of the program have averaged $1,155,000 per year over the period since 1980 (Table 2.2).

Throughout the period since 1980, the GRDC (and its predecessors) have provided strong support for the Wagga breeding program. Over the period since 1980, on average 41%, of total funding has come from the GRDC (Table 2.3). In recent years, the GRDC contribution has been over 50%, and in the past four years, GRDC contributions have averaged 53% of total costs. In addition, in the most recent two years, royalties have amounted to an average of 5% of the total costs of the breeding program. Thus, total industry funding has increased from around 34% in the 1980s to 60% in 2002.

Table 2.3: Source of Annual Funds for Wheat Breeding Program

	Consolidated Revenue *($'000)*	**GRDC** *($'000)*	**Other** *($'000)*	**Total** *($'000)*	**% industry** *(%)*
1980	745[a]	388[a]	0	1,133	34%
1981	745[a]	388[a]	0	1,133	34%
1982	745[a]	388[a]	0	1,133	34%
1983	745[a]	388[a]	0	1,133	34%
1984	745[a]	388[a]	0	1,133	34%
1985	745[a]	388[a]	0	1,133	34%
1986	745[a]	388[a]	0	1,133	34%
1987	745[a]	388[a]	0	1,133	34%
1988	745[a]	388[a]	0	1,133	34%
1989	745[a]	388[a]	0	1,133	34%
1990	745[a]	388[a]	0	1,133	34%
1991	745[a]	388[a]	0	1,133	34%
1992	745	388	0	1,133	34%
1993	665	494	0	1,158	43%
1994	691	502	0	1,194	42%
1995	683	513	0	1,196	43%
1996	638	563	0	1,201	47%
1997	534	588	0	1,122	52%
1998	640	549	0	1,189	46%
1999	607	589	0	1,196	49%
2000	595	624	0	1,219	51%
2001	563	636	5	1,204	53%
2002	463	622	72	1,156	60%
2003	488	630	39	1,158	58%
Mean 80-03	***677***	***473***	***5***	***1,155***	***41%***

a Estimated

The extension of wheat varieties in NSW has been the domain of the extension agronomists. In the period before the mid-1990s, District Agronomists were the main contributors, aided by a smaller group of private agronomists and consultants. Since the mid-1990s, there has been an explosion of private agronomists and consultants, so that the Department's District Agronomists are now outnumbered. Given the existence of these agronomists, the breeding program has not needed its own direct or formal extension service. The varieties are promoted by the agronomists as part of their normal activities, and are not included in the costs here because they would occur whether or not the WWAI wheat breeding program existed.

Similarly, the extensive crop variety trials undertaken across NSW are not part of the breeding program, except insofar as they relate to the advanced breeding trials which have already been included in the costs. These variety evaluation trials would be necessary whether or not the breeding program existed, since the trials are independent of the source of the varieties tested. Therefore, given that we are assessing the differences between scenarios with and without the Wagga program, the costs of the variety evaluation trials are not included in the costs assessed in this analysis.

2.4 Outputs from Breeding Program

The key outputs of the wheat breeding program have been wheat varieties released for commercial production by farmers. Since 1980, 29 varieties have been released by the wheat breeding program at Wagga (see Table 2.4). These varieties are suited to a range of environments, sowing times and market types. They possess diverse disease resistances and acid soils tolerance. There are now varieties suited for sowing from mid-April to the end of June with quality suited to a wide range of end products. These include high quality winter wheats with grazing ability, particularly for grain recovery after grazing, soft noodle wheat for the domestic and export industries, hard wheat for domestic pan bread, and speciality wheats such as purple kibbling wheat.

In addition, a range of other outputs including publications and field days has been developed and produced as part of this program. To assist the efforts of the Departmental extension officers, the results of crop variety trials have been compiled into the *Winter Crop Variety Experiments* publication each year, and further information about varieties is provided in the Department's annual *Winter Crop Variety Sowing Guide*, both of which would still be required if there were no wheat breeding program at Wagga.

2.5 Outcomes from Breeding Program

The key outcome of the wheat breeding program within NSW Agriculture is increased productivity of wheat in both NSW and adjoining states, with the resultant increase in farm and community incomes that flow from increased productivity.

2.5.1 Economic outcomes

The direct outcomes of the improved varieties released by the breeding program are a more productive and profitable wheat industry in NSW. Where the improved varieties have increased yields, then for a given set of inputs the outputs increase. As a result, both production and productivity of wheat increases. Yields per ha on farm have increased considerably in NSW over the past 20 to 30 years, as a direct result of the new varieties produced by wheat breeders.

Table 2.4: Varieties Released from Wheat Breeding Program at Wagga since 1980

Variety	Year of Release	Sown Early/Mid	Hardness	Grade[a]
OSPREY	1983	Early		AH
QUARRION	1983	Early		ASW
CORELLA	1984	Mid		Soft
ROSELLA	1985	Early		ASW/Noodle
GREBE	1986	Early		Soft
DOLLARBIRD	1987	Mid		AH
OWLET	1987	Early		ASW
LARK	1989	Mid		AH
SHRIKE	1990	Mid		APW
DARTER	1993	Early		AH
SWIFT	1993	Mid		AH
WARBLER	1993	Early		Feed
CURRAWONG	1994	Early		Feed
TERN	1994	Mid		ASW (hay)
TRILLER	1994	Early		Soft
PETREL	1996	Mid		ASW
TAILORBIRD	1996	Mid		AH
DIAMONDBIRD	1997	Mid		AH
SNIPE	1997	Early		Soft
WHISTLER	1998	Early		ASW
WYLAH	1999	Early		AH
BABBLER	2000	Mid		APH
PARDALOTE	2000	Early		APW
THORNBILL	2000	Early		Soft
BOWERBIRD	2001	Mid		AH
LORIKEET	2001	Early		ASW/Noodle
KOELBIRD	2001	Mid		Special purpose (kibbling)
DRYSDALE	2002	Mid		AH
EGA_WEDGETAIL	2002	Early		APH

a ASW Australian Standard White, APW Australian Premium White, AH Australian Hard, APH Australian Prime Hard

Where the improved varieties have improved quality or allow production of a higher grade of wheat (as in the release of varieties for Prime Hard in southern NSW), the benefits are shown through the higher prices obtained for the wheat produced. It is clear from analysis of the economic returns from varieties, based on their relative performance in wheat variety trials, that varieties with qualities suitable for higher grades have a clear advantage in terms of economic returns to farmers. For example, Prime Hard prices are generally approximately $30 (or 15-20%) higher than for ASW wheat, which means that where the yields are within, say, 5% of the ASW varieties, farmers have higher returns with the APH variety, even if some extra inputs are required.

Where the improved varieties have higher levels of resistance to diseases, wheat productivity is increased, because of reduced disease losses. There is also a reduced likelihood of needing to use fungicides for disease control in wheat production.

The economic benefits from higher yields of better quality wheat are shared within the wheat industry by producers, processors, input suppliers and consumers, some of whom are non-residents of Australia. To the extent that Australia is a price taker on world markets, few of these benefits flow to overseas consumers and processors[4]. If we assume that the distribution and processing sector in Australia is competitive and that the inputs used in these sectors are readily available, most of the benefits from the wheat breeding program are retained by wheat producers. The burden of levies to fund the breeding program is shared within the industry in a similar way.

