ACIAR's 25 year investment in fruit-fly research

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Summary

Fruit flies are recognised as one of the major pests of fruit and vegetable crops worldwide. Potential benefits from fruit fly research include biosecurity benefits from better quarantine surveillance that reduces the costs of an incursion by a damaging exotic pest fruit fly; market access benefits by enabling new fruit exports; and field control benefits from better crop management.

The Australian Centre for International Agricultural Research (ACIAR)'s investment in fruit-fly research goes back some 25 years to an initial project in Malaysia. Since that time, ACIAR's continued investment has funded a total of 18 projects ranging across several areas of fruit-fly research, and covering Malaysia, Thailand, Philippines, Fiji Islands, Samoa, Tonga, Cook Islands, Vanuatu, Solomon Islands, Federated States of Micronesia (FSM), Papua New Guinea, Bhutan, Vietnam, Laos, and Indonesia. In an impact assessment study of all 18 ACIAR projects, Lindner and McLeod (2008) calculated that the present value (PV) of the total direct investment in these projects by ACIAR and its partners has been A$50.76 million. The PV of total quantifiable realised and prospective benefits that can be attributed to the direct investment by ACIAR and its partners was estimated to exceed A$258.84 million. Of this total PV of quantifiable benefits, A$212.63 million was calculated to accrue to partner-countries. In this paper, the question of why many potential benefits to partner-countries have not been realised to date, and why some future prospective benefits are problematic is examined.

While the total value of benefits generated from the investment by ACIAR and its partners is impressive, the pattern of benefits is variable by type of benefit and by country. One of the most important general lessons, widely known but reinforced by the results from this study, is that while successful research project outcomes may be necessary to enable potential benefits, they rarely are sufficient for benefits to be realised. In particular, potential benefits will only be realised if there is uptake of project outputs. While it is recognized that the conditions for uptake are typically well beyond the influence of the researchers both in time and scope, at the time of project formulation, the necessary conditions for adoption of project outputs often seem to receive insufficient attention. Notwithstanding some 20 years of research on the development of low-cost protein bait sprays from brewery waste, the benefits are still essentially prospective and it has not been conclusively demonstrated that the use of these sprays will be widely adopted as a cost-effective alternative to existing practices in developing countries.

Introduction

Fruit flies are recognised as one of the major pests of fruit and vegetable crops worldwide, and are of major significance in almost all fruit-growing areas of the world, either because they are already present, or because they are capable of establishing in areas presently free of them. The fruit-fly species in the sub-family *Dacinae* are found predominantly in tropical and subtropical regions. Around 10 % of these fruit flies would be classified as pests, and 1% are regarded as major pests.

One potential benefit from fruit fly research that enables better quarantine surveillance systems is to reduce the risk of losses that would result from an incursion into a country or area by a damaging exotic pest fruit fly. In response to such threats, many countries have established sanitary and phytosanitary (SPS) barriers to trade in fresh fruit, so a further potential benefit of fruit-fly research that reduces such threats could be to enable access to new markets for fruit exports.

Another potential benefit from research that enables better methods for the control and management of fruit flies is to avoid at least some of the losses that otherwise would result from infestation of fresh fruit and leafy vegetable crops. Such research also can enable the development of new industries (including new markets) that otherwise would be uneconomic due to prohibitive damage to possible crops of fresh fruit and leafy vegetables. Alternative methods of field control that reduce pesticide use also might result in less environmental damage and/or improved human health.

In this paper, the potential quantifiable benefits that might be generated by the types of research funded by ACIAR have been categorised as follows:

- biosecurity benefits from improved quarantine surveillance to reduce the risk and/or cost of an incursion by an exotic pest fruit fly
- market access benefits from extra fruit exports on the basis of:
  - (i) non-host status, or
  - (ii) postharvest heat treatment
- field control benefits from lower crop losses and/or control costs; and possibly
- the development of new industries and/or markets.

The Australian Centre for International Agricultural Research (ACIAR)'s investment in fruit-fly research goes back some 25 years to an initial project in Malaysia. Since that time, ACIAR's continued investment has funded a total of 18 projects ranging across several areas of fruit-fly research, and covering Malaysia, Thailand, Philippines, Fiji Islands, Samoa, Tonga, Cook Islands, Vanuatu, Solomon Islands, Federated States of Micronesia (FSM), Papua New Guinea, Bhutan, Vietnam, Laos, and Indonesia..

