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An Economic Analysis of GRDC Investment in the National Invertebrate Pest Initiative

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Impact Assessment: An Economic Analysis of GRDC Investment in the National Invertebrate Pest Initiative

Executive Summary

An evaluation has been done of the benefits of the GRDC investment from 2005 to date in the National Invertebrate Pest Initiative (NIPI). The program is achieving its objectives of strengthening the capacity of the grain industry to implement more effective Integrated Pest Management (IPM). A benefit cost ratio of 1.23 to one was estimated based on the investment from 2004/05 to 2010/11 by GRDC and partners of close to $5 million dollars in present value terms. Although the investment has not generated high returns, there is a base to achieve rapid returns to future investments and to provide some insurance against future threats or policy changes likely to make IPM more competitive with current pest management approaches.

Routine reliance on low cost insecticides has been a simple and highly effective strategy. The approach is most widely used for the establishment-stage pests of canola. A consequence has been the run down in the demand for entomological expertise - expertise that will again be needed if the demand for IPM strategies increases. The emerging development of insecticide resistance and impacts on beneficial species are further consequences of routine prophylactic spraying.

NIPI has concentrated on capacity building in southern and Western Australia and has been informed by successful approaches used in northern Australia. Five State departments of agriculture and five universities were involved as part of a new national approach coordinated by CSIRO Entomology. The NIPI projects included research, extension and extensive communication and training for some of the skills needed to adopt IPM. A key output was the delivery of workshops to over 1,300 participants; half of those attending were consultants and agronomists. NIPI partners distribute over 3,000 newsletters, free and online, distributed regularly for early warning on the latest pest activity. Over 200 identifications are provided annually. An extensive array of publications included a special journal issue with 12 papers on aspects of IPM, and a Pest Identification/IPM Training manual.

The evaluation depended on critical assumptions on the likely adoption of outputs from NIPI, particularly the adoption of aspects of IPM and potential cost savings. Concerns for the environmental impacts, increasing regulation of pesticides and farmer concerns using chemicals are other drivers. The limited experience of most grain farmers with IPM suggests that widespread adoption of IPM approaches will not occur unless there is a crisis looming, for example an introduced pest or widespread development of pesticide resistance. Even then, local independent expertise to support confident decision making, including on the challenging not-to-spray decision, will be crucial. But how growers react to increasing resistance is a further issue. If resistance was perceived to spread slowly from other farms rather than from excessive use on their own farm, growers could be even less inclined to reduce insecticide use. In Western Australia 12 cases of red-legged earth mite resistance have been identified since 2006.

Most of the benefits assessed were for canola where there appeared to be the most scope for IPM. However, based on the likely economic drivers, only low rates of adoption due to NIPI were assumed, the area of canola reaching less than 10 percent of the Australian total over the next 15 years. The analysis excluded benefits from the investment in the next phase of NIPI. The analysis did include an assumption of $300,000 annually after 2010/11 to maintain key information services.

The benefits as cost savings assumed from reduced insecticide treatments were not large being in the range from $5 to $10 per ha. If the GRDC had not invested in NIPI it was assumed that resistance would have developed more rapidly. Some current prophylactic treatments applied by adding insecticides to other weed or fungicide treatments cost only a few dollars per ha. Impacts not costed included losses of beneficials and associated flare-ups of non-target species, and losses from shortening the useful life of the insecticide from development of resistance.

Confidence in the assumptions was low. Based on the assumptions made, the net present value was positive with an expected net present value of $1.13 million over 30 years at a 5% discount rate, a benefit-cost ratio of 1.23 to 1, and an internal rate of return of 6.1%. Benefits not specifically valued in the analysis include:

- Environmental benefits - from reduced use of pesticides,
- Biosecurity- from increased surveillance capacity for incursions of exotic pests, and
- Social – including capacity building in terms of collaboration, skills of growers and advisers, and health benefits from reduced usage of chemicals.

Drivers influencing IPM will continue to change in ways difficult to predict. The recent withdrawal of endosulfan and emergence of carbamate resistance in aphids are examples. The analysis concluded that adoption of IPM was unlikely to be rapid unless there were other major changes in the drivers, and unless there was more local expertise available to initiate and support the change from what is in the short term a low risk and low cost strategy. As an example, the longer term risk of resistance developing may not be enough incentive and warrants further research on its rate of spread, as does research on the potential drivers of IPM in general in canola production. The research envisaged would help inform development of more consistent corporate and industry strategies. For example there are significant publications on managing canola pests which do not mention IPM, or many of its components including beneficials and the inevitability of pesticide resistance.

The following table (from Section 5 –Benefits) summarises the notable benefits resulting from the investment in NIPI.

Categories of Notable Benefits from the Cluster Investment

Benefit	**Levy paying industry and its supply chain**	**Spillovers**		
		Other industries	**Public**	**Foreign**
Economic	Increased profitability from practice change Maintaining markets where IPM is valued.	Understanding of pests in common with pastures, cotton and horticulture.		
Environmental	Reduction in pesticide use.		Production from more sustainable practices.	
Social	Enhanced skills and capacity including in supply chain. Improved biosecurity. Benefits to other growers from reduced spread of pest resistance.		Improved perception of the environmental stewardship of the grain industry.	

1. Introduction

This investment cluster is in response to likely changes in the challenges facing the Australian grain industry in managing pest problems. The current well established solution is to rely on pesticides. The decreasing cost of insecticides over recent decades has been one of the key drivers of change. The declining cost and short-term effectiveness of broad spectrum synthetic pyrethroids (SP) was such that they have became widely used as a routine 'just in case' insurance treatment regardless of the incidence of pests. Some of the negative consequences are:

- Increasing occurrence of resistance to SP, for example since 2006 in the redlegged earthmite (RLEM), a common pest of canola crops,
- Decreasing occurrence of resident beneficial organisms, and
- A decline in southern and Western Australia particularly in the demand for entomological services and in the entomological skills of farmers and advisers.

In 2005 GRDC launched a comprehensive project managed by CSIRO Entomology to achieve a strengthened national approach to invertebrate pest management. The project was to explore options for more integrated approaches to pest management which did not rely solely on prophylactic pesticide applications. The National Invertebrate Pest Initiative (NIPI) is now beginning its third phase. The first two phases are the subject of this impact analysis.

Other drivers of an increasing priority for research on improved management of pesticides included:

- Changes in cropping systems particularly from cereal/pasture to cereal/canola and increased use of conservation tillage,
- Increasing interest by graingrowers in minimising insecticide use,
- Increasing concerns by environmentalists and the community generally on pesticide residues in the environment and in food, leading to increased regulation,
- Increasing interest in the value attributable to the ecosystem services provided by invertebrate species in the broader landscape,
- Increasing biosecurity awareness of potential threats to the grain industry from exotic pests, for example the Russian wheat aphid, and
- Changing and increasingly uncertain pest threats as the climate changes.

The drivers such as increasing concerns on impacts of pesticides can have a range of implications for example on government policies. There is an increasing likelihood of key chemical groups being withdrawn from registration. For example endosulfan was recently withdrawn following some decades of use in Australia. Genetically modified crops with pesticide resistance are also a potential driver. However according to Hoffmann et al (2008) that is seen as unlikely in the foreseeable future in Australia.

The above six drivers of a greater priority for increasing GRDC research have not impacted to any great extent on current grower practice. A key question for this evaluation is whether a program of research will have an impact in the absence of a major change in the drivers. Growers would then continue to use their insurance-based approach. Alternatively the research itself can be viewed as insurance. The industry would then have a degree of preparedness in the event of substantial change in the drivers leading to a new economics.

The varying dimensions of pest problems in the three GRDC regions helped shape the national approach pursued by NIPI. GRDC had traditionally funded research projects on some specific pest problems. This was particularly so in the GRDC northern region where the diverse mix of winter and summer cropping and a sub-tropical climate had resulted in problems that are being increasingly resolved by IPM extension underpinned by research. IPM is broadly defined as the integration of a wider range of approaches to manage pests in comparison to strategies which simply concentrate on pesticides. The northern region research was partly a response to developments in the 1990s. Few initiatives in IPM have been pre-emptive.

The more notable drivers in the northern region were the pesticide resistance problems in cotton and the intrusion of the silver leaf whitefly, a pest which had rapidly developed resistance to insecticides in some countries. These developments and expansion in more vulnerable pulse crops led to IPM courses being developed. Since 2006 17 IPM courses have been conducted in Queensland and NSW for over 400 soybean and mungbean producers and their advisors. The courses were based on research including increasing understanding of beneficial insects and economic thresholds for spraying. Understanding was initially at a low level. Brier et al (2008) reported an example where 75 percent of consultants were not able to recognise 50 percent of the most common insects in summer pulses.

In the southern region where insurance spraying had been widely used, there was virtually no knowledge platform on which to build workshops. Diagnostic services identifying pests provided a basis for pest identification workshops.

In the western region there had been some extension activity related to specific research projects and based on a PestFax newsletter service. There had also been a training course run by Curtin University. Western Australia has the largest area of canola, the grain crop with the greatest dependence on insecticide. Spread of RLEM resistance to pesticides is an increasing concern. More recently, resistance by the green peach aphid to an aphid specific insecticide has been identified in a canola crop in Western Australia (Edwards 2010).