The other outputs of a breeding program, such as evaluation of varieties and publications on variety trial results, have industry benefits. There is a role at an industry level for an independent assessment of the relative merits of varieties from different sources, and NSW Agriculture provides an efficient means of delivering that assessment. The information and field days that are held to demonstrate and assess different varieties also provide industry benefits. No attempt has been made to value economic benefits in the form of knowledge about plant breeding that spill over to other breeding programs and to the farming and scientific communities more generally.

2.5.2 Social outcomes

As for economic benefits, the social outcomes of relevance are those that can be attributed to the Wagga program, over and above those that would have ensued from alternative sources of new varieties:

- Social outcomes arise from the improved prosperity of the wheat industry in NSW as a result of the Wagga breeding program. Given the dominance of wheat and the reliance on wheat as a source of income in many dryland farming systems, any improvements in wheat productivity have led to higher incomes than would have otherwise have been obtained for grain farmers, which in turn have meant increased spending in local communities and therefore more prosperous rural communities
- Many rural communities rely on the processing of wheat for their continued existence, with many towns having grain marketing cooperatives, local flour mills, stock-feed processing plants, bakeries, etc. The efforts of wheat breeders to meet the needs of the market specifications have resulted in these industries being more profitable and more beneficial in the local towns in providing employment and income, despite the on-going counter-trend of consolidation of smaller processing industries. NSW is the leading state in terms of industries based on wheat processing. Many of these benefits are already encompassed within the measure of economic benefits described above, but they also have a social dimension.

Advancing technology in wheat production worldwide has meant that the price of wheat has fallen and resources are released from agriculture to higher valued employment elsewhere in the economy. Research and development in Australia agriculture, such as the Wagga wheat breeding program, may have slowed down the rate at which resources leave agriculture and hence maintained regional economies.

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[4] Given that world prices respond to major changes in Australian production, it is difficult to sustain the assumption that Australia is simply a price taker in the world wheat market. Since Australia is one of the four major exporters, variations in its exports can and do affect world wheat prices. Therefore, some of the benefits of improved yield and quality are likely to flow to overseas consumers, even though the level of those benefits is likely to be small compared to those captured by Australian producers.

The additional production and the more specialised wheat quality types have led to increased opportunities for individuals and groups of farmers to meet particular market needs, and to form cooperative ventures to obtain price premiums for their production. Perhaps these new skills add to the social capital of towns in the wheat belt of NSW.

Because the seed of new varieties have been made readily available and there are no advantages in scale of production for particular varieties, wheat breeding has not favoured big producers over small producers or otherwise had any distributional consequences within the farming community.

2.5.3 Environmental outcomes

As for economic and social outcomes, the environmental outcomes of relevance are those that can be attributed to the Wagga program over and above those that would have ensued from alternative sources of new varieties. Some environmental impacts will occur on-farm and be reflected in the costs and returns of the producers and hence in the estimate of economic benefits. However there may be environmental outcomes, discussed below, that affect the broader community. Whether these outcomes are likely to be positive or negative in aggregate is most unclear, as is the marginal contribution of the Wagga breeding program (over that made by alternative breeding programs) to these outcomes. Hence, no attempt has been made to value these outcomes.

In environmental terms, the outcomes of wheat breeding include:

- The development of wheat varieties with improved disease resistance has meant that there has not had to be increased reliance on the use of fungicides in the wheat industry, as has occurred in some other industries. The reduced likelihood of needing to use fungicides for disease control means a reduced likelihood of dangerous chemicals reaching waterways and the environment generally.
- The expansion of cropping into lower rainfall areas in recent decades as a result of yield improvement is likely to have had a negative impact on soil structure in those regions, and has probably increased the risk of exposure to erosion, although the use of minimum tillage has minimised that increase. That is likely to have been associated with an increased usage of herbicides in those areas.
- The clearing of land to enable the expansion of wheat cropping into marginal environments has also had a negative impact on the environment, through higher water tables and possible impacts on salinity.

The extent to which improved varieties from the breeding program have made wheat production more reliable in different environmental and seasonal conditions has also reduced the riskiness of wheat production. This reduction in risk faced by wheat farmers means economic, environmental and social benefits, as production is likely to be higher where the risk is reduced, environmental considerations are likely to be given greater weight if the riskiness of production is reduced, and any reduction in income variability will have socially desirable outcomes.

2.6 Community v Industry Outcomes from Wheat Breeding

The extent to which the benefits from the Wagga breeding program are shared between the wheat industry and the Australian community has implications for public support for wheat breeding. Important economic, social and environmental outcomes were identified above. Many of the economic benefits from the Wagga program clearly flow to producers, but some

are also likely to flow to input suppliers, processors and consumers within the wheat industry. Estimates of these economic benefits are likely to include some private social and environmental outcomes. Some economic, social and environmental outcomes that spill over to the broader community were also identified. In addition, there are a number of further outcomes from the Wagga breeding program lending weight to some level of public support, which take the form of

- The genetic material contained in a wheat variety is a community resource, and it is likely that a less than optimal amount of genetic diversity would be maintained if its conservation were left to the private sector acting in their own interests (Smale 2002).
- Improved product quality has resulted in a reduction in the need for artificial food additives in wheat products, with subsequent benefits to consumers.

Improved resistance to public risk diseases (Ballantyne *et al.* 1994) provides industry-wide benefits. With public risk diseases, the activities of individual farmers in growing a susceptible variety can affect their neighbours, as the presence of a susceptible variety can lead to a build up of inoculum that can then spread to neighbouring properties and cause not only disease losses, but also a breakdown of the resistance in those varieties. Thus, the maintenance of resistance to such diseases provides benefits beyond those to the individual farmers growing those particular varieties, though they are unlikely to flow beyond the wheat industry.

Overall, then, wheat varieties that come from the breeding program have benefits for industry and for the community. The complexity of these outcomes is demonstrated by the complex funding arrangements that have been in place for wheat breeding in Australia. Throughout Australia, there is a mix of public, industry and private funding for the development of new varieties. On balance, it seems that the industry captures a larger share of the benefits of wheat breeding than does the community and hence we would expect industry to fund the larger share of the cost of wheat breeding programs. Institutional arrangements have been in place since the 1950s for the GRDC and its predecessors to collect levies for funding research such as wheat breeding. As noted above, on average, 41% of funds have come from industry sources, increasing to approximately 60% in recent years.