The largest investment by ACIAR and its partners was in a group of seven similar projects with multiple aims, including to generate biosecurity benefits, market access benefits, and field control benefits. The foremost aim was to produce a set of related research outputs that are necessary inputs for the establishment or improvement of effective quarantine surveillance for fruit flies, but the development and uptake of protein bait sprays to generate field control benefits was a secondary common aim that ran through all seven projects for more than two decades. The other significant aim was to establish non host status for certain fruits to enable exports to premium price markets. The PV of these seven projects was about $30 million.

A further group of six projects, for which the PV of the total investment was more than $6 million, shared a single aim of generating field control benefits. The sole focus for some of these projects also was the development and uptake of protein bait sprays, but promotion of other alternative methods of field control was part of some projects.

The sole aim of a third group of three projects, with a PV of total investment in excess of $12 million, was to generate market access benefits by developing improved methods of post harvest disinfestation treatments. The final two projects, with a PV of invested funds of about $3 million, had disparate aims relating to other types of potential benefits.

In an impact assessment study of all 18 ACIAR projects, Lindner and McLeod (2008) calculated that the present value (PV) of the total direct investment in these projects by ACIAR and its partners has been A$50.76 million. In addition to the investment by ACIAR and its partners, other agencies funded a variety of complementary fruit-fly research and development projects that in a number of cases contributed to realised and/or prospective benefits. For this reason, only part of total estimated benefits were attributed to the ACIAR projects on a case-by-case basis.

Lindner and McLeod (2008) found that large benefits have already been realised in both partner countries and in Australia, and that there is the prospect of considerable further benefits being generated in the future. Some important benefits, especially capacity building, but also including possible benefits from mitigation of environmental damage, and improvement in human health, could not be quantified. Nevertheless, the PV of total quantifiable realised and prospective benefits that can be attributed to the direct investment by ACIAR and its partners was estimated to exceed A$258.84 million.

Of this total PV of quantifiable benefits, A$212.63 million was calculated to accrue to partner-countries, and the remaining A$46.21 million to accrue to Australia. Because details of the estimation of the latter benefits have been published in other reports, including Collins and Collins (1998), Monck and Pearce (2007), and Lindner and McLeod (2008), this paper is restricted to an examination of why many potential benefits to partner-countries have not been realised to date, and why some future prospective benefits are problematic.

Biosecurity benefits

Overview

Unless an incursion by an exotic pest fruit fly is detected promptly and appropriate action taken to eradicate it, or at least contain it, most fruit flies can multiply rapidly, quickly become widespread, and cause very large costs. For instance, because the outbreak of *B. papaya* in North Queensland in October 1995 was not detected for some time, the eventual size of the Pest Quarantine Area (PQA) established to contain it covered around 78,000 km^2, and the direct costs of the eradication campaign were about A$34 million. Furthermore, many other costs due to lost production, costly field control methods, restrictions on fruit trade and exports, and postharvest disinfestation treatment were incurred by industry and the community. While no formal estimates were made, Cantrell Chadwick and Cahill (2002) claimed that costs to industry were about A$100 million.

The term ‘biosecurity’ pertains to the mitigation of exotic pest damage by preventing introductions, detecting incursions and eradicating resultant populations, or managing new species as long-term problems, curtailing their impact and preventing their further spread (Waage et al. 2004). Biosecurity results from reducing the risks posed by exotic pests through actions such as exclusion, eradication and control. The growth in tourism, passenger and cargo movements has increased the risk of exotic pest and disease incursions, and it is impossible, or at least prohibitively costly, to totally prevent entry of exotic pest fruit flies into any country.

Possible pathways for exotic pest fruit flies to enter a country include:

- undetected infestations of officially sanctioned imports of host fruits,
- fruit fly stowaways in non-host freight imports,
- travellers (tourists, yachties, etc.) carrying flies and/or infested fruits,
- unassisted passage, including flights for long distances over oceans.

As summarised by Plant Health Australia (2006), the components of plant industry biosecurity for the threats posed by exotic fruit flies are illustrated in Figure 1.

