ON ASSESSING SOME OF THE NET EFFECTS OF IPM

Paola Parigi and Bill Malcolm

School of Agriculture and Resource Management

University of Melbourne, Grattan Street, Parkville VIC 3052

The potential costs and benefits, private and external, of a shift to Integrated Pest Management (IPM) are considered. A method is developed to estimate the private net returns of IPM in particular farm situations. This method is then applied to compare the financial characteristics of IPM and conventional systems in apple and grain legume production in Victoria. A key finding is that in a 'typical year' of a 'typical operation' the annual net returns of a shift to IPM, in both crops, could be positive. Externalities associated with IPM may be positive or negative depending on the circumstances.

CONTENTS

INTRODUCTION

World-wide, recent government efforts to achieve more sustainable pest management have focused on the research, development and promotion of Integrated Pest Management (IPM).

Although there is no unambiguous definition of what IPM means in theory, or in practice, IPM strategies in Australia generally promote four key principles to farmers:

- whenever possible, use non-chemical control technologies (e.g. biological, cultural and mechanical control measures);
- spray only when the level of pest infestation reaches a threshold of economic significance, or when climatic conditions threaten a disease outbreak;
- avoid using sprays in a way that limits the effectiveness of natural controls; and
- do not spray regularly with the one chemical, because this will induce the onset of resistance to chemicals (Barr and Cary 1992).

The principles of IPM were developed to increase the private benefits of pest control and reduce the environmental costs of pesticide use. While the general, 'common sense' principles of IPM appear to be highly consistent with these goals, whether or not the principles of IPM will lead to improved outcomes in farming practice depends on the precise details of each farm situation: the pest, the crop, the location and so on.

In most situations, little is known about the costs and benefits of IPM. For example, the availability of IPM strategies for the control of specific pests in apple and grain legume production in Victoria are relatively new phenomenon. Like many new 'sustainable agriculture' concepts, there is some uncertainty about what is implied in the practice of IPM. No work has specifically addressed this issue and the amount of information is extremely limited.

This study is about how to analyse the costs and benefits of IPM in particular farm situations when the amount of information is extremely limited. Some of the possible costs and benefits, private and external, of IPM are assessed on the basis of existing knowledge in part one. The private net benefits of a shift to IPM in apple and grain legume production in Victoria are estimated in part two. The methods used in this study provide insights to approaches that decision-makers, confronted with a paucity of information, can take to analyse similar investment decisions.

PART ONE:
POSSIBLE PRIVATE AND EXTERNAL IMPACTS OF A SHIFT TO IPM

SUMMARY OF COSTS AND BENEFITS OF IPM

A movement towards IPM will involve private and external costs and benefits. Together, these comprise social or total costs and benefits. Private costs or benefits are defined as those initially accruing to, or borne by, those farmers, and their families, who adopt IPM. Ultimately these costs or benefits or parts of them, may affect others through changes in market prices. External costs and benefits include conventional externalities experienced by other farms or individuals when a farmer shifts from conventional to IPM farming. A summary of possible costs and benefits, private and external, of a movement towards IPM, is presented in Tables 1 and 2. It is not possible to give accurate data on these cost-benefit relations. One reason for this is the location specificity of each IPM program. Another reason is the difficulty of assessing external effects. The tables are intended as a guide only to some of those factors which might (or might not) require further consideration by individuals and agencies making investment decisions about IPM. The following comments are specific to particular cost and benefit items in Tables 1 and 2.

POSSIBLE COSTS OF IPM

Higher Priced IPM Compatible Pesticides

Some IPM programs have led to higher pesticide costs due to the use of more expensive IPM compatible pesticides[1] (Wetzstein et al. 1985). Higher priced IPM pesticides have been identified as an obstacle to the implementation of some IPM programs (Wearing 1988). The situation may change if the resistance of pests to broad spectrum insecticides increases of if the price os selective pesticides declines.

Emergence of 'New' Pests

Changes can occur in the status of pests and the importance of 'new' pests as a consequence of a shift to IPM (Graebner et al. 1984). For example, a shift away from broad spectrum to IPM compatible pesticides can result in the emergence of new pests. Problems may occur when pests, which were inadvertently controlled by broad spectrum pesticides, are left unchecked (for example see Durham 1984, Hussey and Scopes 1985, Morris 1984, Way 1977). Additional control measures may become necessary for 'new' pests adding to the cost of an IPM program.

Increased Use of Some Inputs, E.g. Labour

Concern has frequently been expressed that IPM does not offer an advantage in profits compared to conventional control, particularly because of the cost of labour (Poe 1981, Smith 1981. Stockdale 1980, Willey 1978). The charge for advice on pest control and complex monitoring and staff supervision are factors most commonly identified in the literature in relation to high costs (Antle and Park 1986, De Wilde and Leemans 1981, Readshaw 1984).

---

[1] IPM compatible pesticides are usually defined as those which 'kill' pests but are 'less harmful' to beneficial insects, such as spiders, predatory bugs, lace wings and parasitoids, due to either their mode of action or the way in which they are used.