In addition to the NIPI, GRDC coordinates with other industries, for example with cotton, and with horticulture for some pests such as diamondback moth (DBM) where there is a common interest (Rainbow 2010). Resistance to older insecticide classes is widespread in DBM in both canola and brassica vegetable crops. GRDC has other projects on pesticides, for example on spray drift, and a project to obtain permits for a range of pesticides gaining approval for their use in minor crops and minor uses in major crops. Minor uses are assessed in relation to technological, trade and biological needs which include potential IPM value.

Estimates of impacts from IPM research should begin with overall losses from invertebrate pests in grain crops together with current control costs. Estimates of these amounts help set a limit on possible benefits. However as noted by Hoffmann et al (2008) in their review of available data: "*there are no routine quantitative assessments of the importance of different pests in the Australian grains industry*". Adamson et al (2007) estimated economic effects for Australian agricultural production from *Helicoverpa* spp. The total cost of $324 million included control costs of $106 million and crop losses with control of $218 million. Cotton accounted for over half the cost before GM insect-resistant crops were introduced in 1996. Holtzapffel (2008) reported on an Australian study that estimated that, between

1997 and 2004, the environmental impact of insect-resistant cotton in Australia was 64 per cent lower than the impact of non-GM conventional cotton.

In summary the approaches currently used to control pests of grain crops are currently highly cost effective. Losses from pests in the grain industry are clearly relatively small compared to the gross value of grain production of the order of $10 billion and of losses from diseases in the wheat industry of the order of $1 billion (Murray and Brennan, 2009) and also of the order of $1 billion for losses from weeds in grain crops (Jones 2000).

This assessment will cover the impacts from NIPI activities over the calendar years from 2005 to 2010. Improved knowledge of pests is identified as a major output contributing to improved capacity to develop more sustainable IPM strategies. However, developing and implementing an IPM strategy can be much more complex involving a range of strategic and tactical decisions. The invertebrate community in field crops is diverse and problems can vary from year to year depending on the season and on the fluctuating importance of migratory compared with resident species. Beneficial species may in some situations only be a small and difficult to identify component.

IPM includes decisions based on biological and cultural considerations. Strategic decisions include crop choice, rotations, planting dates, nursery crops, refuges and native vegetation. Tactical decisions include those based on sampling for pests, applying realistic thresholds and then making a decision to respond or not. Natural mortality of pests from beneficials or other factors influences whether thresholds are reached. Knowledge of beneficial and pest abundance is part of the decision on whether some other control is needed. (Gary Fitt, pers. comm., 2010).

The on-farm impact in this analysis is based simply on an assessment of the possible increased profitability over a number of years from reduced costs and increased returns. These are measured against a baseline including likely increases in insecticide resistance by some major pests compared with the likely situation if the investment in NIPI had not been undertaken. The major outcomes are then described to estimate impacts from economic, social and environmental perspectives. A cost benefit framework is utilised and supported where possible with non-financial information on impacts. A sensitivity analysis of the assumptions is undertaken, confidence estimates are provided, and the conclusions and lessons learnt are then discussed in the final section of the report.

2. Project Investment

Projects funded by GRDC

The two projects funded by GRDC that are in this investment cluster as listed in Table 1. The projects were part of the GRDC Output Group 1 – Practices. The current GRDC objective for Practices is:

"Better practices developed and adopted faster"

Details on the projects have been extracted from the contracted specifications for each project or from Final Reports. NIPI had a major emphasis on national collaborative approaches. The lead agency was CSIRO Entomology. Three key partner agencies were:

- CESAR (Centre for Environmental Stress and Adaptation Research, University of Melbourne),
- SARDI (South Australian Research and Development Institute), and
- DAFWA (Department of Agriculture and Food, Western Australia).

Table 1: NIPI Phase I and II Projects Funded by GRDC from 2005-2010

Project Code and Title	**Other Details**
CSE00029: National Invertebrate Pest Initiative (Phase I)	Organisation: CSIRO Entomology (Indooroopilly) Period: 1/1/2005 to 31/12/2007 Principal Investigator: Dr Gary Fitt
CSE00046: National Invertebrate Pest Initiative (Phase II)	Organisation: CSIRO Entomology (Indooroopilly) Period: 1/7/2007 to 31/12/2010 Principal Investigator: Dr Gary Fitt

Table 2 provides a summary of the objectives of each project. The investment cluster was essentially one project with two distinct phases. Although the objectives remained the same, the second phase had detailed milestones that built on Phase I achievements.

Investment Inputs

Table 3 shows the combined GRDC and partner investment for each year. The partner funding was from a wide range of agencies. There were five State agriculture departments and five Universities in the NIPI network. GRDC contributed 57 percent of the total funding.

Table 2: Project Codes, Titles and Stated Objectives

Project Code and Title	**Stated Objectives**
CSE00029: National Invertebrate Pest Initiative (Phase I)	• Deliver robust areawide IPM systems for grain producers supported by workable guidelines which reduce costs and enhance farm environments, • Enhance the flow of relevant information to producers, • Enhance the research capacity for future support of producers, and • Provide more coordinated research and adoption effort for current pest issues which maximise outcomes and provide rapid response capability for emerging threats.
CSE00046: National Invertebrate Pest Initiative (Phase II)	• Deliver robust areawide IPM systems for grain producers supported by workable guidelines which reduce costs and enhance farm environments, • Enhance the flow of relevant information & training to industry advisors & producers, • Enhance research capacity for future support of producers, and • Provide more coordinated research & adoption efforts for current and emerging pest issues.

Table 3: Investment by GRDC and Partners in the Two Projects in the Years from 2005-2011 (nominal $)

Year ending June	GRDC	Partners	Total
2005	310,986	227,813	538,799
2006	424,934	223,067	648,001
2007	424,934	233,751	658,685
2008	177,094	13,511	190,605
2009	421,341	431,601	852,942
2010	421,791	444,948	866,739
2011	209,838	229,085	438,923
Total	2,390,918	1,803,776	4,194,694

Estimates of the funding for the two phases of NIPI are provided in Tables 4.

Table 4: Total Investment by GRDC and Partners in the NIPI projects (nominal $)

Project	GRDC	Partners	Total
CSE00029	1,160,854	684,631	1,845,485
CSE00046	1,230,064	1,119,145	2,349,209
Total	2,390,918	1,803,776	4,194,694

3. Outputs / Activities

The two NIPI projects were complex national projects involving a large number of agencies and activities. The outputs as contracted are necessarily described at a general summary level and are presented in Table 5. The more detailed major activities are then listed in the text following the table. The contracted outputs were achieved or likely to be achieved by the end of 2010 when the project ends. There were some exceptions, adjustments and delays, particularly some resulting from the drought year in 2007. Progress on the objective relating to areawide IPM systems was limited by drought conditions. The economic study which would have been of value to this analysis was unable to be completed. NIPI III will pick up on activities not fully completed.

The NIPI projects included research, extension and extensive communication and training for some of the skills needed to adopt IPM in the grains industries. The major activities undertaken were field and laboratory research, training activities and information services. As NIPI II will not conclude until the end of 2010 some projects are to be completed and some activities are being rolled into NIPI III.

A summary of the main outputs for the three main centres of NIPI extension and communication activity is presented in Table 6. Activity in Queensland included the development of a website for pest identification and some contributions to NIPI planning, for example on workshop design.

Table 5: Summary of Outputs Contracted for the two NIPI Projects

Project	Contracted Outputs
CSE00029	• Establishment of a functional and active collaborative network for grains pest management which improved research outcomes and their delivery to industry and which focuses on area-wide IPM as a model for sustainable management of key pests, • Enhanced adoption and educational outcomes in more sustainable pest management for the grains industry through communication and training of future researchers and growers, and • Robust area-wide IPM strategies being developed for key pests of the canola/wheat production systems of South-Eastern Australia.
CSE00046	• Maintenance of a functional and active collaborative network of researchers and extension specialists which improves research outcomes and their delivery to industry, enhances capacity to respond to emerging pest issues, and focuses on area-wide IPM as a model for sustainable management of key pests, • Enhanced training of industry advisors and producer groups in appropriate components of IPM together with enhanced adoption of more sustainable IPM systems for broadacre grains crops, and • Robust area-wide IPM strategies developed for key pests of the canola/wheat production systems of South-eastern Australia together with focussed research on emerging pest threats.

Table 6: Summary of Major NIPI Activities from 2005 to 2010 for the CESAR, SARDI and DAFWA sub-projects

Output	**Agency**			**Total Or Average**
	CESAR	**SARDI**	**DAFWA**	
<u>Workshops (since 2005)</u>				
Number	12	36	12	60
<u>Participants</u>				
Number	250	900 (approx)	162	1,312
<u>Occupations (approx)</u>				
Consultants/Agronomists %	70	50	44	50
Farmers%	25	40	21	40
Other%	5	10	35	10
<u>Newsletters</u>				
Annual Issues	12	12	27	51
Subscribers to PestFax/PestFacts	925	600	1,500	3,025
Identifications (annual)	80	100	50	230

Research activities – The focus on capacity building included post graduate awards. However there were delays and difficulties in finding suitable post-graduate students to take up the PhD awards on topics based on priorities identified by NIPI activities. Research topics included slug management, lucerne flea in southern farming systems and impacts of climate change.