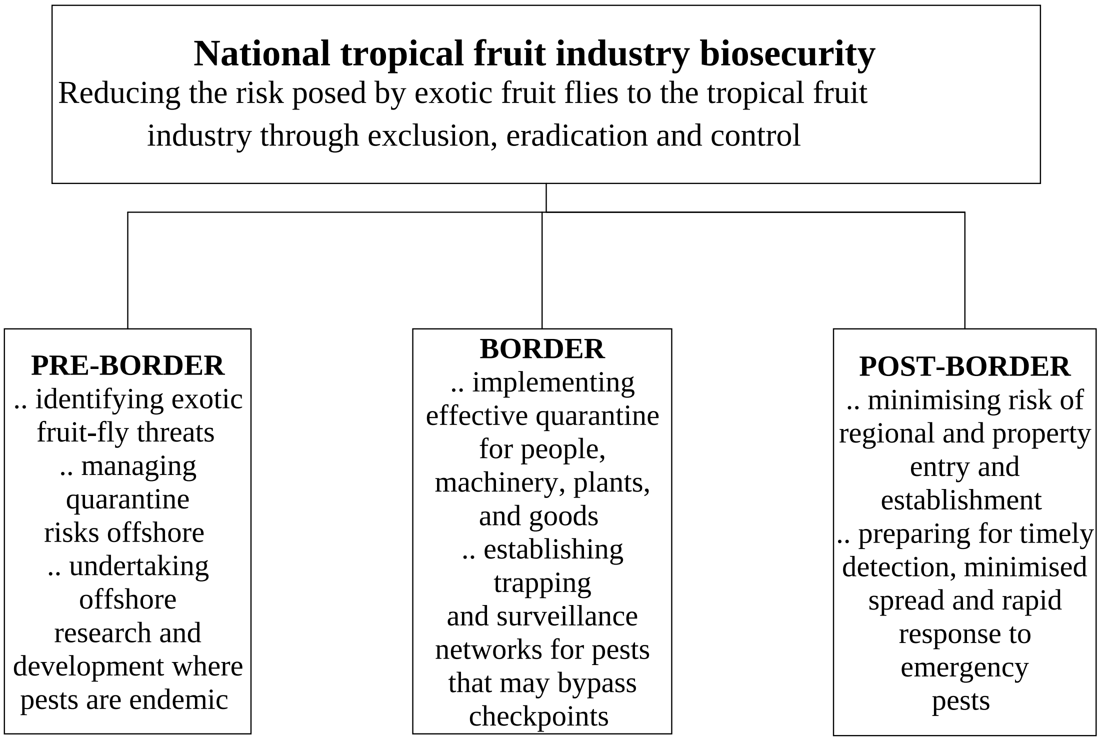


Figure 1: Components of plant industry biosecurity

The main biosecurity contribution of the first group of seven ACIAR projects was to produce outputs that were necessary, albeit not sufficient, to establish trapping and surveillance networks in partner countries for early detection of pest entry that bypasses border checkpoints, and to build the capacity for a rapid response in an emergency by minimising the spread of the pest, and eradicating it where appropriate.

Potential benefits

The threat of a pest outbreak depends on the risk of the entry going undetected at the border and becoming established before it is detected. The capacity to quickly detect a fruit fly incursion by effective post border monitoring and surveillance will substantially reduce:

- the risk of an outbreak if flies can be detected and destroyed before they can breed,
- the time lag to eventual detection of established outbreaks,
- the consequent production and/or trade losses as well as the costs of control and eradication

An important potential benefit from fruit-fly R&D is greater biosecurity that results from enhanced capacity for early detection and quick response to an incursion of an exotic and economically damaging fruit fly. To the extent that an incursion of an exotic pest fruit fly is detected sooner rather than later, the sooner appropriate action can be taken to contain and/or eradicate the exotic pest fruit fly, and the smaller the likely costs of the incursion.

Hence, the potential benefit from R&D that enables early detection and rapid response to an incursion of an exotic pest fruit fly is the avoided loss of:

- higher eradication costs
- loss of trade benefits
- costs of containment and long-term management
- reduced production and consumption due to yield loss from fruit-fly infestation
- amenity losses from production or consumption of pest-damaged fruit.