TABLE 1 - Possible Private and External Costs Associated With a Shift from Conventional Pest Management to Integrated Pest Management

COSTS	PRIVATE	EXTERNAL
Higher priced IPM compatible pesticides	✓	
Emergence of 'new' pests	✓	
Increased use of some inputs	✓	✓
Greater uncertainty about the private benefits of pest control	✓	

TABLE 2 - Possible Private and External Benefits Associated with a Shift from Conventional to Integrated Pest Management

BENEFITS	PRIVATE	EXTERNAL
Decreased use of some inputs	✓	✓
Improved crop yield or quality	✓	
Improved farm management	✓	
Reduced potential loss from rejection of produce in domestic and export markets	✓	
Improved control of resistant pests and extended life of some chemicals	✓	✓
Aggregate income benefits	✓	✓
Reduced risk to human health, safety and the environment	✓	✓

Several studies indicate that the majority of programs did not have, or have overcome, these difficulties (De Wilde and Leemans 1981, Norton and Mullen 1994, Wearing 1988). It is important to note that labour costs associated with IPM will vary from crop to crop. For example, in Goulburn Valley orchards, where property sizes range from 8 to 245 hectares, smaller growers often experience difficulties implementing new pest management technology due to monitoring costs (Bates 1993, Sexton 1993). With the use of techniques such as mating confusion where large treated areas are necessary, orchardists are required to work together with their neighbours in order to succeed (Bates 1993, Sexton 1993).

Greater Uncertainty About the Costs and Benefits of Pest Control

It is well documented that a transition to IPM can involve greater farmer uncertainty about the private benefits of pest control (for example see Wearing 1988). There seems to be a widespread view that greater uncertainty about private benefits from pest control results in increased pesticide use and pesticide costs (Feder and Regev 1979, Longworth and Rudd 1975, Tisdell 1986). Some writers suggest that an affect of this type arises because of risk aversion on the part of landholders (Feder and Regev 1979, Knight and Norton 1989, Longworth and Rudd 1975). For example, Longworth and Rudd (1975) liken the use of pesticides to informal insurance cover, arguing that, as with many forms of informal insurance practiced by farmers, pesticides applied unnecessarily are an expensive form of cover.

Although 'insurance spraying' is usually discussed in the context of conventional control in the economic literature (for example see Knight and Norton 1989, Longworth and Rudd 1975) effects of this sort may also arise under IPM. For example, apple growers may be particularly uncertain when trialing new IPM technologies such as pheromone traps. It is reasonable to expect that growers adopting this new technology might also feel anxious about tolerating codling moth populations which are below threshold. Consequently they might practice both 'IPM' (for example, laying traps and monitoring insect pests) and some form of insurance spraying (for example, blanket spraying from time to time as a 'backup' measure). The costs associated with informal insurance spraying have not been explored in literature on the economics of IPM. However, Pannell et al. (1995) noted that IPM may increase or decrease risk depending on seasonal conditions and runs of seasons, and prices and price sequences. Pannell et al. (1995) also cite a US study of IPM which found no decrease in insurance costs with increasing levels of IPM.

POSSIBLE BENEFITS OF IPM

Decreased Use of Some Inputs, E.g. Pesticides

Cost savings in the short term come from using less inputs in some IPM programs (see Norton and Mullen 1994). In Victoria, Barrass and Brown (1992) found a decrease in overall chemical costs of 48% in one Goulburn Valley pear orchard over one season. However, IPM will not necessarily reduce pesticide costs in every season. Pesticide costs will vary from season to season depending on a number of factors including pest populations, the price of pesticides, the sequential effects of previous pest control actions.

Several studies have noted a possible paradox of IPM technology leading to increased use and pesticide costs per hectare (King and O'Rourke 1977, Napit et al. 1988, Norton and Mullen 1994, Taylor 1980, Wetzstein 1985). For example, Napit et al. (1988) found in the United States that in states with large outbreaks of pests, IPM users, by monitoring their fields and detecting potential pest damage sooner than non-users, might apply more pesticide than a grower who normally sprays according to calendar dates. In certain cases, variance of pesticide cost per hectare also increased significantly with increasing levels of IPM use. The increased variance in pesticide use suggests that application decisions were being made relative to specific pest problems on individual farms. Contrary to what is often hypothesised, Napit et al. (1988) found that pesticide costs per acre increased with increasing levels of IPM in several states. King and O'Rourke (1977) also found greater pesticide use with pear scouting programs in Washington state.

Similar outcomes were recently observed in Victorian processing tomato production. The 1994/95 season was characterised by high pest populations. Preliminary results indicate that IPM users applied more pesticide and experienced higher pesticide costs per hectare than non-users. It is speculated that this outcome occurred because IPM growers were detecting and responding to potential pest damage more frequently than non-users (Smith, M. 1995, pers. comm.)[2]. In contrast, the 1993/94 season was characterised by low pest pressures, and IPM growers applied less pesticide and experienced lower pesticide costs per hectare than non-users. The variance in chemical use from season to season is consistent with Napit's premise that application decisions are being made relative to specific pest problems. It is also consistent with the overall philosophy of IPM.

These findings indicate that there are no simple 'solutions' to problems in agriculture, and affirm the need for careful case-by-case local analyses carried out over a number of seasons.

Improved Crop Yield or Quality

Studies comparing the economic performance of IPM and conventional systems in the short term usually indicate that IPM will maintain or increase yield per hectare. Financial advantage has been linked to improved crop yield or quantity in some IPM programs (Barnett et al. 1978, Norton and Mullen 1994). IPM can lead to improved crop yield or quality for several reasons. Firstly, some IPM technologies, such as IPM compatible pesticides, will achieve better control of resistant pests, at least in the short term. Secondly, frequent and informed crop monitoring can help farmers diagnose pest problems early and act before crop damage occurs. It can also lead to improvements in other aspects of farm management by aiding the early identification of problems relating to irrigation, weed and nutrient management.