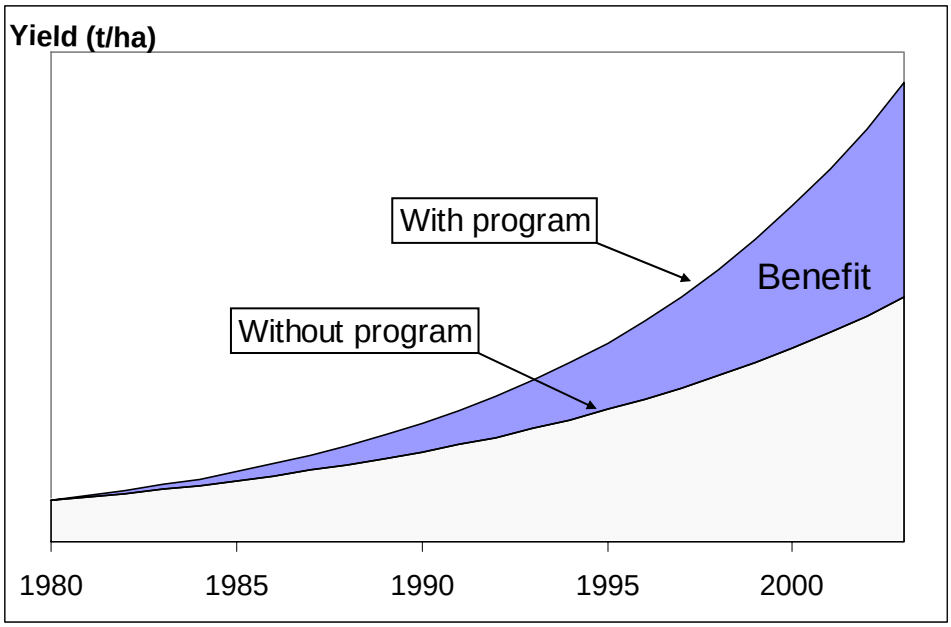
With the development of Plant Breeders Rights and the recent implementation of end-point royalties, we expect an even higher degree of industry funding in the future. All main breeding programs have been converted to a more commercial structure, and the likelihood is that increasing proportions of their funding will come from the flow of royalties, as well as from the GRDC support for the main wheat breeding organizations in Australia. As older varieties are replaced by more recent ones, the proportion of varieties with end-point royalties will increase, and the royalty flow is expected to increase in the future.

3 Defining the "With" and "Without" Scenarios

In this analysis, we have attempted to value the economic outcomes of the breeding program, in terms of the improved yield and quality arising from the varieties released by the breeding program. However, no valuation has been placed on the environmental and social impacts not reflected in productivity gains in the following analysis.

Not all the productivity gains in the NSW wheat industry since 1980 can be attributed to the Wagga breeding program. Some of the benefits that have flowed through higher-yielding and better-quality varieties in NSW since 1980 would have occurred if there had been no program at Wagga. However, it is likely that the rate of improvement would have been lower without the program. Thus the value of the program is the difference between the "with program" and the "without program" benefits (see Figure 3.1). Note that if environmental and social impacts were to be valued 'with' and 'without' scenarios would similarly have to be developed.

Figure 3.1: Benefits from Breeding Program



3.1 The "With Program" Scenario

The "with program" scenario is relatively simple to define for the period to 2003, as the program has existed for the whole of the period since 1980. The observed activities, inputs, outputs and outcomes over that period represent the "with program" scenario.

Since 1980, wheat productivity in NSW increased as a result of improved varieties from several breeding programs, and because of other factors such as more efficient use of inputs and improvements in agronomy and in the farming system being used.

The method used to identify the benefits from new varieties developed by NSW Agriculture, as distinct from these other sources of productivity growth, for each of the four main production regions ("Silo groups") in NSW is as follows:

- Estimate the annual rate of gain in variety value (combining yield and quality) in the region over the period
- Determine the portion of that growth that is due to varieties rather than management and agronomic inputs
- Measure the economic value of those gains in productive value from varieties
- Determine the proportion of those gains that can be attributed to NSW Agriculture's varieties rather than other varieties grown in NSW
- Calculate the value of that contribution over the period 1980 to 2002
- Estimate the benefits from 2003 to 2020 that will flow from the varieties developed and released in NSW Agriculture in the period 1980 to 2002.

3.1.1 Rates of yield and quality improvement

To estimate the annual rate of gain in wheat yields in NSW, the yields for each of the four NSW Silo Groups (South east, South west, North east, North west) were analysed. The annual rate of yield increase in the period 1980 to 2001 in the four Silo Groups, based on log-linear regression analysis[5], is shown in Table 3.1. Across NSW, the rate of improvement was 3.19% per year, while in each Silo Group the rate of increase ranged from 2.75% per year in the North east to 3.92% per year in the South east. In a study of 8 shires across NSW from 1965 to 1997, Brennan and Bialowas (2001) found that 54% of the improvement in wheat yields was due to variety improvement, and 46% was due to other factors. However, there have been remarkable changes in agronomic practices in the period since 1980, most notably the inclusion of crops such as canola in rotations, improved weed management, improved tillage practices and improved management of nitrogen (Brennan and Quade 2000). On that basis, we conservatively assume here that varieties contribute 30% of the improvement in NSW wheat yields since 1980. The annual yield gains from the program are 0.45% in the South east, 0.36% in the South west, 0.10% in the North east and 0.23% in the North west. These percentage increases are cumulative over time, since the yield increase each year is maintained and built on in all subsequent years.

In addition, Brennan and Bialowas (2001) showed that varietal change had led to an improvement in bread-making quality of wheat by 1.77% per year in the southern shires and 0.94% per year in the northern shires (where quality was higher at the start of the analysis period). On the basis that, we assume quality improvement of 1.80% per year in the south and 0.80% per year in the north, but we assume that only 30% of those increases were due to varieties, with the other 70% being the result of increased inputs (particularly nitrogen) and improved farming systems. There have also been improvements in aspects of wheat quality other than bread-making quality, such as the improvement in colour and colour stability of dough for noodles, but the different quality improvements are all assumed to have occurred at an equivalent rate to the improvement in bread-making quality for bread wheat.

Combining the rate of yield increase due to the Wagga program with the rate of quality increase gives the increase in value due to the program (Table 3.1). The average annual gains in the south are 0.46%-0.56%, while in the north they are 0.10%-0.23%.

[5] The log-linear analysis provides a convenient form of the equation for a parameter that has a constant rate of (compound) growth each year. It fits the equation $Y_n = Y_0 (1+a)^n$ in the form: $\log(Y_n) = \log(Y_0) + n \log(1+a)$, where Y_n is yield in year n, Y_0 is yield in year 0, a is the annual rate of growth and n is the number of years.

Table 3.1: Varietal Improvement With and Without Wagga Wheat Breeding Program, 1980 to 2001 ***(% per year)***

	South east	South west	North east	North west
Rate of yield increase per year:				
- with program	3.92%	3.60%	2.75%	3.18%
- without program	2.42%	2.42%	2.42%	2.42%
- difference	1.50%	1.19%	0.33%	0.76%
Proportion due to varieties	30%	30%	30%	30%
Yield increase due to program	0.45%	0.36%	0.10%	0.23%
Rate of quality increase per year:				
- with program	1.80%	1.80%	0.80%	0.80%
- without program	1.44%	1.44%	0.80%	0.80%
- difference	0.36%	0.36%	0.00%	0.00%
Proportion due to varieties	30%	30%	30%	30%
Quality increase due to program	0.11%	0.11%	0.00%	0.00%
Increase in value due to breeding	**0.56%**	**0.46%**	**0.10%**	**0.23%**

3.1.2 NSW Agriculture variety share

The data on the share of varieties from the Wagga breeding program in the total wheat production in NSW were based on several different sources. Up to 1988, the data relate to the percentage area sown to each variety in each shire, as collected by the Australian Bureau of Statistics, and collated by Fitzsimmons (1996). The shires were aggregated into Silo Groups based on groupings shown in Appendix A.