Figure 2 indicates the consequences of preventing a large incursion. With demand as shown, and *S1* being the initial supply curve, market price and quantity are *P1* and *Q1*. An incursion results in damage to crops and loss of supply. This shifts the supply curve in, with a larger contraction for a larger incursion. With a small incursion the market price and quantity is *P1, Q2*. For a larger incursion the price and quantity are *P1, Q3*.

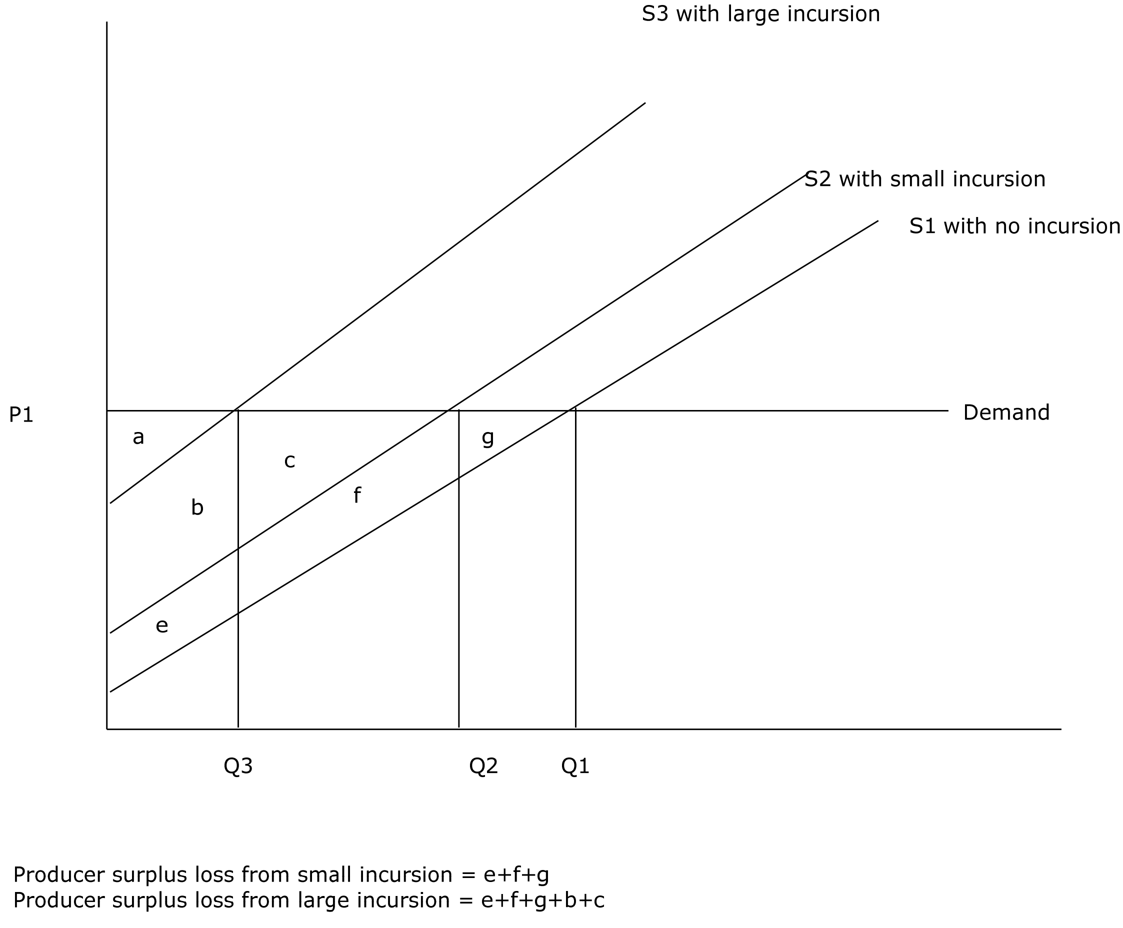


Figure 2: Potential benefits from mitigating a large incursion

Initial producer surplus is the total area (*a*+*b*+*c*+*d*+*e*+*f*). With a small incursion, producer surplus is (*a*+*b*+*c*) giving a loss of (*d*+*e*+*f*). Under a large incursion, with supply at *S3*, produce surplus is reduced to *a*, with a loss of (*b*+*c*+*d*+*e*+*f*). The difference, which is area (*b*+*c*), is the lost producer surplus if small incursions become large incursions. The avoidance of these losses is the potential benefit from biosecurity activities that mitigate the chances of a large incursion.