---

[2] It is not clear whether crop loss was reduced as a consequence of the increased use of pesticides.

In some cases, however, 'new' pests have emerged as a consequence of a shift away from broad spectrum pesticides to IPM technologies (see Section 1.2.2). In cases where the 'new' pests have directly attacked fruit, large financial losses have occurred in a short time (Barr and Cary 1992, Hussey and Scopes 1985).

Reduced Potential Loss From Rejection of Produce in Domestic and Export Markets

A major objective of many publicly funded IPM programs is to reduce consumer concern about chemical residues in produce. Similarly, a major motivation for adopting IPM at the farm level is to meet consumer demand for less residues on produce in export and domestic markets (Australian Parliament 1990, Bach 1992). Research which specifically examines whether IPM has reduced economic damage associated with chemical residues is rare.

Improved Control of Resistant Pests and Extended Life of Some Pesticides

The resistance of pests to pesticides is a major impetus to the research and development of publicly funded IPM programs and an important stimulus to the use of IPM at the farm level (Australian Parliament 1990, Corbet and Smith 1976, Morris 1984, Smith and Huffaker 1973, Wearing et al. 1982). The resistance of pests to pesticides can influence pesticide costs and crop yields, affecting both the level and stability of farm income. Primarily because pests are mobile, the pest control actions of one farmer can affect other farmers, and pest control activities can have significant environmental and distributional implications for society as a whole (Knight and Norton 1989).

Unfortunately, owing to the dynamic and complex nature of resistance, no wor. has specifically examined the economic implications of different pest management practices on resistance. However, introducing IPM compatible pesticides can improve the control of pests which have lost their susceptibility to conventional pesticides, leading to increased yields or lower pesticide costs, at least in the short term[3].

The potential for reversion of pesticide resistance in the field to prolong the life of a compound is generally considered low under continued pesticide usage. However, some IPM strategies might extend the usefulness of specific pesticides by encouraging the use of unrelated pesticides and the careful targeting of the 'sensitive life stage' of pests (Daly et al. 1988, Knight and Norton 1989).

Aggregate Income Benefits

Aggregate IPM analyses assess the impacts of IPM programs upon those not directly involved in their use as well as upon the agricultural community. To the extent that IPM has been adopted by a large number of agricultural producers, resulting cost reductions and changes in supply can influence commodity prices. Thus, in aggregate there are potential distributional effects on producers and consumers.

---

[3] The productivity of a most new pesticides, immediately following their introduction, is high. But, as pest lose their susceptibility to pesticides the productivity of pesticides usually declines over time through either reduced yields or higher pesticide usage costs for the same yields (Knight and Norton 1989). It cannot be guaranteed that resistance of pests to IPM compatible pesticides will not occur over the medium term. For example, populations of Indianmeal moth and diamondback moth in the field have already developed resistance to *Bacillus thuringiensis* or Bt, a relatively new microbial insecticide with is especially important to many IPM and organic farmers (Georghiou 1989, Hindmarsh 1992).

Studies addressing the aggregate income effects of IPM usually report extraordinarily high returns. For example, a study by Napit et al. (1988) found that the annual internal rates of return in investment in IPM were 452% in Texas and 300% in Mississippi. Another study by Lambert (1983) found that aggregate returns to IPM in cotton, in 11 American states, amounted to $133,598,000 annually (see also Rajotte et al. 1987, Taylor and Lancewell 1977). However, most of these studies suffer from a lack of data and/or methodological problems (only one of which is the use of the IRR - a flawed measure in such cases).

Few studies have evaluated the relative income benefits of IPM to producers and consumers. The empirical studies that do exist relate to American commodities. Napit et al. (1988) and Taylor and Lancewell (1977) found that consumers receive most of the aggregate benefits of cotton IPM programs through increased quantities of cotton lint at lower prices. Lancewell (1977) points out that calculations of consumer and producer surplus often find a loss to producers as a result of adopting new technologies (including IPM practices). The reason offered for the loss is price decline due to additional supply. Alston et al. (1994), however, disagree with this 'generalisation' due largely for its failure to take into account the influence of international trade. The prices of most agricultural commodities are influenced by world market prices. Trade tends to moderate price effects that result from changes in domestic production, consequently increases in supply do not result in as sharp a price decline as is frequently assumed. Hence Napit et al. (1988) and Taylor and Lancewell (1977) probably overestimated the benefits to consumers relative to producers (Norton and Mullen 1994).

Reduced Risks to Human Health and Safety and the Environment

A major goal of most publicly funded IPM programs is to reduce the external environmental[4] costs of pesticide use (Borror et al. 1981, Clarke 1995). Fundamental to the IPM concept is the belief that IPM will replace or reduce the use of conventional inputs (such as broad spectrum pesticides) with inputs which are less damaging to the environment (such as biological controls, pest-resistant plant varieties and selective pesticides).