Since 1989, data have not been available on the *area sown* to different varieties, so it has been necessary to use the available data on the variety shares of the wheat *received for marketing* by the Australian Wheat Board (now AWB Ltd). From 1989 to 1995, Silo Group data on the share of AWB wheat receivals for the previous 6 Silo Groups (Fitzsimmons 1996) were modified to reflect the current four Silo groups. From 1997 onwards, data have been based on the percentage share of AWB receivals (R. Williams, AWB Ltd, Personal communication) for the north and the south of the state. For 1996, the data were interpolated between the earlier and later data, in view of the shire-level data available for 8 shires in NSW (Brennan and Bialowas 2001).

Since deregulation of the domestic wheat market, a large proportion of production has been marketed through channels other than the AWB. Given that prior to deregulation in 1989, the Australian Wheat Board controlled the vast majority of wheat marketed in Australia, the data on shares of AWB receivals prior to that time were taken as representative of all production. However, following deregulation, many other marketing channels opened up, and increasing amounts of wheat, particularly for domestic bread, biscuits, noodles and starch and ethanol, were traded through those other channels. Industry estimates were obtained on the proportion of varieties marketed for use in biscuits, noodles and starch and ethanol production in NSW in 2002. These figures were then assumed to be unchanged back to 1994. A five-year adjustment

process was assumed, so that the figures between 1989 and 1994 were interpolated linearly between the 1988 and the 1994 estimates for each Silo group.

For each Silo Group, the variety shares for AWB receivals and those for non-AWB wheat were aggregated (weighted by receivals in each system), to provide a percentage share of the total production that was made up of Wagga varieties. The steps to these calculations are as shown in Table 3.2. Because some of the individual data are confidential, the figures shown in this Table are generalised to indicate the method, and do not relate to any particular year.

Table 3.2: Illustration of Method of Calculation of Wagga Program's Share of Varieties in NSW Wheat Production

A. Total production (000 t)	3000	From ABARE
B. AWB receivals (000 t)	2000	From AWB
C. Non-AWB wheat (000 t)	1000	= A-B
D. Wagga Share of AWB receivals (%)	35%	From AWB (confidential)
E. Wagga Share of non-AWB wheat (%)	40%	Confidential industry sources
F. Wagga Share of AWB receivals (000 t)	700	= BxD
G. Wagga Share of non-AWB receivals (000 t)	400	= CxE
H. Wagga Share of total wheat production (000 t)	1100	= F+G
I. Wagga Share of total wheat production (%)	37%	= H/A

These calculations were made for each Silo Group for each year from 1980 to 2001. On that basis, the Wagga program's share of varieties in NSW production is as shown in Table 3.3.

In projecting beyond 2001, approximate recent levels (average of the five years to 2001) were assumed to continue for the next 10 years, before the impact of the current breeding program declines linearly to zero over the following ten years. Thus, for the South east the Wagga share was projected at 42%, 40% for the South west, 6% for the North east and 2% in the North west. From 2013, the share of those varieties was assumed to decline linearly to zero by 2020.

3.2 The "Without Program" Scenario

Without the NSW Agriculture wheat breeding program at Wagga, clearly NSW wheat growers would still have had wheat varieties to grow. Also, clearly, those varieties would have continued to improve in yield and quality over the period. Both Victoria and Queensland agricultural departments had wheat breeding programs during that period, and there was also the University of Sydney program at Narrabri, the private program at Tamworth aimed at hybrid wheats, and the CSIRO feed wheat program based in Canberra. NSW Agriculture has played an important role in evaluating and selecting varieties from other programs and from interstate. Without this information, knowledge of the agronomy and quality would not have been available as rapidly as they have been.

Table 3.3: Wagga Program's Share of Varieties in NSW Wheat Production

	South east	South west	North east	North west	NSW Total
1980	87%	86%	34%	17%	70%
1981	84%	82%	34%	15%	57%
1982	56%	57%	37%	17%	44%
1983	41%	44%	43%	18%	35%
1984	28%	33%	39%	20%	28%
1985	37%	38%	31%	14%	30%
1986	40%	35%	26%	10%	29%
1987	32%	26%	22%	8%	22%
1988	21%	22%	18%	7%	16%
1989	28%	24%	12%	7%	18%
1990	30%	30%	11%	5%	18%
1991	48%	43%	14%	6%	30%
1992	59%	37%	8%	3%	32%
1993	66%	35%	6%	4%	28%
1994	82%	75%	13%	8%	50%
1995	68%	37%	7%	4%	32%
1996	55%	30%	3%	3%	22%
1997	50%	32%	5%	3%	22%
1998	32%	32%	5%	2%	19%
1999	39%	41%	4%	1%	21%
2000	48%	49%	7%	2%	34%
2001	45%	47%	7%	4%	33%

However, there are definite advantages in selection of superior lines within a breeding program taking place within the environment in which the varieties are to be produced commercially. Selection from outside the region means that local production environments cannot be as well characterised, and local farming systems cannot be as well incorporated into the selection process. Thus, the without-project scenario is for improving productivity within NSW, but at a slower rate than was the case in the presence of the Wagga breeding program.

It is less clear what the "without program" scenario will be in the future. However, since the bulk of the analysis in this report relates to the period between 1980 and 2003, this issue is not a critical one for the outcome of the analysis, although it remains an important issue for evaluating benefits from 2003 to 2020.

The "without program" scenario for the analysis is based on the level of yield improvement that has been achieved in the other states apart from NSW in the period since 1980. The rest of Australia had increased yields at the rate of 2.42% per year, somewhat lower than that achieved in the NSW Silo Groups (Table 3.1). Therefore, we assume that without the Wagga breeding program, the rate of yield increase in each of the NSW Silo Groups would have been the same as for the rest of Australia. In relation to quality, other states have made substantial improvements in quality as well as NSW, but to a lesser extent than in southern NSW. Therefore, the without-project scenario for quality is that quality would have improved at 80% of the rate that has been achieved in southern NSW over the period of the analysis, and 100% of that achieved in the north.

For the period from 1980 to 2002, these assumptions may well be conservative in relation to the outcomes, since it is clear that selection within the production region confers considerable advantage on the gains that can be expected in a breeding program. As a result, if selection were made from outside NSW for NSW production regions in the case of there being no Wagga breeding program, then it is unlikely that the rate of yield increase would be as high as in the rest of Australia, where selection has been carried out in their target environments. However, in an analysis of future investments, some different assumptions might be necessary. There has been an increase in private-sector wheat breeding in very recent times, accompanied by the formation of larger wheat breeding entities that are better equipped than in the past to make selections based on performance in NSW environments. Therefore, it is likely that a “without Wagga program” scenario in future would include a higher rate of yield improvement than is used in this analysis based on varieties developed by 2002.

4 Benefit-Cost Analysis

4.1 Basis for Economic Analysis

The market framework of research-induced innovations as shifts in the supply and /or demand curves is well established (e.g., Alston *et al.* 1995). The development of yield-increasing varieties leads to a downwards shift in the supply curve, while quality-improving effects can be seen as an upward shift in the demand curve (Unnevehr 1986) or a shift between market segments (Brennan *et al.* 1989). For simplicity, in this study the change in the value of production is used as a measure of the change in social welfare. This approach is equivalent to assuming that the demand curve is perfectly elastic and the supply curve is perfectly inelastic.