In the With R&D scenario, it is assumed that an effective quarantine surveillance system enabled by the various ACIAR projects will detect an incursion at an early stage and eradicate it before it causes major losses. Conversely, under the Without R&D scenario, it is assumed that an incursion by an exotic pest fruit fly will not be detected until it has become widely established and caused major losses. The difference in producer surplus between the two scenarios is attributable to the various activities, including ACIAR projects, that contribute to enhanced biosecurity.

Impact pathway

The following outputs from the ACIAR projects were necessary inputs to enable potential biosecurity benefits in any given host country:

- a comprehensive taxonomy of tropical fruit-fly species
- supporting infrastructure, such as a suitable taxonomic key, supported by an authoritatively identified set of preserved fruit-fly specimens to enable rapid detection and identification of exotic pest fruit flies, and a laboratory to maintain breeding colonies of key fruit-fly species to support research on introduced flies
- documented knowledge about the geographic distribution, host range and seasonal abundance of endemic *Tephritid* fruit-fly species in host countries
- documented knowledge about the host range and ecological niches of high-threat exotic pest fruit-fly species, as well as potential damage levels for each pest *Tephritid* fruit-fly species
- necessary knowledge to establish effective border quarantine surveillance procedures for early detection of entry of exotic pest fruit flies in order to prevent an incursion becoming widely established and thereby avoid or mitigate losses from possible incursions
- raised awareness in government of large potential losses from incursions of exotic pest fruit flies
- partner-country personnel trained in fruit-fly identification and biology, trapping and survey methods, rearing fruit-fly colonies, principles of fruit-fly containment and eradication.

These ACIAR projects clearly raised partner country governments' awareness of likely costs of incursion of an exotic fruit-fly species, and the benefit of early implementation of effective quarantine surveillance systems. While adoption of simple border quarantine systems would have happened without the ACIAR projects, the risk of detecting entry that bypasses these simpler measures is very low unless there also is in-country capacity building based on knowledge of fruit-fly taxonomy and biology. An effective quarantine surveillance system involving pest trapping and host-fruit surveys to detect pests that bypass border checkpoints, requires significant scientific expertise and taxonomic knowledge to identify exotic fruit flies species that would not have been available without the projects. A detailed understanding about the host range and geographical distribution of endemic fruit-fly species also was important in developing SPS protocols for the importation of pest-free host fruits. Clearly, such in-country capacity building was an essential precursor to the establishment of effective quarantine surveillance measures.

Figure 3 uses an ACIAR pathways template to show how the fruit-fly research undertaken in the various relevant projects leads to biosecurity benefits.