However, as suggested earlier, IPM will not necessarily replace or reduce the use of conventional pesticides in practice. In fact, a recent survey of 61 IPM programs found that 13 led to an increase in the use of pesticides (Norton and Mullen 1994). Even when a reduction in pesticide use occurs, it cannot be assumed that non-conventional inputs are environmentally benign and that broad spectrum pesticides are environmentally undesirable. For example:

- Some IPM compatible pesticides have higher toxicity ratings than their conventional alternatives.
- Many biological controls are exotic organisms and exotic organisms can reduce biodiversity (e.g. through competition, predation or habitat degradation (Coblentz 1990, Roper 1993)). Queensland's infamous Cane Toad is an extreme but compelling example.
- 'Naturally occurring organisms' may have hidden environmental costs. For example, the extensive use of *Bacillus thuringiensis* or Bt[5], could disrupt the role that insecticidal protein plays in the natural ecosystem (New Zealand Department of Scientific and Industrial Research 1990). It could also cause a dramatic change in pest population dynamics which would disrupt pollinator and natural plant communities, both locally and regionally (see Burch et al. 1990). Already, some strains of Bt have been found to be detrimental to beneficial earthworms (Hindmarsh 1992).

---

[4] The word 'environment' is used here to refer to the natural environment as well as human health and farm worker safety.

[5] Bt is a naturally occurring microbial insecticide which is especially important to many IPM and organic farmers (Georghiou 1989, Hindmarsh 1992).

- Naturally occurring toxins can be extremely dangerous and the engineering of plants for resistance to pests may produce metabolites in food that are more harmful to humans than existing pesticides (Doyle 1988, Pimintel et al. 1984).

These examples should not be viewed as grounds for rejecting the notion of IPM from a public policy perspective. They merely demonstrate that externalities associated with IPM may be positive or negative, depending on the circumstances. They also highlight the need for case-by-case analyses of IPM technologies at the landscape level. Much of this research is of a public good nature and therefore requires some form of centralised organisation by government.

IMPLICATIONS FOR COST-BENEFIT ANALYSIS

One critical point to emerge from Tables 1 and 2, and the foregoing discussion is that a large number of items need to be considered in a complete cost-benefit analysis of a shift to IPM. These items relate not only to changes in inputs and outputs, farm management, and risk, but also to changes over time and within and between locations. This point highlights the need for careful case-by-case analyses conducted over a number of seasons.

The difficulty is that owing to the complex and dynamic nature of pest management systems, and the lack of significant data sets, it is not possible to incorporate and measure all of the items requiring consideration in a complete economic cost-benefit analysis of IPM. Instead, the following sections of this study focus on the extent to which a shift to IPM increases the private, net returns of pest control. Because this is a major goal of IPM (see Borror et al. 1981 Ross 1965) the remainder of this study could be viewed as focusing on the 'effectiveness' of IPM (see Owen 1993); that is, on the extent to which IPM is consistent with this goal.

PART TWO:
MEASURING THE PRIVATE NET RETURNS OF A SHIFT TO IPM

In this section the private economic impacts of a shift to IPM are explored. The results of previous empirical evaluations are summarised first. A framework which can be used to compare the financial characteristics of IPM and conventional control is then outlined and applied to apple and grain legume production in Victoria.

REVIEW OF PREVIOUS EMPIRICAL EVALUATIONS

Economic evaluations of IPM programs have been undertaken all over the world for roughly 20 years, particularly in the United States of America. Findings from specific evaluations in American cotton, fruit and nut, vegetable, soybean, tobacco, peanuts, corn and alfalfa programs have been summarised by Norton and Mullen (1994). In most cases it is found that when an IPM system is used, costs for controlling pests are either lower than or the same as conventional control methods, net returns are enhanced, and risk (usually measured by variability in quality or average level of net return) is the same as or lower than that found with conventional control methods. Relatively little empirical work has been completed in Australia. A review of the literature revealed only five studies in two commodities. The findings of these studies were summarised by Parigi (1995a). It was not possible to cite an Australian study in either grain legume or apple production.

A COMPARISON OF CONVENTIONAL AND IPM SYSTEMS IN GRAIN LEGUME AND APPLE PRODUCTION

In order to determine the economic impact of IPM in Victorian apple and grain legume production, a method, based on the partial budgeting approach, was developed. The approach involves the following steps.

i) Defining key pests (i.e. pests which cause the most economic damage) and identifying the frequency and extent of damage and how it affects the crop.
ii) Defining IPM control methods, how often they need to be carried out and the time taken for the system to reach a steady state.
iii) Defining conventional control methods and how often they need to be carried out. Traditional pest control programs usually involve the application of pesticides at given intervals or at some specific growth stage of the crop.
iv) Listing, measuring and comparing the expected inputs, outputs, costs and revenues of IPM and conventional pest control methods.

Methodology and Data Sources

Due to the immense variation in pest and pest damage levels between farms and seasons it was necessary to conduct a 'snapshot' economic evaluation. That is, to make a series of assumptions about the likelihood of occurrence of pest infestations and the success of control with and without pest management practices in a 'typical year' of a 'typical operation'. Findings and conclusions based on a 'typical situation' give some fixed points of comparison for decision makers to use in deciding what to do in the current situation, and give some scope to appropriately adjust actions according to the extent to which the 'current situation' differs from the 'typical situation' which has been analysed.

There are a range of analytical techniques which can be used to measure the economic impacts of different pest management practices. An extensive review of key techniques indicated that budgeting approaches, particularly when allied with break-even threshold analysis, provide a useable tool for evaluating the economic impact of IPM at the farm level (see Parigi 1995b). Although most studies employ budgeting approaches at the farm level it was not possible to find an example of their practical application to IPM in the literature. In the absence of a framework to guide the economic evaluation of IPM at the farm level, it was necessary to formulate one. The approach draws on standard farm management principles (see Makeham and Malcolm 1993) and practical experience in the application of budgeting to grain legume and apple production. The principles will be similar in other crops.