Following Brennan (1989), there are several implications from this simplified approach. First, changes in wheat production from new varieties are assumed to be sufficiently small that there will not be a fall in the world wheat price. While this is unlikely to apply to the Australian wheat breeding industry as a whole, it seems a reasonable assumption for an individual breeding program. Second, it implies that no additional inputs are required to achieve the gains from the genetic improvements in the new varieties (although there are agronomic changes occurring at the same time). Third, the relevant price for estimating producer surplus is the farm gate price, since the supply of marketing services is assumed to be perfectly elastic at a fixed unit cost (that is, the difference between *fob* export prices and farm-gate prices does not vary with the levels of production). Under those conditions, total social welfare gains equal producer gains (Freebairn, Davis and Edwards 1982). Finally, possible increases in production that can take place because wheat becomes more competitive with other alternative enterprises are ignored. However, that supply response is likely to be small compared to the change in the value of production (Norton and Davis 1981). Any issues relating to an expansion in the area of wheat grown in NSW relative to livestock industries can be ignored in this analysis, as the wheat area in NSW in the early 1980s was greater than the area sown at any time throughout the period of the analysis.

4.2 Time Period of Analysis

Where a research program such as a breeding program is an on-going activity, it is necessary to define a particular period for the economic analysis. The Wagga wheat breeding program has been operating for approximately 100 years, and so defining a period for the analysis is difficult. However, given the available data, the analysis is based on breeding activity since 1980. This time period ensures that the results are not inflated by the outstanding success of the program in the varieties released in the 1970s, particularly the semi-dwarf varieties that have transformed the Australian wheat industry (Brennan and Fox 1995).

In wheat breeding, there are lags between the cross being made and the release of an improved variety. In recent years, these lags have averaged approximately 12 years, so that adoption on farms does not take place until the 13^{th} year after the initial cross. On that basis, the benefits are only measured from 1993 onwards. In the analysis, the costs from 1980 to 1993 are included.

There are always difficult attribution problems in the economic analysis of research, particularly in relation to an on-going breeding program. The approach adopted here assumes that the benefits from 1993 are solely due to breeding activities since 1980, even though some of those benefits could be attributed to earlier work. Similarly, the approach implies that none

of the expenditure between 1980 and 1992 had any impact before 1993. In addition, arbitrarily cutting benefits off at 2020 denies benefits in later years from breeding work between 1980 and 2003.

Given that the costs are measured until 2003, the benefits must be estimated for the future, since the varieties developed and released before 2003 will have a productive impact for many years. Brennan and Bialowas (2001) found that varieties are grown for approximately 17 years after release, so that the benefits are measured to 2020 (though in a declining rate of adoption from 2014 onwards). Thus the analysis involves a large component of ex-post analysis (relating to the period 1980 to 2003), but also involves some ex-ante analysis for the benefits flowing from those activities over the period to 2020.

The analysis is carried out using the total costs of the program, regardless of the source of the funds, so that the analysis relates to the effectiveness of the whole breeding program, not merely NSW Agriculture's contribution to it. A discount rate of 4% per annum is used in the analysis, and benefits and costs are expressed in 2002 dollars.

4.3 Valuing Benefits

The benefits calculated in the analysis are the net benefits from the program, that is, the difference between the "with" and "without program" scenarios (as shown in Table 3.1). The analysis is equivalent to carrying out separate analyses for the "with program" and "without program" scenarios and calculating the difference between them.

The steps in quantifying the gains from the Wagga breeding program are as follows:

1. Combine the yield per hectare in each year with the annual rate of improvement in yield and quality due to the program, to get an estimate of the equivalent yield gain (in t/ha) for that year[6]. Note that the rates of gain compound forward since the gains from each year are maintained and built on in subsequent years.
2. Combine that estimate of yield improvement with the annual area sown to obtain an estimate of the increase in production that year. This gives an estimate of extra production from breeding in NSW for that year (and all subsequent years).
3. The Wagga program's share of production is applied to that estimate, to give the Wagga contribution to increased production in NSW for that year (and all subsequent years).
4. The gain from the program is converted to 2002 dollars by multiplying by a real price of \$164/t[7], an average of the past five years. The same price was used for all years, to ensure that all production is valued the same. To the extent that real wheat prices have fallen over the period since 1980, this will understate the value of the benefits.
5. These benefits for each of the four Silo Groups are aggregated to give an annual benefit for NSW as a whole.
6. The benefits from 1993 until 2002 are compounded forward to 2002 and the benefits from 2003 to 2023 are discounted back to 2002 at a real discount rate of 4% to convert benefit flows to a present value in 2002.

[6] The calculations are made as follows: If yield in year n is Y_n and growth is a% per year, then $Y_n = Y_{n-1}(1+a)$. The extra production in year n because of the growth in yield is $Y_n - Y_{n-1} = Y_n - Y_n/(1+a) = Y_n\,(a/(1+a))$

[7] This is the on-farm equivalent of the average *fob* price of \$214/t over the five years to 2001.

The steps in the calculation for each Silo group are shown in Appendix A. The aggregation of the Silo Groups and the analysis itself is shown in Table 4.1. The overall contribution of the Wagga program was to increase yields and quality combined by 0.27% per year in the South east, 0.20% per year in the South west, and 0.02% per year in the North east and North west.