The major field project relates to underpinning science to support enhanced pest management in canola. The focus is to quantify insect communities in canola and their links to communities in nearby crops. Foodweb analysis and a landscape ecology approach are being used to provide underpinning science for areawide understanding of pest dynamics. Initial research showed the considerable potential for breeding canola varieties with resistance to common pests, although having host plant resistance high on the agenda of canola breeders remains an issue. In addition three postgraduate student projects were completed on issues identified by the NIPI network as priorities to develop capacity for future IPM activities. The collaborations established in NIPI II also facilitated the successful development of further national projects - UWA00134 - Developing and promoting Integrated Pest Management in Australian Grains, which is led through UWA and CSE00051 - Pest suppressive landscapes: linking IPM and natural resource management, which is led by CSIRO.

In relation to the research on areawide IPM systems which was delayed to some extent by drought conditions, this has become a priority area for NIPI III. The benefits of an area wide approach have yet to be demonstrated in southern and western grain systems compared with progress with more mobile species in northern cropping. Schellhorn et al (2008) have reviewed evidence on managing ecosystem services. They conclude that solving area wide approaches with potential benefits for individual farms will need a well defined research agenda to solve the technical and social aspects. In relation to natural enemies and pollinators, they state there is little direct evidence that area wide approaches will have benefits beyond what can be achieved at farm level. Nash (2008) showed some potential for remnant grassland to be a refuge for predators of slugs.

Information services – PestFax and PestFacts are two example supported by NIPI. The services have been highly effective in developing a responsive information service about current and developing pest issues. Over 3,000 clients in the southern and western regions receive regular information (Mangano et al 2009). PestFacts updates are made throughout the growing season on an "as-needed" basis providing the latest information on invertebrate pests in broad acre crops in South Australia and western Victoria. The service was based on the PestFax system developed previously in Western Australia. Services in all regions are now delivered by email only. In addition the PestFacts/Pest Fax groups have been providing free pest identification services for growers and consultants. This service has been drawn on extensively. In Queensland NIPI supported development of an IPM Website run by DEEDI (Department of Employment, Economic Development and Innovation, Queensland).

The range of crops involved is indicated by the data from identifications done in South Australia. Over the period from 2006-10, crops of canola accounted for 32 percent, cereals 28 percent and pulses 21 percent of pests submitted.

IPM training workshops - Some 60 workshops have been held mainly in the GRDC southern and western regions. The participants number over 1,300 and include consultants, agronomists and farmers. About one half of the audiences have been consultants or agronomists. The workshops cover key grain crop invertebrates, including pests and natural predators. Basic principles of pest management, damage, sampling techniques and resistance issues are covered. Workshop components include oral presentations, a practical, an open forum discussion and a farm walk. Group size was capped at 25 participants (Bellati et al 2009).

Publications – The two major publication achievements of NIPI were:

- A special edition of 12 papers of the Australian Journal of Experimental Agriculture (48:12, 2008) titled "*Invertebrate pests of grain crops and integrated management: Current practice and prospects for the future*". This special issue captured the state of knowledge of grains pest management and involved scientists in the NIPI network.
- 'I SPY', a Pest Identification/IPM Training manual being used as the basis to introduce the main components for all grains IPM training activities titled: "*Insects of broad-acre farming systems, identification manual and training resource".*

Numerous industry publications have been produced. These provide clear information about pests and pest management which serve to expose growers and consultants to the potential to modify management approaches. There were a wide range of more informal activities promoting information and products developed by NIPI. For example the SARDI staff involved with NIPI gave presentations at 37 events which gave an opportunity to promote NIPI. The events included grower meetings and various GRDC events including the crop research Updates held in the GRDC southern region.

4. Outcomes

The range of outputs listed in the previous section included workshops, manuals and information services which enable more rapid and effective identification of pest occurrence, and expose industry sectors to options for more integrated pest management. Together these provide a platform to enable more effective IPM strategies to be developed and implemented. There will be further contributions to knowledge and capacity building as the research projects are completed. NIPI I and II have provided a solid base for NIPI III to build on.

In the short term, the major outcome is likely to be some increase in the range of IPM strategies adopted that can be attributed to NIPI I and II. There are likely to minor increases in adoption of IPM from projects not included in NIPI, for example from some consultancy services promoting IPM in Victoria. More recently GRDC has funded a major project at the University of New England (UNE00013: Introduction and Extension of IPM in Northern NSW). The UNE project aims to complement rather than duplicate existing services.

There can be a wide variation in strategies and tactics adopted and adapted depending on crop, region, and the particular pests prevalent in a particular season. One generally accepted indicator is the reduction in insecticide applications, or at least a change in the type of insecticide, for example to delay resistance developing, or to encourage beneficial species. Reduced applications will also reduce secondary outbreaks of pests that were not being targeted and result in some yield increases. There will also be social benefits from farmers and advisers in the supply chain being better equipped to manage pests and to reduce dependence on chemical solutions. The economic impacts will be discussed in more detail in Section 7 on the measurement of benefits. Achieving mainstream practice change remains a challenge however because current economics of pest management mitigates against general change.

Because invertebrate pests are currently being controlled by pesticides at low cost in many situations, growers generally rate such pests as a minor current problem. However continued reliance on pesticides, despite their low cost, exposes the industry to increased risks of pesticide resistance, ongoing environmental impacts and potential disruption should pesticide groups be withdrawn from registration as has recently occurred with endosulfan. Excessive use of SP's is now generating issues with resistance in a major pest RLEM. NIPI outcomes are likely to slow development of resistance and defer the management changes and cost increases that will be needed to handle resistance (Mangano and Micic 2008). As RLEM are also a major pest of pastures, some associated benefits to pastoral industries could be expected.

A summary of the principal outcomes follows:

- Improved knowledge of invertebrate species and of pest management leading to more responsible and safer use of pesticides, and improved biosecurity capacity,
- Increased profitability from reduced use of pesticides and reduced costs of pest management, and from increased yields through avoiding production losses from pests,
- Cost savings from delays in the onset of resistance for pests of grain crops
- Increases in beneficial invertebrates,
- Reduced need for increased pesticide regulation and more effective implementation of current regulations, and
- Increased farmer and community wellbeing, and more sustainable farming systems from reduced reliance on insecticides.

Improved knowledge of invertebrate species has been promoted by NIPI ouputs including PestFax (WA), PestFacts SA and Western Victoria and PestFacts South-Eastern (Victoria/NSW). These services have a wide circulation throughout Southern and Western Australia.

5. Benefits

The major benefits being delivered by the investment are increased profitability of grain production resulting from the increased capacity developed in aspects of IPM. The NIPI projects had a concentration in GRDC southern and western regions where there was the greatest need for capacity building and for research. The benefits will be greatest for growers of canola which is the crop most prone to insect damage and where there is likely to be increasing problems, for example from the major pest, RLEM, developing resistance to repeated use by individual growers of the currently widely used and cost-effective SP insecticides. More integrated approaches to pest management can reduce the rate of increase in resistance and save growers the extra costs that would be involved.

Development of resistance by RLEM is regarded as inevitable. The rate at which this occurs is unclear. At issue is whether the resistance has developed on a number of properties independently or if it is "home grown". The latter is a result of excessive use of pesticides on the property of origin. If the rate is determined to an appreciable extent by the geographic spread of resistance, there is an externality to be managed. In that case, the actions of an individual grower impose costs on others in the industry. Conversely, if a grower assumes resistance is mainly from external sources, that grower will have a reduced incentive to take steps to defer resistance developing. As with research on resistant weeds (Weersink et al 2005), the likelihood of resistance developing can be treated as a non-renewable resource which is effectively mined with each pesticide application. The rate at which resistance develops will then be a driver of development of alternative approaches and products.

NIPI is also making important contributions to biosecurity by expanding the number and the skills of growers and advisers with the capacity for earlier detection of exotic pests. Costs can be reduced by early detection. The Ute Guide (GRDC 2008) lists nine of the many potential threats not yet reported in Australia. The Russian wheat aphid which has had devastating impacts in some countries is included.

Reduced numbers of pesticide sprays could also result in benefits from reduced risks faced by beekeepers. Canola for example is a valuable floral resource in spring.

Overview of Benefits

An overview of benefits in a triple bottom line categorisation is shown in Table 7. Most benefits are likely to be in the canola industry with smaller more scattered areas benefiting for other crops. The largest areas of canola are in Western Australia. Overall canola accounts for about 6 percent of the Australian area of grain crops. Most canola is grown on mixed farms as part of a rotation with larger areas of cereals and with pasture. Thus at a landscape or catchment scale the environmental benefits will only be minor.

Table 7: Categories of Notable Benefits from the Cluster Investment

Benefit	Levy paying industry and its supply chain	Spillovers		
		Other industries	Public	Foreign
Economic	Increased profitability from practice change Maintaining markets where IPM is valued.	Understanding of common pests in pastures, cotton and horticulture.		
Environmental	Reduction in pesticide use.		Production from more sustainable practices.	
Social	Enhanced skills and capacity including in supply chain Improved biosecurity. Benefits to other growers from reduced spread of pest resistance.		Improved perception of the environmental stewardship of the grain industry.	