The estimates used in this analysis were based on expected values per year over a run of years. They were formulated after extensive discussions with: entomologists involved in the research and local farmers, farm management economists, pest management consultants, and chemical resellers (from where most farmers get first hand advice). Chemical resellers were also interviewed to obtain retail prices for the materials used by growers. From this data, representative pest control programs were prepared for conventional and IPM control methods in apple and grain legume production in a 'typical' set up.

Analyses

Grain Legumes

The findings of the grain legume analysis are summarised in Table 3. A key finding is that a shift to IPM might reduce costs associated with pest damage and control by around $6.00/ha per annum. Assuming total variable production costs of $135.54/ha per annum, net on-farm revenue of $240/ha per annum and a price of peas of $210 per tonne, this figure represents a saving of about 4.4% in total variable production costs, or a potential increase in net on-farm revenue of about 2.5%. These gains are due largely to reduced grain loss (and to a lesser extent, reduced pesticide use).

Table 3: Grain Legume IPM - Change in Net Farm Income per Hectare

Proposed change:
Shift from 'conventional' to 'IPM' field pea production (Mallee region of Victoria).
Key pest:
Budworm
IPM control methods:

- Forecasting egg laying based on moth trap catches at the regional level
- Predicting periods of peak larval activity using a budworm simulation model
- Crop monitoring for larvae using sweep netting
- Deciding on the need to control based on the stage of crop development and pod inspection.

Conventional control method:
Spraying after flowering, often without knowledge of the actual pest densities in the crop.
Time frame:
One 'typical' year. Estimates were based on expected values per year over a run of ten independent years (1992/93 prices were used)
Key assumptions:
Over a run of ten years:

- Farmers spray their crops in eight out of ten years under conventional control and in seven out of ten years under IPM.
- Under conventional control, damaging infestations of budworm are not controlled in 3 years in 10
- No sequential effects of pest control actions taken in any one year.

ITEMS THAT ADD TO NET INCOME PER HECTARE

Added Returns:
Yield loss prevented $5.04

Reduced Costs:
Insecticide $1.65
Risk assessment $0.00

TOTAL ADDED RETURNS AND REDUCED COSTS(A): $6.69

ITEMS THAT REDUCE NET INCOME PER HECTARE

Reduced Returns:
Nil

Added Costs:
Crop monitoring $0.75

TOTAL REDUCED RETURNS AND ADDED COSTS (B): $0.75

A MINUS B EQUALS CHANGE IN NET FARM INCOME: $5.94/ha per annum

To determine the influence of changes in the level of grain loss on net returns, Table 4 lists net returns for various levels of grain loss of total yield harvested. The table indicates that in order for the IPM system to be profitable in a 'typical' set up, annual grain loss, due to controllable pest actions, must not exceed 4.83%, or about 55% of that experienced under conventional control. In the considered opinion of IPM specialists, grain loss under IPM is not likely to exceed this figure with frequent and informed crop monitoring and appropriate action based thereon.

Table 4: IPM - Net Returns for a Range of Damage Rates

Price = $210 per annum

Annual Crop Loss Under IPM	Yield Loss Prevented Under IPM ($/ha per annum)	Change in net Farm Income ($/ha per annum)
0% (0.0t/ha)	9.24	10.14
1% (0.02 t/ha)	7.14	8.04
2% (0.04 t/ha)	5.04	5.94
3% (0.06 t/ha)	2.94	3.84
4% (0.08 t/ha)	0.84	1.74
4.83% (0.09t/ha)	(0.9)	0
5% (0.1 t/ha)	(1.26)	(0.39)

Apples

The findings of the apple analysis are summarised in Table 5. In this case it was found that a shift to IPM might reduce costs associated with pest control by around $600/ha per annum. These gains are due largely to reduced pesticide costs, which outweigh any additional labour costs associated with monitoring and staff supervision. Assuming total variable production costs of $22,041/ha per annum and net returns of $20,134/ha per annum, this figure represents a saving of up to 4% in total variable production costs and a potential increase in net on-farm revenue of about 6%. These results are considered 'good' and are not likely to be replicated every year. For example, the 1994/95 season had a high incidence of pest infestation and anecdotal information suggests that IPM growers applied more pesticide and experienced higher pesticide costs than conventional growers. In hindsight, the 'good' results probably reflect the fact that the data was limited to a period of four stable years, with relatively moderate incidences of pest infestation.

Table 5: Apple IPM - Change in Net Farm Income Per Hectare

Proposed change:
Shift from 'conventional' to 'IPM' granny smith apple production (Goulburn Valley, Victoria)
Key pests:
Codling moth, light brown apple moth, twospotted mite, apple dimpling bug
IPM control methods:
- Using IPM compatible and conventional pesticides
- Crop monitoring to predict the behaviour of pests and diseases and selecting and timing sprays accordingly

Conventional control method:
Applying conventional pesticides at given intervals, often without knowledge of actual pest densities in the crop.
Time frame:
One stable year. Annual cost and return estimates were based on expected values per year over a run of four years (1993/94 prices were used).
Assumptions:
- Yields and premiums did not change between systems.
- IPM and conventional pest control methods have the same year to year (sequential) effects.