Table 4.1: Analysis of Benefits and Costs of Wagga Wheat Breeding Program

Year	Benefits from Program					Total	Net	Discounted		
	SE	SW	NE	NW	Total	costs	benefits	Benefits	Costs	Net
	($'000)	*($'000)*	*($'000)*	*($'000)*	*($'000)*	*($'000)*	*($'000)*	*($'000)*	*($'000)*	*($'000)*
1980	0	0	0	0	0	1,133	-1,133	0	2,684	-2,684
1981	0	0	0	0	0	1,133	-1,133	0	2,581	-2,581
1982	0	0	0	0	0	1,133	-1,133	0	2,482	-2,482
1983	0	0	0	0	0	1,133	-1,133	0	2,386	-2,386
1984	0	0	0	0	0	1,133	-1,133	0	2,294	-2,294
1985	0	0	0	0	0	1,133	-1,133	0	2,206	-2,206
1986	0	0	0	0	0	1,133	-1,133	0	2,121	-2,121
1987	0	0	0	0	0	1,133	-1,133	0	2,040	-2,040
1988	0	0	0	0	0	1,133	-1,133	0	1,961	-1,961
1989	0	0	0	0	0	1,133	-1,133	0	1,886	-1,886
1990	0	0	0	0	0	1,133	-1,133	0	1,813	-1,813
1991	0	0	0	0	0	1,133	-1,133	0	1,744	-1,744
1992	0	0	0	0	0	1,133	-1,133	0	1,677	-1,677
1993	799	334	5	26	1,163	1,158	5	1,656	1,649	7
1994	1,033	517	7	37	1,594	1,194	400	2,181	1,634	547
1995	1,902	805	12	63	2,782	1,196	1,586	3,661	1,574	2,087
1996	2,949	1,215	17	98	4,279	1,201	3,078	5,414	1,520	3,894
1997	3,557	1,588	24	117	5,285	1,122	4,163	6,430	1,365	5,065
1998	4,048	2,063	29	130	6,270	1,189	5,081	7,335	1,391	5,945
1999	4,910	2,638	36	146	7,729	1,196	6,533	8,694	1,346	7,348
2000	6,193	3,535	42	164	9,934	1,219	8,716	10,745	1,318	9,427
2001	7,337	4,343	49	189	11,918	1,204	10,714	12,395	1,252	11,143
2002	8,007	4,799	55	206	13,066	1,156	11,910	13,066	1,156	11,910
2003	8,688	5,262	60	223	14,233	1,158	13,075	13,685	1,113	12,572
2004	9,380	5,732	66	240	15,418	0	15,418	14,255	0	14,255
2005	10,084	6,209	72	258	16,623	0	16,623	14,778	0	14,778
2006	10,800	6,694	77	276	17,847	0	17,847	15,256	0	15,256
2007	11,527	7,186	83	294	19,091	0	19,091	15,691	0	15,691
2008	12,267	7,686	90	313	20,355	0	20,355	16,086	0	16,086
2009	13,019	8,193	96	331	21,639	0	21,639	16,444	0	16,444
2010	13,784	8,708	102	350	22,944	0	22,944	16,765	0	16,765
2011	14,561	9,231	108	370	24,270	0	24,270	17,052	0	17,052
2012	15,351	9,762	115	389	25,617	0	25,617	17,306	0	17,306
2013	16,155	10,301	121	409	26,986	0	26,986	17,530	0	17,530
2014	16,855	10,779	127	427	28,187	0	28,187	17,606	0	17,606
2015	17,448	11,183	132	442	29,205	0	29,205	17,540	0	17,540
2016	17,931	11,512	136	454	30,032	0	30,032	17,343	0	17,343
2017	18,299	11,763	139	463	30,663	0	30,663	17,026	0	17,026
2018	18,548	11,933	141	469	31,091	0	31,091	16,600	0	16,600
2019	18,675	12,019	142	472	31,308	0	31,308	16,073	0	16,073
2020	18,675	12,019	142	472	31,308	0	31,308	15,455	0	15,455

4.4 Benefit Cost Results

Putting the flows of costs and benefits together, the analysis is shown in Table 4.2. The costs flow from 1980 to 2003, and the benefits flow from 1993 to 2020. With the present value of the costs $43.2 million, and the present value of the benefits $364.1 million over the period from 1980 to 2023, the Net Present Value is $320.9 million. The benefit-cost ratio is 8.4, with an internal rate of return of 16.3%.

Table 4.2: Results of Benefit-Cost Analysis

Present Value of Costs	$'000	43,191
Present Value of Benefits	$'000	364,066
Net Present Value	$'000	320,874
Benefit-Cost Ratio		8.4
Internal Rate of Return	%	16.3%

These results indicates that the funds invested, by both NSW Agriculture and their collaborative partner the GRDC, in the Wagga wheat breeding program over the past 23 years have been a sound investment, returning $8.40 for every dollar invested in the program. The returns to that investment have been substantial, and certainly higher than many alternative uses for those funds.

5 Conclusions

The Wagga wheat breeding program has been operating for over 100 years. In that time, it has released a flow of new wheat varieties for wheat growers in south-eastern Australia. Those varieties have led to increases in both yields and grain quality. The average annual rate of yield improvement in NSW has been 3.2% compared to the average for Australia of 2.4% with a significant proportion of these productivity gains arising from new varieties.

In this analysis, investment in the program from 1980 to 2003 has been evaluated. Given the lags inherent in wheat breeding investments, the benefits from those investments are being measured from 1993 to 2020. The broad structure of the program has remained relatively stable for most of the period since 1980. The program consists of 2-3 wheat breeders, one breeder-pathologist, and a cereal chemist, with appropriate technical and field support, totaling approximately 15 full-time equivalents per year. The costs of the program have averaged approximately $1.2 million per year (in 2002 dollars) over the period.

In assessing the Wagga wheat breeding program it is important to consider how the industry would have developed without the program. The benefits of the program were measured as the difference in returns from improved wheat varieties in NSW over that period and the returns that would have been achieved in the absence of the Wagga breeding program. The assumption used to determine the impact without the Wagga program was that the rate of yield improvement in NSW would have been the same as for the rest of Australia. For quality, without the Wagga program the assumption was that in southern NSW the increase in quality would have been 20% slower, and in the north there would have been no change in the rate of quality improvement.

Not all of those gains from new varieties in NSW are attributable to the Wagga wheat breeding program. Over half of all productivity gains are attributable to technologies other than new varieties and other breeding programs have contributed some of new varieties adopted. Wheat breeding within NSW was estimated to have increased the value of wheat per hectare (incorporating both yield and quality) by approximately 0.50% per year in southern NSW and by approximately 0.15% per year in northern NSW. The share of the area sown to wheat in NSW of Wagga program varieties over the study period averaged around 46% in southern regions and 11% in northern regions. The benefits were projected into the future on the basis that the varieties released before 2003 will have a significant impact on production until 2013, but from then, these benefits will decline to zero by 2020.

Based on these assumptions, the benefit-cost ratio found in the analysis was 8.4, with an internal rate of return of 16%. The Net Present Value of the total resources used in the program over the period since 1980 was estimated at $321 million. An economic benefit that we have not attempted to value is the knowledge about plant breeding gained during the wheat program that has ‘spilled over’ to other breeding programs.

The economic benefits of the breeding program are shared by producers, processors and consumers in the wheat industry, some of whom live overseas. Because Australia is largely a price taker on world wheat markets and because the wheat processing and distribution sector in Australia is generally considered to be competitive, most of the benefits of the wheat breeding program are likely to remain with producers. However these gains are offset by declines in the world price in response to advancing technology throughout the world.

These economic benefits have positive social consequences, largely through their contribution to the incomes of farmers and those who handle and process wheat in regional NSW. Some of these gains are in the form of new marketing and processing industries around the increasingly specialised industry segments resulting directly from the changes that have occurred in wheat varieties. Perhaps these new skills add to the social capital of towns in the wheat belt of NSW.

In environmental terms, the wheat breeding program itself is not likely to have major impacts, since the wheat industry would have been very similar whether or not there was a Wagga breeding program. However, to the extent that improved productivity from the Wagga program's varieties has allowed an expansion of the wheat industry, there could be some negative environmental consequences of the breeding program, such as those arising from the clearing of land, increased cultivation and increased use of herbicides. On the other hand, the high levels of disease resistance developed and maintained has meant that wheat production is not associated with large-scale fungicide use, and hence the danger of chemical contamination of the environment is less than it would have been without the resistance developed in this program. Some of these environmental impacts affect the costs and incomes of wheat farmers and hence are reflected in economic benefits and some spill over to the broader community and have not been valued here.

It is not clear that these social and environmental impacts would be much different without the Wagga breeding program except through the extent to which the Wagga program has allowed the wheat industry in NSW to develop more than it otherwise would have. Without the Wagga program the slower gains in yield and quality would also be associated with some social and environmental impacts and it is the difference that is critical in evaluating the Wagga program.