Public versus Private Benefits
The benefits identified from the investment are predominantly private benefits, namely benefits to grain producers and their supply chains. There will be a social benefit to the industry for example if the spread of resistance to RLEM is shown to be increased beyond the property of origin. There also will have been some minor public benefits produced, mainly environmental and social in nature, from reduced use of pesticides. The evidence on benefits from enhanced ecosystem services was not clear in research completed to date. Nevertheless it should be clear that future IPM systems will be dependent on services derived from healthy ecosystems and landscapes beyond individual fields.

Benefits to other Primary Industries
Benefits to other industries would be limited apart from minor economic benefits to industries based on pastures, and to cotton and horticulture where there are some pest issues in common.

Distribution of Benefits along the Grains Supply Chain
There will be some benefits for example from advisers and input suppliers having increased capacity to meet any increased demand for IPM from growers. Increased adoption of IPM could also be a factor reducing the need for increased regulation of pesticide use or for ensuring more effective implementation of existing regulations.

Benefits Overseas
Minor consumer benefits are possible in markets where IPM is valued.

Match with National Priorities
The Australian Government's national and rural R&D priorities are reproduced in Table 8.

Table 8: National and Rural R&D Research Priorities 2007-08

Australian Government	
National Research Priorities	**Rural Research Priorities**
1. An environmentally sustainable Australia 2. Promoting and maintaining good health 3. Frontier technologies for building and transforming Australian industries 4. Safeguarding Australia	1. Productivity and adding value 2. Supply chain and markets 3. Natural resource management 4. Climate variability and climate change 5. Biosecurity *Supporting the priorities:* 1. Innovation skills 2. Technology

Table 9 identifies the relative importance of the rural research priorities addressed by the cluster as a whole.

Table 9: Categorisation of Benefits by Priorities

Benefit	**National Research Priority Addressed**	**Rural Research Priorities Addressed**
Increased profitability		Priority 1***
Reduced pesticide use	Priority 1	Priority 3**
Biosecurity capacity	Priority 4*	Priority 5*
Capacity building		Priority 2** Supporting Priority 1**

*** Strong contribution   **Some contribution   * Marginal contribution

Additionality and Marginality

The investment in this cluster was targeted principally towards benefits to grain producers from increased adoption of IPM. These projects would have been regarded as a medium priority by levy payers. However, the investment had an insurance aspect. The priority could increase if pesticide resistance became widespread or if withdrawals of chemicals or restrictions on use became more common. In the event that the government matching contribution to GRDC was restricted, it is likely that many of the projects in the cluster would have still been funded by industry, assuming a levy system was still in place and the issue became higher priority.

The limited public spillovers that have been identified would therefore still have been delivered. If no public funding at all had been available for GRDC, it is estimated that the investment would have been limited to about 70 percent of the investment actually recorded. A summary of the potential response to reduced public funding is provided in Table 10.

Table 10: Potential Response to Reduced Public Funding to GRDC
(assuming the reduction occurred prior to the GRDC investment in the cluster)

1. What priority were the projects in this cluster when funded?	Medium priority for GRDC and industry
2. Would the investments still have been made in this cluster if 50% less public funds were available to GRDC?	Yes, but with less total funding
3. Would industry and others have funded this cluster if no public funds were available to GRDC?	Yes, to the extent of about 70% of that actually funded

6. Pathway to Adoption

Developing capacity to implement IPM was a major objective of the NIPI projects. Adoption was seen to be dependent on growers getting better information to underpin their decisions on managing pests. In addition to delivering better information directly to growers, NIPI recognised that advisers and consultants were a key pathway. Further, it was recognised that in the southern and western regions particularly, their skills in pest management were limited. The success, ease of application and low cost of using preventative treatment had virtually eliminated the need for developing skills relevant to IPM. A key factor determining low cost was that an insecticide could be simply added to a routine herbicide or fungicide treatment.

However the low cost of a pesticide treatment is not indicative of costs to society if there are externalities, for example from damage to the environment or from the spread of pest resistance to growers other than the farm of origin. In either case, there is potential in the future for community responses which will influence adoption. In addition the reliance on low cost pesticides sets the industry up for potential disruption should pesticide resistance emerge more rapidly. The next section on estimation of benefits will take these aspects into account.

Horne et al (2008) refer to studies listing 21 definitions of IPM. Problems of defining pathways to adoption are further complicated by the term "pests" often being used for a range of pests other than invertebrates, for example for crop diseases caused by viruses. Horne et al in a case study on canola and cereals in Victoria also concluded that IPM could be successfully implemented in broadacre cropping using existing information and rapid field scale testing. But the success depended on action learning and close collaboration between the farmer, an agronomist adviser and backup entomological support to reduce stress and engender confidence. Stress is inevitable when there is uncertainty whether the crop will suffer a major economic loss if a low cost insecticide is not used. The uncertainty is compounded by the lack of knowledge of the dynamics of beneficial insects and how soon if ever they would be effective, and lack of knowledge of resistance developing.

Achieving high rates of adoption of IPM approaches is clearly a challenge. Pesticide-based approaches are widely adopted, and effectively marketed by chemical companies to eliminate uncertainty. In contrast on both aspects, there is limited marketing of IPM and much uncertainty with limited adoption. The next section will estimate benefits in terms of how the GRDC investment might close the gap.

7. Measurement of Benefits

The benefits valued in this analysis are limited to the increased profitability from adopting IPM as a consequence of the GRDC investment in NIPI I and II. The increase is from a baseline of the situation that would have resulted if there had been no investment. The evaluation is over a forward period of 30 years, sufficient time for the benefits of the increased capacity developed by the NIPI investment to date to translate to increased economic benefits. But the evaluation excludes benefits that might be attributed to the subsequent GRDC investments in NIPI III.

The baseline from which to estimate the benefits is not simply the status quo but the future profitability in the absence of further investment in research and extension in entomology in the grain industry. As discussed in the Introduction, there are several drivers which are likely to contribute to increasing difficulties in managing pests of grain crops. As discussed by Loxdale (2005) in a European context, there will be increasing demand for a wider range of strategic and applied research if pesticides are reduced in variety and quantity in response to community demand and government policy, and as resistance to pesticides increases. These trends suggest that the benefits from the investment in NIPI could increase over time and can also be viewed as a form of insurance.

A broad definition of IPM is used for simplicity in this evaluation. IPM is closely aligned with a triple bottom line framework as the emphasis is on economically justified approaches that minimise risks to the environment and to human health. IPM promotes using a wider range of approaches to manage pests and at the same time reducing reliance on pesticides. Broader approaches for farmers include cultural, biological and chemical tactics. Other longer term strategies including plant breeding for host plant resistance are not specifically included in this evaluation.

Benefits not specifically valued and the extent to which the benefits can be attributed to the GRDC investment will also be considered in this section. A summary of the key assumptions is presented at the end of this section in Table 16.

Ideally and from the point of view of society, an assessment of the benefits of changed practice in relation to pest management should take into account four dimensions:

- the likelihood of achieving the desired result in relation to uncertainty,
- impacts on beneficials (predator, parasite, pathogen-prey relationships),
- impact on resistance including beyond the farm of origin, and
- impact on the environment.

Assessments that fail to take account of all dimensions can lead to wrong decisions, over use by individual decision makers, and externalities. These consequences are amplified by uncertainty.

In this simplified assessment, the extra benefits to be quantified each year are from changes in on-farm profitability. They are the product of the extra benefits/ha, and the area benefitting for each year of the analysis as determined by the rate of adoption. The latter will clearly be determined by the benefits/ha. The benefits/ha will be considered first after considering some background information on pests.

IPM Surveys

GRDC in its performance indicators uses measures such as the proportion of growers with improved confidence in managing pests, weeds and diseases (GRDC 2007a). These measures would potentially indicate changes in attitudes to IPM if they were targeted specifically at pests. However there is not a simple translation from grower confidence to industry or community benefit if externalities are not taken into account. This perspective needs to be kept in mind when considering grower-focussed information on pesticide use.

Results from the survey of 1,300 growers based on the 2008 winter crop (GRDC 2010a) included reports of a statistically significant increase in the incidence of RLEM. Mentions of RLEM incidence were highest in Victoria with 32 percent of growers. It is likely that those growers who had attended a NIPI course on identification would have been able to respond with more confidence. Overall there was a high level of awareness of IPM (60 percent), 30 percent responded they are currently adopting IPM, 30 percent are likely to, and 22 percent have sought information on IPM. These results appear encouraging from the point of view of an industry aiming to achieve more sustainable approaches to pest management.

In a survey of canola growers and advisers (Insightrix 2007), 12 percent listed pests as a limiting factor. RLEM was the most common pest mentioned.

Responses to questions on pesticide use were added to the major survey on no-till (Llewellyn and D’Emden 2009). Results are summarised in Table 11.