ITEMS THAT ADD TO NET INCOME PER HECTARE

Added Returns:
Nil

Reduced Costs:	
Chemical	$ 971.00
Application	$ 8.00
Total:	$ 979.00

TOTAL ADDED RETURNS AND REDUCED COSTS(A): $ 992.50

ITEMS THAT REDUCE NET INCOME PER HECTARE

Reduced Returns:
Nil

Added Costs:	
Management time	$275.00
Crop monitoring	$55.00
Pheromone traps	$13.50
Mite release	$22.00
Total:	$365.50

TOTAL REDUCED RETURNS AND ADDED COSTS (B): $365.50

A MINUS B EQUALS CHANGE IN NET FARM INCOME: $613.50/ha per annum

To determine the influence of change in chemical costs on net returns, Table 6 lists net returns for given reductions in chemical costs. The table indicates that in order for the costs of a shift to IPM to break-even with returns in a 'typical' set up, IPM must lead to a reduction in pesticide costs of around $344/ha per annum; or around 25% of those experienced in a 'typical' conventional set up. In the considered opinion of IPM specialists, a reduction in pesticide costs of this magnitude is highly possible in a season with moderate incidences of pest infestation, but is less possible in seasons with unusually high levels of pest infestation due to an anticipated increase in the use of pesticides by growers.

Table 6: IPM - Impact on Benefits of a Change in Chemical Costs.

Reduction in Chemical Costs ($/ha per annum)	On-Farm Benefits of IPM ($/ha per annum)
0	(334)
200	(144)
344	0
600	256
800	456
992.5	627

CONCLUDING COMMENTS

Studies comparing the economic performance of integrated and conventional approaches usually indicate that IPM will maintain or increase yields. However, contrary to what is often hypothesised, IPM will not necessarily reduce the costs of pesticide use. The costs of pesticide use will vary depending on the particular farm situation, including the crop, the pests, the pest control technologies, and the sequential impacts of previous pest control decisions. This point highlights the need for careful case-by-case economic analyses of all new pest management programs over a number of seasons.

In this study, a method based on the partial budgeting approach, was developed to investigate the expected private net benefits of a shift to IPM in particular farm situations. This method was applied to IPM in Victorian apple and grain legume production in a 'typical' set up. It was found that the magnitude of benefits is highly dependent on the extent to which IPM prevents yield loss in grain legumes, and reduces pesticide costs in apples. In the case of grain legumes, the yield response required for a shift to IPM to be profitable was considered possible with frequent and informed crop monitoring and appropriate action based thereon. In the case of apples, the reduction in pesticide costs required to break-even with returns was considered possible in seasons with moderate incidences of pest infestation, but less possible in seasons with higher than usual pest populations, due to an anticipated increase in the use of pesticides by growers. The results of subsequent analyses will be of interest.

Few studies have evaluated the effects of IPM on the environment. At this stage, the environmental effects of most IPM programs can only be 'guestimated'. The potential of new and existing programs for developing sustainable agriculture must be carefully evaluated. Much of this research is of a public good nature and therefore requires some form of centralised organisation by government.

REFERENCES

Alston, J.M., Norton, G.W., & Pardey, P.G. 1994, *Science Under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting*, Ithica, Cornell University Press.

Antle, J.M. & Park, S.K. 1986, 'Economic Benefits and Costs of an Integrated Pest Management Program for Processing Tomato Production', *California Tomato Grower*, May, pp.4-5.

Australian Parliament, 1990, Senate Select Inquiry into Agricultural and Veterinary Chemicals, Australian Government Publishing Service, Canberra.

Babcock, B.A., Lichtenberg, E. & Zilberman, D. 1992, 'Impact of Damage Control and Quality of Output: Estimating Pest Control Effectiveness', *Amer J Agric Econ*, vol. 1992, pp. 163-172.

Bach, F. 1992, IPM in the Goulburn Valley - First Round Interviews, The University of Melbourne, School of Agriculture and Forestry, Melbourne.

Barrass, I.C. & Brown, D. 1992, 'Integrated Control and Cost Reduction in Pear Orchards of the Goulburn Valley, Australia', *Proceedings of the Second International Symposium on Integrated Fruit Production*, The Netherlands, August 1992.

Barnett, W.W., Davis, C.S. & Rowe, G.A. 1978, 'Minimising Pear Pest Control Costs Through Integrated Pest Management', *California Agr*, February.

Barr, N. & Cary, J. 1992, 'To Use or Not Use Chemicals' in *Agriculture, Environment and Society: Contemporary Issues for Australia*, eds G. Lawrence, F. Vanclay & B. Furze.

Bates, V.I. 1992, An Insect Management Survey of Murray Goulburn Valley Fruitgrowers, Agriculture Victoria, Institute for Sustainable Agriculture, Tatura Centre.

Bates, V.I. 1993, 'Broadening the Range of Pest Management Tools - Integrated Pest Management in the Apple and Pear Industry' *Plant Prot Quart*, vol. 8, no. 4, pp 141-143.

Borror, D.J., DeLong, D.M. & Triplehorn, C.A. 1981, *An Introduction to the Study of Insects, 5th Edition*, Saunders College Publishing, Philadelphia.

Burch, D., Hulsman, K., Hindmarsh, R. and Brownlea, A. 1990, Biotechnology Policy and Industry Regulation: Some Ecological, Social and Legal Considerations, Submission to the House of Representatives Standing Committee on Industry, Science and Technology, Inquiry into Genetically Modified Organisms, September.

Clarke, R.A. 1995, 'Integrated Pest Management in Forestry: Some Difficulties in Pursuing the Holy-Grail', *Australian Forestry*, Vol 58, No. 3, pp. 147-150.