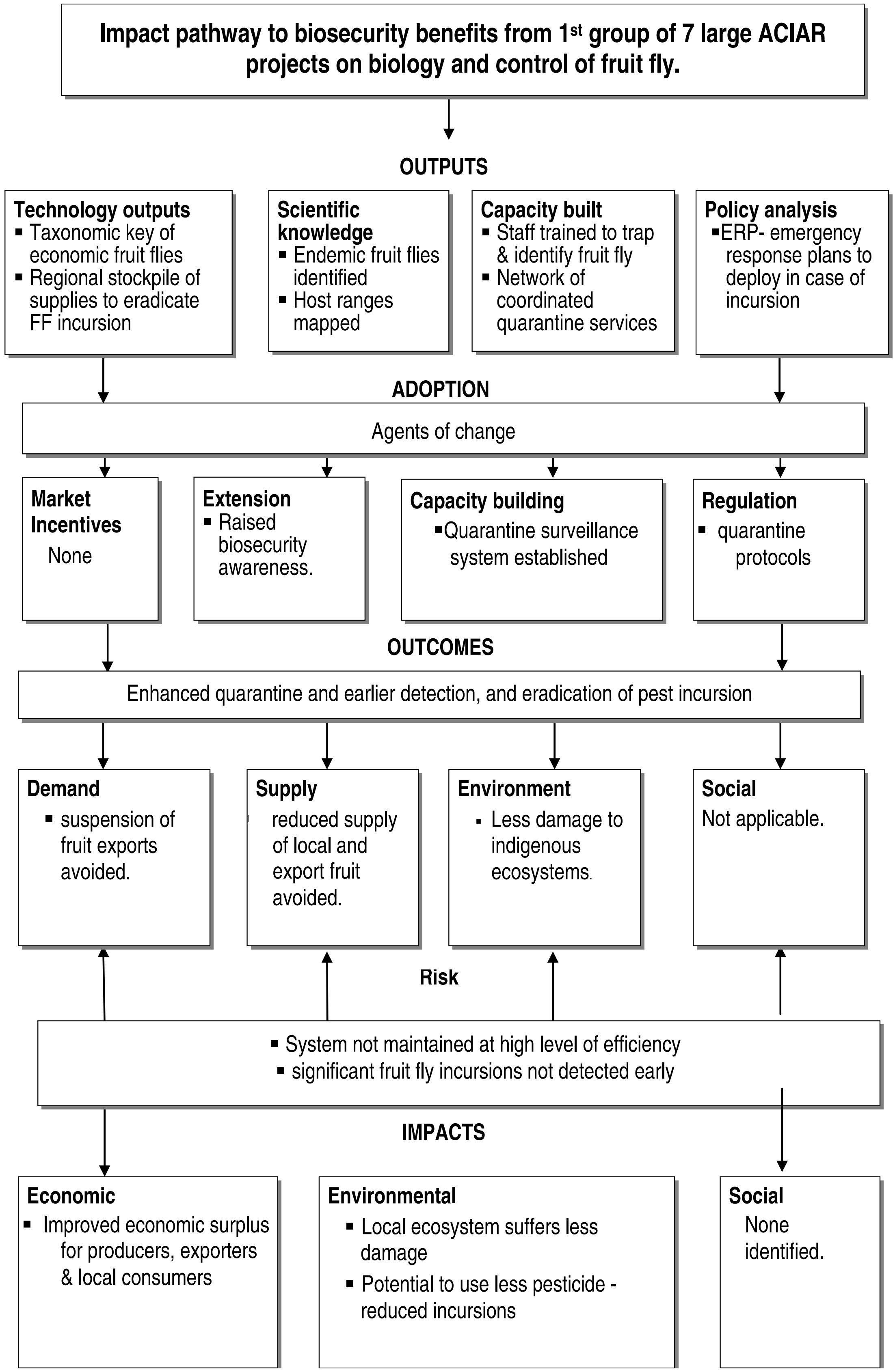


Figure 3: Pathways to benefits from biosecurity research

Other necessary conditions to realise biosecurity benefits

If biosecurity benefits are to be realised, it is vital for a country to have the capacity to minimise the risk of pest fruit-fly incursion, and to respond rapidly and effectively to any incursion that does occur. Lack of shared land borders and geographic isolation provide a degree of natural protection from exotic pest threats for the Pacific island countries (PICs) that helps to prevent the introduction of harmful exotic fruit-fly pests but, in the absence of a strong quarantine surveillance system, there is still a significant risk of incursions by exotic pest fruit flies due to assisted movement of fruit flies from tourism, imports and exports, and changing transport practices. Hence, partner-country governments also need to commit sufficient resources to implement, operate and maintain an effective quarantine surveillance system. The formulation of pest incursion Emergency Response Plans (ERP) to ensure a rapid and effective response to incursion of fruit-fly pests also had to be prepared.

Conversely, for countries with extended land borders, the potential for unassisted entry by fruit-fly pests is high. While a sophisticated national quarantine surveillance system might reduce the risk somewhat, the probability of entry and establishment for these countries or regions would still remain high. Furthermore, some developing countries do not maintain effective national quarantine surveillance systems due to a lack of resources, and/or government breakdown due to civil unrest. The counterfactual scenario is based on the assessment that early-detection enhanced biosecurity systems would not have been established in the absence of the necessary joint input from ACIAR projects and complementary projects funded by other agencies. However, no biosecurity benefits were estimated for those countries where such early-detection enhanced biosecurity systems had not been established, or not adequately maintained, or where there was a low likelihood of a quarantine surveillance system significantly reducing the risk of a pest incursion.

Realised and prospective benefits in partner countries

Table 1 shows the estimated realised and prospective biosecurity benefits attributed to the first group of 7 large ACIAR projects for selected countries.