The average number of times when insecticides are applied of 1.5/crop (3 every 2 years) defines the scope to reduce the number of applications. In addition two out of three growers monitor before deciding to spray. This appears to provide a good basis for some adoption of IPM when combined with the GRDC survey showing 30 percent had adopted IPM and a further 30 percent intended to.

However the view of NIPI researchers was generally that a figure of 60 percent that had adopted or intended to adopt did not suggest that a very demanding or useful definition of IPM was being invoked. For example the survey showed that the majority monitor before spraying. Growers who monitor might well consider they are adopting IPM according to their definition. These proportions adopting or intending to, would not translate on their own into major decreases in pesticide use based on improved understanding of IPM. In any case this analysis is tasked with assumptions on the proportions that could be attributed to NIPI activity.

Table 11: Responses to Survey Questions on Pesticide Use by Oilseeds (mainly Canola) Growers

Oilseed Grower (mainly Canola) Pesticide Use	**% Respondents**
% who have grown any oilseeds in the last three seasons	38
% who in that period have used an insecticide on oilseeds	88
% who use an insecticide as a protectant spray:	
• Always	56
• Sometimes	35
• Never	9
% who monitor for insects before deciding to spray an insecticide on oilseeds :	
• Always	64
• Sometimes	30
• Never	6
% of growers by times when insecticides are usually applied to oilseed crops (the total indicates 1.5 applications/crop)	
• Pre-sowing	32
• Seed insecticide treatment	14
• Post sowing pre-emergence	55
• Post emergence	47

Source: From data on supplementary questions to the survey (Llewellyn and D'Emden 2009) of 1,172 Australian Grain Farmers. (Personal Communication, Rick Llewellyn 2010)

Some Most Mentioned Pests of Cereal Crops

Trends in the incidence are as summarised from Hoffmann et al (2008) who considered changes related to pesticide use, climate change, and changed farming practices. For a comprehensive list and details of pests of grain crops in southern Australia see the Ute Guide (GRDC 2008).

In years of widespread rainfall in eastern Australia, such as the La Niña of 2010, large swarms of migratory locusts can be a threat to cereal crops containing green matter. Losses are less frequent in Western Australia. The Australian Plague Locust Commission coordinates responses. The NIPI projects have not targeted locusts.

RLEM is regarded as the most serious pest of grain crops. It is increasing in incidence, but is restricted to Mediterranean climate southern and western cropping areas. The buildup of RLEM during the pasture phase of a rotation can be controlled by a spraying as determined by the TIMERITE® service (Ridsdill-Smith et al 2008) which provides farmers with the date for a spring spray that achieves high levels of control through to the following autumn.

RLEM can cause considerable damage particularly at establishment of canola and of pulses. Control of RLEM needs to consider impacts on blue oat mites. Bare earth sprays can provide protection of the germinating seedling. Occurrences of resistance are increasing (Micic, 2010) with 12 identified in Western Australia. RLEM spread rapidly through Australia's Mediterranean climates when they first appeared from South Africa almost a century ago. The rate of spread of resistance is being investigated and will depend on the mechanism of inheritance and how severe the selection pressure is.

There are a range of pests that can become prominent in different environments and seasons. They include, but are not limited to:

- DBM or Cabbage moth is a pest of canola and other Brassica with increased incidence likely following drier and warmer autumns and winters. There is resistance to older insecticides and evidence of tolerance to newer SP.
- Aphids – improved weed control over summer may have reduced incidence of aphids. Aphids have a role in transmitting viruses. Observation of potential damage can necessitate spraying. Aphid specific insecticides are available to conserve beneficials. (As discussed previously, incipient resistance has been reported in Western Australia).
- Armyworms – their reduced incidence is probably related to drier autumns and winters.
- Helicoverpa – increased incidence particularly in grain legume/cotton rotations and there is resistance to some older broad-spectrum chemicals.
- Mandalotus - has emerged in recent years as a pest of canola on some soil types. Increased incidence has probably resulted from the increase in minimum tillage. The weevil has a high tolerance to pesticides.

Benefits/ha

The information on benefits is limited. In the GRDC northern region where there has been a high level of adoption of IPM, Brier et al (2008) have reviewed the drivers, few of which are currently applicable in the other grain regions. Some drivers, such as a crisis for example from concerns of increased resistance or the arrival of an exotic pest, are likely drivers of more rapid adoption of IPM in the future. Others, such as the outstanding success with breeding sorghum resistant to the sorghum midge, have not been applicable in other regions. IPM adoption in the northern region also had a more solid knowledge base built up over the previous decade from research to increase understanding and from workshops to develop the skill base. As a result there was a strong on-ground network linking advisers, industry and entomologists able to rapidly adopt research and to adapt to emerging issues. The NIPI investment was concentrated in southern and western regions building on experience in the northern region.

In southern Australia there are reports of an IPM perspective being a priority for the management of 40,000 ha (Horne et al 2008). The Grain and Graze research program for mixed farms included trials of IPM (Grain and Graze 2008). A farmer commented on a scoping study at Cowra "*For a crop like canola that is expensive to establish, spraying allowed you to sleep at night for a relatively small cost*." However the report on withholding insecticide sprays showed no significant economic loss. Application costs were saved allowing numbers of beneficial insects to build up. Hives (2008) reported savings after a few years of adopting IPM of from $4 to $25. The savings were for growers on grain crops in higher rainfall areas of Victoria. However reducing input costs was rarely the main motivation for adoption of IPM.

The Acknowledgements Section at the end of this report has an extensive list of the expertise consulted to inform the assumptions. Although not a formal survey, there was a general view that a simple view of IPM could be captured as summarised in the Cowra experience. The key aspects were:

- Adopting IPM can be simply viewed as a reduction in the average number of sprays as determined by more careful and informed monitoring as problems varied considerably from year to year,
- There was no consensus on yield gains or losses but the net effect after a few years was likely to be small on average, however it could take some years for beneficial numbers to build up, and
- Monitoring costs were likely to increase, particularly until experience develops.

The only major driver of change that was mentioned with some frequency was the desire by farmers to reduce their use of pesticides to avoid toxic chemicals.

The crop of origin for pests submitted for identification provides one indicator of the grain crops potentially benefitting from an IPM approach. For samples submitted in South Australia (NIPI project reports), canola accounted for close to one third, cereals 28 percent, and pulses 20 percent. The proportions are not indicative of the extent of problem pests, only of pests (probably unusual ones) that senders wanted identified. The evaluation will be restricted to these three categories, canola, pulses and cereals. Some crops such as soybeans are not specifically included. However at a national scale, their area is minor.

Per ha costs of insecticide treatments vary from a few dollars when a cheap insecticide is added to a planned herbicide or fungicide spraying to up to $40 or more for aerial spraying. Costs are typically higher for canola. Budget estimates for Western Australia ranged from $15 for cereal crops to $25 for canola (quoted in Micic et al 2008). However, in addition to variation between crops, there are large year to year and regional differences in insecticide costs. A wide range of gross margin budgets of likely costs are published for the range of crops and zones in NSW (Table 12). Notes to the budgets include comments such as cereals are rarely sprayed in some regions whereas treatments are generally needed to ensure canola establishment. Cereals will be included to take some account of areas which are likely to be subject to more problems, mostly sporadic, but requiring insecticide treatments. The insecticide use patterns assumed are in line with those reported in the Farming Systems Trial undertaken by the Birchip Cropping Group. A review of the patterns showed a much higher frequency of insecticide treatments for canola with lower frequencies for pulse crops and much lower frequencies for cereals (Personal communication, Sarina Macfadyen, 2010).

Table 12: Examples of Costs Budgeted for Insecticide Treatments for Canola, Chickpeas, and Faba Beans in Two NSW Zones.

Crop Examples	**Pest Schedule**	**Average Annual Cost/ha**
Canola (Central NSW Zone East) • Earthmite control is essential to protect seedlings. • Monitor regularly from flowering onwards for chewing and sucking insects eg. aphids and heliothis. • Heliothis control is needed in most years.	May: Mites October: Heliothis September: Aphids (1 year in 2) Total	$7 $22 $25 $54
Chickpeas (Southern NSW Zone East) • Heliothis must be controlled. Monitor regularly from budding to pod-fill. • Heliothis may need to be sprayed twice if a second flight occurs late in the season.	October: Heliothis	$37
Faba beans (Southern NSW Zone East)	September: Heliothis	$16

Source: Industry & Investment NSW (2010).

The cost/ha range is from $16 for Faba beans to canola at $54/ha. The average annual frequency of 2.5 insecticide treatments for canola is above the average of 1.5 insecticide treatments as shown in Table 11. The cost savings from IPM were stated as from $4 to $25 for the Hives (2008) example. The limited available evidence supports an assumption of cost savings of the order of 20 percent, for example from avoiding an insecticide treatment either every year or once every two years. These are assumed to contribute to the per ha benefits of $10 for canola and $5 for pulses. In the absence of any data for wheat, a conservative estimate of $5 is used as for pulses.

For simplicity the benefits for canola have not taken into account that resistance would have eventually become a bigger problem in the absence of NIPI I and II. Costs of alternatives would then most likely have increased so that the benefit/ha would increase over time. However, the adoption rates developed in the following do reflect an increasing incentive for adoption.