Colbentz, B.E. 1990, 'Exotic Organisms: a Dilemma for Conservation Biology', *Conservation Biology* 4, 261-65.

Corbet, P.S. & Smith, R.F. 1976, 'Integrated Control: A Realistic Alternative to Misuse of Pesticides?', in *Theory and Practice of Biological Control*, eds C.B. Huffaker, P.S. Messenger, New York: Academic, pp. 661-82.

Daly, J.C., Fisk, J.H. & Forrester, N.W. 1988, 'Selective Mortality in Field Trials Between Strains of *Heliothis armigera* (Lepidoptera: Noctuidae) Resistant and Susceptible to Pyrethroids: Functional Dominance of Resistance and Age Class', *J of Econ Entom*, vol. 81, pp. 1000-1007.

DEST 1995, *Techniques to Value Environmental Resources: An Introductory Handbook*, ISBN: 0 644 24869 4, Department of Environment, Sport and Territories, AGPS Canberra.

De Wilde, J. & Leemans, A. 1981, 'Cost-Benefit Aspects of Integrated Pest Management, International Organisation for Biological Control of Noxious Animals and Plants', *Conference on Future Trends in Integrated Pest Management, Bellagio, Italy*, London, Centre for Overseas Pest Resear..h, pp 42-49

Doyle, J. 1988, 'Potential Food Safety Problems Related to New Uses of Biotechnology. Biotechnology and the Food Supply', Proceedings of a Symposium, National Academy Press, Washington.

Durham, M.S. 1984, 'Commercial Monitoring of Insect Pests and Beneficials of Seed Lucerne in Southeast South Australia', *Proceedings of the Australian Applied Entomol Research Conference, 4th, Adelaide*, eds P. Bailey & D. Swincer. Adelaide, Australia: Gov. Print. pp. 121-27.

Feder, G., & Regev, U. 1979, Biological Interaction and Environmental Effects in the Economics of Pest Control,' J Environ Econ Manage, vol. 2, pp. 75-91.

Georghiou, G. 1989, 'Implications of Potential Resistance to Biopesticides', in Proceedings of a Conference, eds D. Roberts and R. Granados, Boyce Thompson Institute for Plant Research, Cornell University, Ithaca.

Graebner, L., Moreno, D.S., & Baritelle, J.L. 1984, 'The Fillmore Citrus Protective District: A Success Story in Integrated Pest Management', *Bull Entomol Soc Amer*, vol. 30, pp. 27-33.

Higley, L.G. & Wintersteen, W.K. 1992, 'A Novel Approach to Environmental Risk Assessment of Pesticides as a Basis for Incorporating Environmental Costs into Economic Injury Levels', *Amer Entomol*, pp. 34-39.

Hindmarsh, R., 1992, 'Agricultural Biotechnologies: Ecosocial Concerns for a Sustainable Agriculture', *in Agriculture, Environment and Society: Contemporary Issues for Australia*, eds G. Lawrence, F. Vanclay and B. Furze, MacMillan Australia, pp. 278-303.

Horne, P.A. 1995, 'Threatened Ecosystems: Agricultural Environments', *The Vic Nat*, Vol. 112, pp.56-58.

Hussey, N.W. & Scopes, N.E.A. 1985, *Biological Pest Control. The Glasshouse Experience*, Poole, Dorset, U.K. Blandford.

Jacobs, M. 1991, *The Green Economy: Environment, Sustainable Development and Politics of the Future*, Billing and Sons Ltd. Worchester, U.K.

King, N.B. & O'Rourke, A.D. 1977, 'The Economic Impact of Changes in Pesticide Use in the Yakima Valley Orchards', *Bull 891*, Wash State Univ, College of Agric Res Centre.

Knight, A.L., & Norton, G.W. 1989, 'Economics of Agricultural Pesticide Resistance in Arthropods', *Ann Rev Entomol*, vol. 34, pp. 293-313.

Kovach, J., Petzoldt, C., Degni, J. & Tette, J. 1992, 'A Method to Measure the Environmental Impact of Pesticides', *New York's Food and Life Sci Bull*, Number 139, New York State Agricultural Experimental Station, Geneva, NY.

Lambert, W.R. 1983, 'A Decade of Extension Cotton Integrated Pest Management', *Proceedings of the 1983 Beltwide Cotton Production Research Conference*, San Antonio, Texas, January.

Langham, M. & Edwards, W.F. 1969, 'Externalities in Pesticide Use', *Amer J Agric Econ*, vol. 51, pp. 1195-1201.

Longworth, J.W., & Rudd, D. 1975, 'Plant Pesticide Economics with Special Reference to Cotton Insecticides', *Australian J Agric Econ*, vol. 19, no. 3, pp. 261-273.

Makeham, J.P., & Malcolm, L.R. 1993, *The Farming Game Now*, Cambridge University Press, Sydney.

Malcolm, L.R. 1992, 'Farm Risk Management and Decision-Making', *Proceedings of the National Workshop on Risk Management*, Melbourne 9-11 November, pp.69-86.

Morris, W.J. 1984, 'SIRATAC and SIRATAC Limited', *Proceedings of the Aust. Appl. Entomol. Res. Conf., 4th, Adelaide*, ed. P. Bailey & D. Swincer, Adelaide, Australia, Gov. Print, pp.135-38.