The costs of this program have been met partly by the NSW taxpayers through NSW Agriculture, partly by the grains industry through levies from the GRDC, and recently by additional royalty payments ("end-point royalties"). The nature of the outputs of plant breeding programs is that there are large economic benefits that flow directly to producers, processors and consumers in the industry. However the social and environmental impacts on the broader community, while not explicitly valued here, are considered to be small relative to economic benefits and relative to some other programs of NSW Agriculture that have been evaluated.

Hence it is appropriate that the industry, though GRDC levies and royalties on production, has increasingly funded the operations of the wheat breeding program. Recent institutional changes for the wheat breeding program have made it even more commercially-based for the future and less reliant on government funding.

The new institutional arrangements for plant breeding programs and the strengthening role of the private sector in supplying varieties traditionally supplied by the private sector (eg, see Morris and Ekasingh 2002) mean that the place of public plant breeding programs is being re-assessed. A key question is whether publicly-operated programs, can offer some additional benefits either to the industry or to the community, which would not result from the complete privatisation of the plant breeding sector. One key issue is the role of public breeding programs in the conservation of germplasm, particularly the concern that the longer-term investment in essential genetic resources may be lower in a more commercial plant breeding

environment. While that question has not been addressed directly in this analysis, the results indicate that past investments in public wheat breeding program at WWAI, Wagga, have certainly been a productive use of public funds over the past 20 years or so.

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Appendix A: Shires Aggregated into Silo Groups

North West
Bogan
Brewarrina
Central Darling
Cobar
Coonabarabran
Coonamble
Gilgandra
Moree
Narrabri
Narromine
Walgett
Warren

North East
Barraba
Bingara
Coolah
Dubbo
Gunnedah
Inverell
Manilla
Merriwa
Mudgee
Murrurundi
Muswellbrook
Nundle
Parry
Quirindi
Rylstone
Scone
Wellington
Yallaroi

South West
Balranald
Bland
Carrathool
Conargo
Griffith
Hay
Lachlan
Leeton
Murray
Murrumbidgee
Parkes
Wakool
Wentworth
Windouran

South East
Berrigan
Blayney
Boorowa
Cabonne
Coolamon
Cootamundra
Corowa
Cowra
Culcairn
Evans
Forbes
Gundagai
Harden
Holbrook
Hume
Jerilderie
Junee
Lockhart
Narrandera
Temora
Urana
Wagga
Weddin
Yass
Young

Appendix B.1: Calculation of Benefits from Wagga Wheat Breeding Program – Silo Group South East

Year	Area *(000 ha)*	Yield *(t/ha)*	Yield gain *(t/ha)*	Prod'n gain *(000 t)*	Wagga share *(%)*	Gain *($'000)*	Cumulative *($'000)*
1980	922	1.43	0.0079	7.31	87%	1,044	-
1981	901	2.08	0.0116	10.42	84%	1,429	-
1982	961	0.56	0.0031	2.97	56%	273	-
1983	1,067	2.49	0.0138	14.76	41%	994	-
1984	1,027	1.84	0.0102	10.51	28%	482	-
1985	970	1.99	0.0111	10.73	37%	642	-
1986	802	2.02	0.0112	9.01	40%	592	-
1987	582	2.00	0.0111	6.48	32%	341	-
1988	476	1.98	0.0110	5.22	21%	184	-
1989	439	2.00	0.0111	4.86	28%	222	-
1990	476	2.11	0.0117	5.58	30%	279	-
1991	313	2.25	0.0125	3.92	48%	308	-
1992	420	3.11	0.0173	7.25	59%	707	-
1993	450	2.97	0.0165	7.41	66%	799	799
1994	384	0.82	0.0046	1.75	82%	234	1,033
1995	484	2.89	0.0160	7.76	68%	869	1,902
1996	664	3.16	0.0175	11.64	55%	1,047	2,949
1997	570	2.36	0.0131	7.46	50%	608	3,557
1998	594	2.87	0.0159	9.46	32%	491	4,048
1999	733	3.30	0.0183	13.42	39%	862	4,910
2000	836	3.48	0.0193	16.18	48%	1,283	6,193
2001	851	3.25	0.0180	15.36	45%	1,144	7,337
2002	599	2.87	0.0159	9.53	43%	670	8,007
2003	599	2.91	0.0162	9.69	43%	681	8,688
2004	599	2.96	0.0165	9.85	43%	692	9,380
2005	599	3.01	0.0167	10.01	43%	704	10,084
2006	599	3.06	0.0170	10.18	43%	716	10,800
2007	599	3.11	0.0173	10.35	43%	728	11,527
2008	599	3.17	0.0176	10.52	43%	740	12,267
2009	599	3.22	0.0179	10.70	43%	752	13,019
2010	599	3.27	0.0182	10.88	43%	765	13,784
2011	599	3.33	0.0185	11.06	43%	777	14,561
2012	599	3.38	0.0188	11.24	43%	790	15,351
2013	599	3.44	0.0191	11.43	43%	804	16,155
2014	599	3.50	0.0194	11.62	37%	700	16,855
2015	599	3.55	0.0197	11.81	31%	593	17,448
2016	599	3.61	0.0201	12.01	24%	483	17,931
2017	599	3.67	0.0204	12.21	18%	368	18,299
2018	599	3.74	0.0207	12.42	12%	249	18,548
2019	599	3.80	0.0211	12.62	6%	127	18,675
2020	599	3.86	0.0214	12.83	0%	-	18,675

Appendix B.2: Calculation of Benefits from Wagga Wheat Breeding Program – Silo Group South West

Year	Area *(000 ha)*	Yield *(t/ha)*	Yield gain *(t/ha)*	Prod'n gain *(000 t)*	Wagga share *(%)*	Gain *($'000)*	Cumulative *($'000)*
1980	899	0.89	0.0041	3.71	86%	524	-
1981	910	1.58	0.0073	6.64	82%	894	-
1982	897	0.40	0.0018	1.65	57%	155	-
1983	1,041	2.20	0.0102	10.59	44%	767	-
1984	938	1.52	0.0070	6.58	33%	357	-
1985	964	1.47	0.0068	6.54	38%	403	-
1986	814	1.59	0.0074	5.99	35%	346	-
1987	511	1.97	0.0091	4.65	26%	202	-
1988	611	1.81	0.0084	5.11	22%	184	-
1989	571	1.66	0.0077	4.37	24%	172	-
1990	581	1.80	0.0083	4.83	30%	235	-
1991	416	1.45	0.0067	2.79	43%	197	-
1992	460	2.01	0.0093	4.27	37%	260	-
1993	531	2.35	0.0109	5.77	35%	334	334
1994	447	0.73	0.0034	1.50	75%	184	517
1995	577	1.76	0.0081	4.69	37%	288	805
1996	777	2.30	0.0106	8.24	30%	410	1,215
1997	751	2.03	0.0094	7.03	32%	372	1,588
1998	827	2.40	0.0111	9.17	32%	476	2,063
1999	811	2.27	0.0105	8.50	41%	575	2,638
2000	996	2.42	0.0112	11.12	49%	897	3,535
2001	1,013	2.26	0.0104	10.56	47%	808	4,343
2002	719	2.08	0.0096	6.92	40%	456	4,799
2003	719	2.11	0.0098	7.02	40%	463	5,262
2004	719	2.15	0.0099	7.13	40%	470	5,732
2005	719	2.18	0.0101	7.24	40%	477	6,209
2006	719	2.21	0.0102	7.35	40%	485	6,694
2007	719	2.25	0.0104	7.47	40%	492	7,186
2008	719	2.28	0.0105	7.58	40%	500	7,686
2009	719	2.32	0.0107	7.70	40%	507	8,193
2010	719	2.35	0.0109	7.82	40%	515	8,708
2011	719	2.39	0.0110	7.94	40%	523	9,231
2012	719	2.43	0.0112	8.06	40%	531	9,762
2013	719	2.46	0.0114	8.18	40%	539	10,301
2014	719	2.54	0.0117	8.45	34%	477	10,779
2015	719	2.59	0.0119	8.59	29%	404	11,183
2016	719	2.63	0.0121	8.73	23%	329	11,512
2017	719	2.67	0.0123	8.88	17%	251	11,763
2018	719	2.72	0.0126	9.03	11%	170	11,933
2019	719	2.76	0.0128	9.18	6%	86	12,019
2020	719	2.81	0.0130	9.33	0%	-	12,019