The Determinants of Adoption

Micic et al (2008) state in relation to their recognition of the relatively little adoption of IPM in broadacre farming in southern Australia:*"The driving forces behind lack of adoption are unknown, although overreliance on broad spectrum insecticides ....is undoubtedly a key factor".* Given the lack of information on adoption, some of the generic factors influencing adoption need to be considered. The factors assume a given regulatory environment. Changed regulations could of course have a significant impact.

The evaluation of the GRDC investment in Precision Agriculture (GRDC 2007b) considered adoption in terms of the six general criteria as listed in Table 13. In common with IPM, Precision Agriculture involves acquiring information and a range of skills to facilitate practice change. Considering first the three on the left, the only one where IPM may rate more positively is for researchability, or the scope for a grower to undertake pilot scale testing, for example by not spraying a strip. But two potentially crucial limitations which contribute to inherently high levels of uncertainty are:

- limited understanding of the role of non-resident pests and the population dynamics of beneficials, and
- difficulties in estimating time until resistance develops and the extent to which it might be determined by insecticide use patterns of other growers.

Table 13: Six Generic Attributes determining Adoption of a Practice Change

Return How readily can the average rate of return or profitability be assessed?	**Complexity** Is it difficult to understand and implement?
Risk How likely that the actual return will be much higher or lower than the average?	**Compatibility** Does it fit in with the way the farm is operated and with the goals of the farm business?
Researchability How easy is it to test the likely success?	**Communicability** Is it easy to get the information needed to the decision maker?

For the three attributes on the right in Table 13, compatibility is likely to rate highly for many in terms of IPM reducing use of pesticides and in terms of farmer goals to reduce use of potentially harmful chemicals. In general IPM is seen as complex although specific skills such as improving identification of pests and beneficial is being aided by courses, publications and services such as PestFacts. There are many strategic and tactical approaches contributing to IPM. However availability of time needed for monitoring for more complex alternatives is one limitation, particularly for managing establishment pests when there is pressure to get a crop established as soon as possible to avoid yield penalties.

Baker (2009) as part of the Canola Best Practice Management Guide has provided a comprehensive review of canola pests and their control. In summary "*Growers should be prepared to treat each year at, or soon after, sowing to control mites and budget for an aerial spray between flowering/podding and maturity."* However the potential for IPM was not mentioned. In fact the only reference to IPM was in a context of use of a particular insecticide (a non SP) with advice that it should be used as part of an IPM approach to RLEM management. There were also no mentions of resistance, beneficial pests or other components of an IPM approach.

Case studies of crop establishment practices used by nine established canola growers (GRDC 2010b) do provide some further indication of the scope for benefits from adoption of information generated by NIPI. Table 14 summarises the experiences of the growers covering the main areas growing canola.

The experiences of canola growers as shown in Table 14 highlight the importance of the establishment period in achieving a successful crop. Also growers have developed relatively routine approaches to handling some pest problems. Other pest problems vary regionally, are more sporadic and are managed more by monitoring and then treating. Again IPM was only mentioned once. Again, none mentioned beneficials or the potential for RLEM resistance. The three issues are potential drivers of greater adoption of NIPI research findings, particularly now there are farms in Western Australia reporting resistance.

Experience in other situations can inform adoption assumptions. Horne et al (2008) outlined the approach adopted for the Grain and Graze project in Victoria. They concluded that successful adoption of IPM requires:

- collaboration between farmers and advisers,
- local demonstrations, and
- availability of expertise to support decisions and build confidence.

Successes in the GRDC northern region provide a further example. The important role of a crisis as a key driver has already been mentioned. There was a history of research to underpin more confident adoption of IPM practices. Brier et al (2008) state that adoption of IPM, including greater use of more selective pesticides has depended on strong 'grass roots' links between researchers, extension officers, consultants, growers and key industry bodies. There were also strong links with the cotton industry to develop area wide management (AWM) approaches.

From the two examples it can be concluded that:

- either a very intensive, heavily supported environment is needed as for the Grain and Graze example, or
- in the northern region, IPM adoption needs to be underpinned by research findings and with adoption driven by concerns about resistance or the arrival of an exotic pest; all combined with an across-industry approach to support grower efforts including their capacity to manage whatever situations emerge.

Both examples depended on growers who recognised that IPM was a desirable goal and aspirations could be met if the skills and knowledge were adequate. The GRDC Survey showed that nationally over one half of growers surveyed had implemented or planned to implement IPM. There can be questions about the rigour of definitions. But the response does show that there is a majority aspiration even if it only emerged once in Table 14.

Table 14: Summary of Experiences with Canola Establishment Pests for Nine Growers

Farm Location	Summary - Grower Experience with Canola Establishment Pests
Dinninup, WA	• Initial insect control was achieved in combination with the knockdown herbicide. • Bare earth control for RLEM was achieved post-sowing pre-emergence. • *"Having the crop under siege from pests such as slugs at establishment was the recipe for some sleepless nights".* • Monitoring was required in the early emergence phase to check for slugs on areas of susceptible loamier soil types and baits were applied as necessary. • Late season monitoring for diamondback moth larvae and heliothis revealed no large infestations, while the odd head was infested with cabbage aphid, although no control was necessary.
Neridup, WA	• Negative aspect - it is a relatively high input crop $450/ha that exposes the farm business to a higher level of risk. • No seed dressings are used. Canola is a very robust crop once it

	gets past the early establishment stage. Canola receives an application of an SP with the last knockdown for vegetable weevil, RLEM and Balaustium mite control. • Another SP is applied immediately after sowing for increased redlegged earthmite control. Depending on the season a late insecticide may be applied for aphids or budworm control.
Temora, NSW	• One of the most difficult aspects of growing canola has been unpredictable insect attacks which have significantly reduced yield. These include scarabs, diamondback moth and aphids. • The application of a bare earth insecticide post-sowing has provided good control of insect pests. • Close monitoring is needed as retaining stubbles can create a physical impediment to germinating canola and be an ideal habitat for insect pests.
Lockhart, NSW	• The application of a bare earth insecticide post-sowing has provided good control of insect pests.
Mallee, Victoria	• Need to monitor the canola closely as it comes out of the ground for insect pests - mainly RLEM and lucerne flea.
Horsham, Victoria	• Seed dressing for insects such as RLEM. • RLEM, lucerne flea are sprayed after sowing (seed dressing not enough).
Inverleigh Victoria	• Early vigour of the hybrids as early vigour of canola is important. In triazine tolerance varieties, the establishment is slow and it leaves the plants vulnerable to pests etc. • Occasional seed dressing for insects such as RLEM. Also sprayed after sowing, but they are trying to go down the IPM path, and will in future try to avoid insecticides in most cases. But they do bait for slugs.
Tarlee South Australia	• Some insecticide seed dressing, some baiting for snails and slugs. • Some trouble in the past with false wireworm, RLEM, lucerne flea, snails and slugs, so these are the main threat at emergence. • Scouting is needed at emergence; if these pests aren't managed they can damage the crop in a short timeframe.
Owen South Australia	• Seed dressing provides some protection against RLEM. • Due to the mulch on the soil, earwigs and millipedes can be a problem if not managed. Sowing rates are a little higher than necessary to provide some margin for insect damage.

Source GRDC (2010b)

Experience suggests that a driver such as a crisis from a new pest or a resistant pest is needed to achieve high rates of adoption of IPM. Four further ingredients needed to turn awareness of IPM and an aspiration providing motivation are:

- knowledge - good understanding of IPM strategies based on research,
- skills - resources to build skills in the form of products such as training courses, PestFacts, Ute Guides, training manuals such as ISPY,
- support, for example from advisers or entomologists to back-up grower knowledge and skills, and
- support coordinating promotion of IPM, for example in best practice publications.

In relation to the point on corporate support, there may be a case to defer promotion until there is a more comprehensive body of research to increase awareness of the benefits of IPM and until guidelines and demonstrations are available to support practice change. NIPI III has a project which will provide comparisons of current approaches with IPM-based approaches in a range of crops and environments. As reported in Farm Weekly (2010), GRDC Western Panel member Ralph Burnett stated

"*An IPM approach has the potential to reduce reliance on broad-spectrum pesticides and improve environmental outcomes for the community, but the economics are yet to be determined*." The project will investigate the effectiveness of pest management techniques comparing:

- A conventional farmer's practice approach using preventative and remedial insecticides.
- An alternative approach, incorporating IPM strategies of pest biology and measuring economic, environmental and social impacts.
- Impacts on the crop when no control is taken.

NIPI I and II in the southern and western regions has concentrated on resources to build skills and on strengthening support. For example an estimated 650 consultants and advisers have attended one day workshops concentrating on pest identification. Over 3,000 subscribe to regular newsletters such as PestFacts on current pest reports. In summary the two key factors most likely to be constraining IPM adoption are the lack of locally relevant research results to underpin IPM strategies and the shortage of skilled entomologists to support decision making. The training of advisers that has been done, while clearly a good start, could not be expected to equip those attending for anything more than an introductory advisory role in IPM. As shown by Bellati et al (2009) participants nominated decisions on when to intervene as the area they needed most assistance on.