Napit, K.B. 1986, Economic Impacts of Extension Integrated Pest Management Programs in the United States, MS Thesis, Virginia Polytechnic Inst and State Univ.

Napit, K.B., Norton, G.W., Kazmierczak, Jr., R.F., & Rajotte, E.G. 1988, 'Economic Impacts of Extension Integrated Pest Management Programs in Several States', *J Econ Entomol*, vol. 81, pp. 251-256.

New Zealand Department of Scientific and Industrial Research 1990, *Genetic Engineering: a Perspective of Current Issues*, DSIR, Christchurch.

Norton, G.W. & Mullen, J. 1994, *Economic Evaluation of Integrated Pest Management Programs: A Literature Review*, Department of Agricultural and Applied Economics, Virginia Polytechnic Institute and State University, Blacksburg, VA.

Owen, J. 1993, *Program Evaluation: Forms and Approaches*. Allen and Unwin, Sydney.

Pannell, Malcolm & Kingwell 1995, Are We Risking Too Much?, AAES Conference, Perth 1995.

Parigi, P. 1995a, Measuring the On-Farm Economic Impact of IPM: an Introductory Guide, Agriculture Victoria.

Parigi, P. 1995b, Measuring the On-Farm Economic Impact of IPM: a Review of Analytical Techniques. Agriculture Victoria.

Pimentel, D. & eleven others, 1980, 'Environmental and Social Costs of Pesticides: A Preliminary Assessment', *OIKIS*, vol. 34 pp. 126-140.

Pimentel, D., Glenister, C., Fast, S. and Gallahan, D. 1984, 'Environmental Risks of Biological Pest Controls', *OIKIS* 42, 238-290.

Poe, S.L. 1981, 'An Overview of Integrated Pest Management', *Hort Science*, vol. 16, pp. 501-506.

Rajotte, E.G., R.F. Kazmierczak, Jr., G.W. Norton, M.T. Lambur, & W.A. Allen 1987, *The National Evaluation of Extension's Integrated Pest Management (IPM) Programs*, VCE Publication 491-010, Virginia Tech, February.

Readshaw, J.L. 1984, 'Application of Pest Management Programs', in *Proceedings of the Australian Applied Entomol Res Conf, 4th Adelaide*, eds P. Bailey & D. Swincer, Adelaide, Australia, Gov Print, pp. 150-162.

Roper, M.M. 1993, 'Biological Diversity of Micro-Organisms: An Australian Perspective', *Pacific Conservation Biology* 1, 21-28

Ross, H.H. 1965, *A Textbook of Entomology, 3rd Edition*. John Wiley & Sons, New York.

Sexton, S 1993, *Integrated Pest Management of Codling Moth in Apple and Pear Orchards Using Isomate C*, Grower Information Bulletin, Biocontrol Ltd, 24 Palmerin Street, Warwick, Queensland.

Smith, R.F. and Huffaker, C.B. 1973, 'Integrated Control Strategy in the USA and its Practical Implementation', *EPPO Bull*, vol. 3, pp.31-49.

Stockdale, J.D. 1980, 'Pest Management and the Social Environment: Conceptual Considerations', in *Pest Control: Cultural and Environmental Aspects*, eds D. Pimintel & J.H Perkins, Boulder, Colo, Westview, pp. 181-215.

Taylor, C.R. 1980, 'The Nature and Benefits and Costs of use of Pest Control Methods', *Amer J Agric Econ*, vol. 62, pp. 1007-1011.

Taylor, C.R. & Lancewell, R.D. 1977, 'Bollweevil Control Strategies: Regional Benefits and Costs', *South J Agric Econ*, vol. 9, pp. 129-135.

Tisdell, C.A. 1986, 'Levels of Pest Control and Uncertainty of Benefits', *Australian J Agric Econ*, vol. 30, pp. 157-162.

Way, M.J. 1977, 'Integrated Control - Practical Realities', *Outlook Agric*, vol. 9, pp. 127-35.

Wearing, C.H., Thomas, W.P. & Collyer, E. 1982, 'The Decision to Implement IPM: Prerequisites and Consequences' in *Proc. Australas Workshop Dev Implementation IPM, Auckland*, eds P.J. Cameron, C.H. Wearing, W.M. Kain, Auckland, New Zealand, Gov. Print, pp. 198-210.

Wearing, C.H. 1988, 'Evaluating the IPM Implementation Process', *Ann Rev Entomol*, vol. 33, pp. 17-38.

Wearing, C.H., Thomas, W.P. & Collyer, E. 1982, 'The Decision to Implement IPM: Prerequisites and Consequences', in *Proc Australas Workshop Dev Implementation IPM, Auckland*, Auckland, New Zealand, Gov Print, pp. 198-210.

West, S. & Twyford, K. 1993, 'Horticultural Costs and Returns, A Budget Guide for 1993', *The Murray Pioneer*, Renmark.

Wetzstein, M.E.. Musser, W.N., Linder, D.K., & Douce, G.K. 1985, 'An Evaluation of Integrated Pest Management with Heterogeneous Participation', *West J Agric Econ*, vol. 10, no. 2, pp. 344-353.

Whalon, M.E. & Croft, B.A. 1984, 'Apple IPM Implementation in North America', *Ann Rev Entomol*, vol. 29, pp. 435-70.

Wynen, E. and Edwards G. 1990, 'Towards a Comparison of Chemical-Free and Conventional Farming in Australia', *Australian J Agric Econ*, Vol. 34, no. 1, pp. 39-55