Appendix B.3: Calculation of Benefits from Wagga Wheat Breeding Program – Silo Group North East

Year	Area *(000 ha)*	Yield *(t/ha)*	Yield gain *(t/ha)*	Prod'n gain *(000 t)*	Wagga share *(%)*	Gain *($'000)*	Cumulative *($'000)*
1980	532	0.57	0.0006	0.31	34%	17	-
1981	546	2.05	0.0021	1.12	34%	62	-
1982	448	0.61	0.0006	0.27	37%	16	-
1983	571	2.32	0.0023	1.32	43%	93	-
1984	453	1.70	0.0017	0.77	39%	50	-
1985	462	2.02	0.0020	0.93	31%	47	-
1986	371	1.98	0.0020	0.74	26%	31	-
1987	309	2.05	0.0021	0.63	22%	23	-
1988	290	1.93	0.0019	0.56	18%	16	-
1989	256	1.84	0.0018	0.47	12%	10	-
1990	239	2.14	0.0021	0.51	11%	10	-
1991	178	1.71	0.0017	0.30	14%	7	-
1992	197	2.37	0.0024	0.47	8%	6	-
1993	202	2.62	0.0026	0.53	6%	5	5
1994	131	0.55	0.0006	0.07	13%	2	7
1995	253	1.85	0.0018	0.47	7%	5	12
1996	370	3.00	0.0030	1.11	3%	5	17
1997	346	2.39	0.0024	0.83	5%	7	24
1998	302	1.99	0.0020	0.60	5%	5	29
1999	361	2.79	0.0028	1.01	4%	7	36
2000	310	1.96	0.0020	0.61	7%	7	42
2001	316	1.83	0.0018	0.58	7%	7	49
2002	279	2.17	0.0022	0.61	6%	6	55
2003	279	2.20	0.0022	0.61	6%	6	60
2004	279	2.23	0.0022	0.62	6%	6	66
2005	279	2.27	0.0023	0.63	6%	6	72
2006	279	2.30	0.0023	0.64	6%	6	77
2007	279	2.34	0.0023	0.65	6%	6	83
2008	279	2.37	0.0024	0.66	6%	6	90
2009	279	2.41	0.0024	0.67	6%	6	96
2010	279	2.45	0.0025	0.68	6%	6	102
2011	279	2.49	0.0025	0.69	6%	6	108
2012	279	2.52	0.0025	0.71	6%	6	115
2013	279	2.56	0.0026	0.72	6%	7	121
2014	279	2.65	0.0027	0.74	5%	6	127
2015	279	2.69	0.0027	0.75	4%	5	132
2016	279	2.74	0.0027	0.76	3%	4	136
2017	279	2.78	0.0028	0.78	2%	3	139
2018	279	2.83	0.0028	0.79	2%	2	141
2019	279	2.87	0.0029	0.80	1%	1	142
2020	279	2.92	0.0029	0.82	0%	-	142

Appendix B.4: Calculation of Benefits from Wagga Wheat Breeding Program – Silo Group North West

Year	Area *(000 ha)*	Yield *(t/ha)*	Yield gain *(t/ha)*	Prod'n gain *(000 t)*	Wagga share *(%)*	Gain *($'000)*	Cumulative *($'000)*
1980	994	0.44	0.0010	1.00	17%	28	-
1981	1,233	1.16	0.0026	3.27	15%	80	-
1982	847	0.39	0.0009	0.75	17%	21	-
1983	1,313	2.03	0.0047	6.11	18%	179	-
1984	1,175	1.45	0.0033	3.89	20%	125	-
1985	1,258	1.30	0.0030	3.73	14%	88	-
1986	1,107	1.17	0.0027	2.96	10%	50	-
1987	938	1.31	0.0030	2.81	8%	37	-
1988	927	1.66	0.0038	3.53	7%	39	-
1989	850	1.40	0.0032	2.72	7%	33	-
1990	866	1.80	0.0041	3.57	5%	31	-
1991	595	1.14	0.0026	1.55	6%	16	-
1992	614	1.59	0.0036	2.24	3%	12	-
1993	790	2.45	0.0056	4.42	4%	26	26
1994	459	0.78	0.0018	0.82	8%	11	37
1995	1,004	1.62	0.0037	3.72	4%	26	63
1996	1,353	2.30	0.0053	7.14	3%	35	98
1997	1,228	1.62	0.0037	4.54	3%	19	117
1998	1,428	1.51	0.0034	4.92	2%	13	130
1999	1,493	2.05	0.0047	6.99	1%	16	146
2000	1,513	1.27	0.0029	4.39	2%	18	164
2001	1,540	1.18	0.0027	4.17	4%	26	189
2002	1,142	1.66	0.0038	4.34	2%	17	206
2003	1,142	1.69	0.0039	4.41	2%	17	223
2004	1,142	1.71	0.0039	4.48	2%	17	240
2005	1,142	1.74	0.0040	4.55	2%	18	258
2006	1,142	1.77	0.0040	4.62	2%	18	276
2007	1,142	1.79	0.0041	4.69	2%	18	294
2008	1,142	1.82	0.0042	4.76	2%	18	313
2009	1,142	1.85	0.0042	4.83	2%	19	331
2010	1,142	1.88	0.0043	4.91	2%	19	350
2011	1,142	1.91	0.0044	4.98	2%	19	370
2012	1,142	1.94	0.0044	5.06	2%	20	389
2013	1,142	1.96	0.0045	5.14	2%	20	409
2014	1,142	2.03	0.0046	5.30	2%	18	427
2015	1,142	2.06	0.0047	5.39	2%	15	442
2016	1,142	2.10	0.0048	5.48	1%	12	454
2017	1,142	2.13	0.0049	5.57	1%	9	463
2018	1,142	2.17	0.0050	5.67	1%	6	469
2019	1,142	2.20	0.0050	5.76	0%	3	472
2020	1,142	2.24	0.0051	5.86	0%	-	472

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