Target Areas and Adoption Rates

The previous tables have summarised current pesticide practice and the GRDC Survey indicated current levels of awareness and interest in IPM. However there is little evidence to indicate likely adoption that could be attributed to NIPI. Bellati et al (2009) has shown that two thirds of agronomists/consultants attending NIPI workshops were very likely to use three pieces of information from the workshop. However control decisions were the most selected area by agronomists/consultants and growers where they needed more assistance. But IPM principles were the least selected area.

There are other technologies/practices that can provide some insights on possible adoption levels. Integrated weed management (IWM) and conservation tillage are in many ways analogous to IPM in that many specific practices can be seen to contribute. An evaluation of weeds research (GRDC 2009) where herbicide resistance was a major driver used an adoption rate nationally of 2.5 percent for practices contributing to IWM. The annual research investment over a decade was of the order of $15/ha adopting. For conservation tillage (including no till and reduced tillage) in northern NSW, the equivalent figure estimated from Scott and Farquharson (2004) was about $100/ha adopting for an annual adoption rate of about 4 percent. Llewellyn and D'Emden (2009) have analysed adoption of no till in Australia over longer periods. The rate of less than 1 percent for the first two decades to the early 1990s was followed by very rapid phase of adoption averaging 5 percent annually. The authors attributed the rapid rise to the diffusion once a critical number of early adopters became influential. There were clearly other major drivers. Reduced herbicide costs and machinery developments were just two drivers that were able to build on the large investments in research and extension over the period. In northern NSW with an area of crop of about one million ha the investment was over $50 million over a period of two decades.

As with conservation tillage, IPM adoption could accelerate once a critical number of early adopters became influential. However early adopters may have different motivators including greater influence from non-economic factors than other growers.

Adoption that can be attributed to NIPI will depend on assumptions made concerning extension and advisory support to IPM initiatives by growers as well as key drivers such as increased resistance of RLEM to pesticides and changes in regulations governing pesticide use. As the evaluation is of NIPI I and II, the benefits that might flow from the current investment in NIPI III will be excluded. In the absence of NIPI III or of further GRDC investment, it is unlikely that the extension and advisory services provided by NIPI partners would be maintained by the partners increasing their investment. Adoption would then be reduced to very low levels. A more workable (if somewhat arbitrary) assumption is to assume continued investment of $300,000 pa which is about half the rate for NIPI I and II. This would be sufficient to maintain some level of support. Note that the assumption has been made by the author in the interests of demonstrating a possible scenario of benefits from an investment in capacity building. In common with some investments in capacity building, further investment is often necessary to exploit additional knowledge and skills. If the further investment was not assumed, there would only have been very low rates of increased adoption assumed that could be attributed to NIPI I and II. The importance of the assumption of a continuing investment will be checked in a sensitivity analysis. (See Table 21).

If resistance increases in the next few years, an adoption rate of one percent annually appears feasible for canola. However much lower rates would be appropriate for pulses and even less for cereals. The problems in cereals are mostly sporadic and generally assumed to offer less incentive for acquiring skills to underpin practice change. The preceding analyses do not provide any evidence that would support optimistic levels of adoption of practice change to implement aspects of IPM unless there is some radical change in the key drivers. This assumption does take into account that canola growers also grow cereals and pulses and some of the skills they need to acquire to adopt IPM will be relevant to other crops.

Based on the above, adoption trends for the period of the analysis are presented in Table 15.

Table 15: Key assumptions for the NIPI I and II evaluation

Item	**Canola**	**Pulses**	**Cereals**
Adoption/Benefit Trend Attributable to NIPI I and II as a % of Target Area			
To 2009*	0	0	0
2009 to 2014	0.25	0.1	0.01
2014 to 2019	0.5	0.2	0.01
2019 to 2024	1.0	0.2	0.02
2024 to 2034	0	0	0
Target Area** (m ha)	1.5	1.65	20
Maximum area (m ha) reached 2024	0.131	0.033	0.030

*Note: Benefits are assumed zero to 2009 and then increasing from 2010.
**Source: Based on recent and forecast average Australian totals (ABARE 2010).

The areas of crop potentially benefitting and the annual adoption trends as a percentage of the Australian areas (ABARE 2010) are estimated on a national basis as shown in Table 15.

The areas of crop potentially benefitting are assumed constant although small changes in the cropping mix and in rotations could be expected depending on the economics of pest management. There may also be crops not currently grown in some areas and seasons because of pest management considerations. For simplicity adoption is defined by the existence of a dollar benefit from a practice change as part of an IPM approach. The analysis is general in that drivers, practices and pests are not specifically linked to the benefit calculations.

The NIPI project began in 2005. However the first year of benefits is assumed to be 2010 to allow for an earlier period of IPM with zero benefits as experience developed and because more time is needed for monitoring.

The main driver of the trend in benefits is the assumption of resistance of RLEM to pesticides increasing over the next decade. The increase is regarded as inevitable. The rate of increase in resistance cannot yet be forecast. The rate of adoption selected will be the key variable to be subject to a sensitivity analysis. The rate is however set at a low level to reflect that the economic incentives to change practice are not large, they are uncertain and they are in the future.

As shown in Table 15, benefits are assumed to reach a maximum by 2024 and then level off to 2034 before declining to zero by the end of the 30 year period of analysis. The decline pattern assumes that the knowledge and skills developed by NIPI I and II no longer provide a base for further research to build on. Management and research are likely to be confronted by numerous unpredictable changes. For example changes in technology, environmental policy and impacts of climate change, any of which could render research from two decades previously obsolescent.

Benefits not Valued

As discussed in Section 5, the principal additional benefits that can be identified but have not been specifically valued in the analysis include:

- Benefits from strategies to reduce resistance thus prolonging the useful life of the insecticides involved,
- Environmental benefits - from reduced use of pesticides,
- Biosecurity- from increased surveillance to more rapidly identify incursions of exotic pests,
- Social – including capacity building in terms of skills, and health benefits from reduced usage of toxic chemicals, and
- Spillover benefits to other industries.

Attribution

The analysis to date has flagged the importance of high levels of technical support for advisers to ensure that growers can more confidently manage the risks of changing to an IPM based approach. Increased adoption will require additional resources other than those attributable to NIPI I and II. In the GRDC northern region for example, increases in adoption of IPM will continue to result from activities of other agencies and from other GRDC projects. In southern Australia there are agencies involved in promoting IPM and in training, for example Horne and Page (2008). Taking into account other activities, 60% of the estimated benefits are assumed to be attributable to NIPI.

Summary of Assumptions
A summary of the key assumptions made is shown in Table 16.

Table 16: Summary of Assumptions

Variable	Assumption			Source
	Canola	Pulses	Cereals	
Benefit ($/ha)	10	5	5	Based on approximately 20% savings. See Table 12 (Industry & Investment NSW, 2010).
Maximum area benefiting (m ha)	0.131	0.033	0.03	From adoption/benefit trends (Table 15) assuming increasing RLEM resistance in canola crops to drive accelerating adoption.
Year economic benefits start	2010			Assumed to be year of first benefit allowing a lag for beneficials to increase after earlier IPM adoption
Year maximum reached	2024			Table 15
Maximum adoption	2024-2034			Table 15
Adoption at final year of 30 year analysis	0			Author estimate of a benefit decline assumed from 2034
Additional extension costs ($m)	0.3 pa from 2012 to maintain minimum level of services			Author estimate assuming limited capacity of partners to maintain current levels post NIPI I and II.
Attribution of Benefits to NIPI I and II	60%			Author estimate

Results
All past costs and benefits were expressed in 2009/10 dollar terms using the CPI. All benefits after 2009/10 were expressed in 2009/10 dollar terms. All costs and benefits were discounted to the year of the final investment, 2010/11 using a discount rate of 5%. The base run used the best estimates of each variable, notwithstanding a high level of uncertainty for many of the estimates. All analyses ran for the length of the investment period plus 30 years from the last year of investment to the final year of benefits assumed.

Investment criteria were estimated for both total investment and for the GRDC investment alone. Each set of investment criteria were estimated for different periods of benefits. The investment criteria were only positive if benefits were totalled for periods greater close to 25 years as reported in Tables 17 and 18.

Table 17: Investment Criteria for the Total Investment and Total Benefits for Each Benefit Period from 2010/11
(discount rate 5%)

Criterion	Years from Last Year of Investment						
	0	**5**	**10**	**15**	**20**	**25**	**30**
Present value of benefits (m$)	0.10	0.09	1.10	3.00	4.63	5.80	6.06
Present value of costs (m$)	4.94	4.94	4.94	4.94	4.94	4.94	4.94
Net present value (m$)	-4.84	-4.84	-3.84	-1.93	-0.31	0.86	1.13
Benefit cost ratio	0.02	0.02	0.22	0.61	0.94	1.17	1.23
Internal rate of return (%)	neg	neg	neg	1.5	4.6	5.9	6.1

Table 18: Investment Criteria for the GRDC Investment and Benefits to GRDC for Each Benefit Period from 2010/11
(discount rate 5%)

Criterion	Years from Last Year of Investment						
	0	5	10	15	20	25	30
Present value of benefits (m$)	0.06	0.05	0.63	1.72	2.65	3.32	3.44
Present value of costs (m$)	2.86	2.86	2.86	2.86	2.86	2.86	2.86
Net present value (m$)	-2.80	-2.80	-2.23	-1.14	-0.20	0.47	0.58
Benefit cost ratio	0.02	0.02	0.22	0.60	0.93	1.16	1.20
Internal rate of return (%)	neg	neg	neg	1.4	4.5	5.9	6.0

The analysis was undertaken by estimating benefits for three categories of grain crops. Their contributions as determined by the assumptions in Table 16 are shown in Table 19.

Table 19: Contribution of the Three Categories of Grain Crops to Total Benefits

Crop Category	Contribution to Total Benefits (%)
Canola	77
Pulse Crops	13
Cereals	10
Total	100

The annual cash flows of undiscounted benefits are shown in Figure 1.

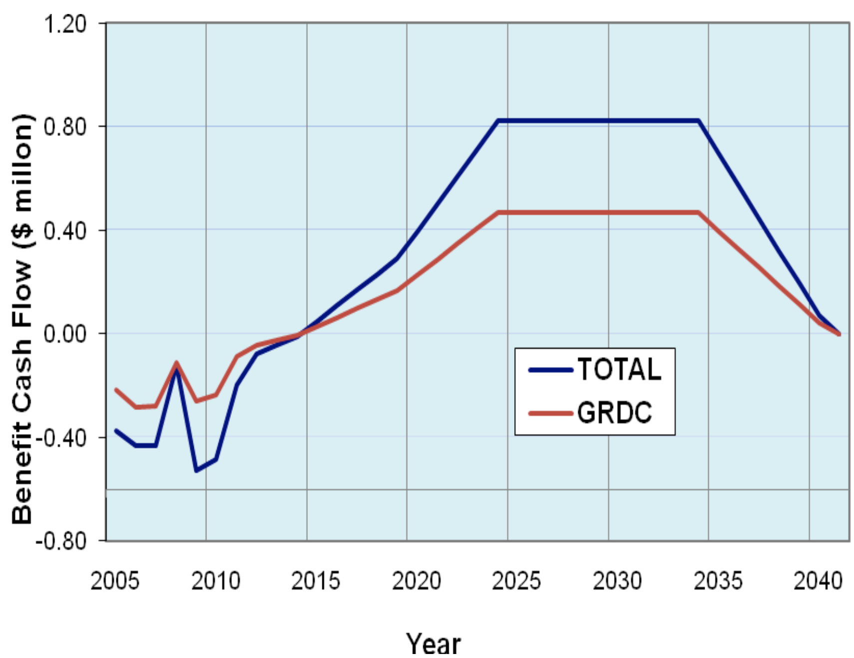

Figure 1: Annual Benefit Cash Flow

The cash flows are for the 30 year period from the final year of the investment. The fluctuations up to 2011 mainly reflect the funding pattern and a year of low funding in the transition from NIPI I to NIPI II. The acceleration in benefits to 2025 reflects the assumptions made in relation to adoption as determined by the increasing levels of pesticide resistance.

Sensitivity Analyses

Sensitivity analyses were carried out on key variables. The results are reported in Tables 20 and 21. The key variables in Table 21 were selected to take account of assumptions about which there was most uncertainty. Sensitivity analyses were based on a 5% discount rate with benefits attributed to GRDC taken over the life of the investment plus 30 years from the year of last investment. All other parameters were held at their base values.

Table 20: Sensitivity to Discount Rate
(GRDC investment, 5% discount rate, 30 years)

Criterion	**Discount rate**		
	0%	5%	10%
Present value of benefits (m$)	8.08	3.44	1.63
Present value of costs (m$)	2.55	2.86	3.21
Net present value (m$)	5.53	0.58	-1.58
Benefit cost ratio	3.17	1.20	0.51

The investment is sensitive to the discount rate and fails to break even at a 10 percent rate. The main factor involved is that benefits do not reach a high level until fifteen years after the investment has been completed. As shown in Figure 1, maximum benefits are not reached until 2025.

Table 21: Sensitivity of the Investment Criteria to Changed Assumptions regarding the Adoption/Benefit Rate and Extension Costs
(GRDC investment, 5% discount rate, 30 years)

Item	**Sensitivity to Adoption Lag and to Extension Costs**		
	Slower Adoption	Base case	More Rapid Adoption
Assumption Changed			
Year Benefits Start	2014	2010	2006
Extension Costs (2012 on)	$150,000	$300,000	$450,000
Criterion			
Present value of benefits (m$)	2.93	3.44	3.96
Present value of costs (m$)	2.86	2.86	2.86
Net present value (m$)	0.08	0.58	1.10
Benefit cost ratio	1.03	1.20	1.39

The sensitivity analysis shows that the assumptions made on changes in when adoption starts and changes in the extension costs do not result in fundamental changes in the investment criteria. Halving the extension cost results in a scenario which is close to breaking even. For a scenario with no additional extension costs assumed, the adoption rates would be reduced even further and the investment would be well below a break-even level.

It can be concluded that the most critical assumption is the level of benefits as determined by the product of the area benefiting by the per ha benefit each year. For example doubling either estimate simply doubles the benefit to cost ratio.

8. Confidence Rating

The results produced are dependent on the assumptions made, particularly on the benefits which are uncertain. There are two factors that warrant recognition. The first factor is the coverage of benefits. Where there are multiple types of benefits it is often not possible to quantify all the benefits that may be linked to the investment. The second factor involves uncertainty regarding the assumptions made, including the linkage between the research and the assumed outcomes.

A confidence rating based on these two factors has been given to the results of the investment analysis (Table 22). The rating categories used are High, Medium and Low, where:

High: denotes a good coverage of benefits or reasonable confidence in the assumptions made

Medium: denotes only a reasonable coverage of benefits or some significant uncertainties in assumptions made

Low: denotes a poor coverage of benefits or many uncertainties in assumptions made.

Table 22: Confidence in the Analysis

Coverage of Benefits	**Confidence in Assumptions**
Medium	Low

9. Conclusions and Lessons Learned

The major focus of the projects evaluated has been increasing the capacity of the Australian grain industry to manage invertebrate pests in a more sustainable way. The benefit was assumed to be from increased profitability of production of canola, pulses and cereals from areas reducing pesticide use and adopting some aspects of IPM. These were the only benefits quantified. Other benefits not valued, all positive, include reduced environmental impacts, improved biosecurity and social benefits including capacity building and health benefits from reduced use of chemicals.

The evaluation showed that based on the assumptions the investment to date in NIPI I and II was only likely to result in benefits slightly in excess of costs. There are three important qualifications relating to the investment criteria:

1. the focus on capacity building will provide a solid base for further benefits to be more rapidly realised,
2. the insurance aspects so that capacity is more readily available if the grain industry has to meet any new threats, and
3. the benefits could be much higher if there are unforseen increases in the benefits and reductions in the uncertainties of an IPM approach compared with the current reliance on low cost and low risk insecticides.

Most of the benefits valued were from assumed savings in costs of canola production. The areas adopting some aspects of IPM in canola as a consequence of the NIPI investment to date were assumed to be less than 10 percent of the Australian total after 15 years. This low rate was based on an assumption that it would take a major change in the drivers to shift growers from their current low cost/low risk approach of an "insurance" type use of insecticides. The GRDC investment could also have been usefully viewed as insurance if there is some major surge in demand for IPM. The continuing and inevitable spread of resistance by RLEM to insecticides was assumed to be one of the main drivers in this evaluation. However there is no information available on likely future extent or rates of spread.

Confidence in the assumptions was low. Based on the assumptions made, the total investment of $4.94 million (present value terms) has been estimated to produce gross benefits of $6.06 million (present value terms) providing a net present value of $1.1 million and a benefit cost ratio of 1.23 (over 30 years, using a 5% discount rate). GRDC contributed 57 percent of total funding to the program.

The projects were clearly successful in achieving a strengthened national approach to developing IPM expertise. Highly effective workshops targeting pest identification were held and a range of products developed to give the industry rapid access to timely information on pest issues. However, the limited experience with IPM suggests that widespread adoption of IPM will not occur unless there is a major change, for example a crisis looming such as an introduced pest or widespread development of resistance. Changes in regulations governing insecticide use could also be a factor. Adoption of IPM will still depend on local independent expertise or action learning to support confident decision making, including on the risky not-to-spray choice. The capacity and expertise already developed should only be viewed as a start. There are current NIPI projects not included in the costs or benefits of this evaluation which will provide improved information to support IPM adoption.

How growers react to increasing resistance is a further problematic issue. In Western Australia 12 cases of red-legged earth mite resistance have been identified since 2006. If resistance was perceived to spread from other farms rather than from excessive use on their own farm, growers could be even less inclined to reduce insecticide use. The policy implications also differ. Research is needed on factors leading to adoption of IPM as well as the causes and extent of the spread of resistance. Concerns about resistance developing may not deter some growers from continuing use of low cost/low risk practices.

The research envisaged would help inform development of more consistent corporate and industry strategies. For example, there are significant publications on managing canola pests which surprisingly do not mention IPM, beneficials or resistance.

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