Table 1: Realised and prospective biosecurity benefits in those partner countries where ACIAR projects produced the necessary R&D outputs. (Present Value A$million 2007)

Host Country	Realised	Prospective	Total
	$million	$million	$million
COOK ISLANDS	1.541	0.458	2.000
FIJI ISLANDS	4.157	4.677	8.834
FEDERATED STATES OF MICRONESIA	NE	NE	NE
INDONESIA	0	0	0
MALAYSIA	0	0	0
PAPUA NEW GUINEA	0	0	0
SAMOA	1.229	1.416	2.645
SOLOMON ISLANDS	0	0	0
THAILAND	0	0	0
TONGA	4.917	6.327	11.244
VANUATU	NE	NE	NE
VIETNAM	0	0	0
TOTAL	**11.844**	**12.878**	**24.722**

Legend: 0 = no evidence of uptake/impact
NE = insufficient information to quantify

The countries in the table above can be divided into two main groups. In the first group are the Cook Islands, Fiji Islands, FSM, Samoa, Solomon Islands, Tonga and Vanuatu, all Pacific Island countries in which economic losses from endemic fruit fly species historically have been quite small relative to the losses that would be incurred if serious exotic pest fruit fly species became widely established. In general, these countries are characterised by having a limited number of endemic fruit fly species that cause serious damage to a wide range of fruit hosts, and an absence of long land borders with countries that have high levels of serious pest infestations. As result, the benefit from preventing incursions by serious exotic pest fruit fly species is high for such countries, while the cost of maintaining an effective quarantine surveillance system to detect any incursion at an early stage is relatively low because large ocean distances surrounding these countries provide natural barriers that limit frequent entry.

Within this group of countries, there was substantial and convincing evidence that the quarantine surveillance system established with considerable help from the ACIAR projects were still operational, and highly effective in the Cook Islands, Fiji Islands, Samoa, and Tonga. This is the reason why it was possible to quantify estimates of biosecurity benefits for these countries using methods described in Lindner and McLeod (2008). Although quarantine surveillance systems also were established in the other three countries in this group, no attempt was made to estimate of biosecurity benefits for these countries because of conflicting evidence about whether such systems were still highly effective. The capacity of government in all three countries is constrained by a severe lack of resources, which has been further exacerbated by domestic violence in the Solomon Islands.

The other main group of countries comprised Indonesia, Malaysia, Papua New Guinea, Thailand, and Vietnam. In all of these countries, a large number of pest fruit fly species are endemic, and at least some are extremely serious pests, either because they cause major crop damage, and/or because they infest a wide range of fruit hosts. For these countries, the benefit of excluding exotic pest fruit flies is limited because domestic fruit growers have adapted to high fly infestation levels by adopting costly but broadly effective field control measures such as blanket cover sprays, and/or by adopting damage mitigation measures. Hence, there is little further loss to be avoided by keeping out other serious pest fruit fly species that could and would be controlled by those measures already being used routinely. Furthermore, these countries also have long easily crossed land borders, so any quarantine surveillance system would be both costly to maintain, and of doubtful effectiveness. For such countries, it was always unlikely that fruit fly research projects that provided at least some of the essential inputs for a fruit fly quarantine surveillance system would ever generate significant biosecurity benefits.

Lessons

Biosecurity benefits are another example where potential benefits have not always been realised. While a number of Pacific island countries have obtained significant biosecurity benefits, there have been little or no realised biosecurity benefits for some other partner countries. With the benefit of hindsight, some of the necessary preconditions for biosecurity benefits to be realised were absent in some countries with long land borders and large numbers of endemic pest fruit-fly species that infest a range of economically important crops and cause severe losses. They also were absent in countries without the financial and organisational capacity and commitment to continue necessary ongoing quarantine activities. The last issue also is a concern in terms of realising future potential benefits from capacity building that has been an impressive outcome from the fruit-fly projects.

Market access benefits

Overview

In general, gaining access to export markets increases demand for a country's production of fresh fruit and leafy vegetables. If the price in the export market exceeds the cost of production and exporting, then gaining access to such markets can generate significant benefits to growers and/or exporters.

Not surprisingly, prices tend to be lower in those countries, such as many in Asia and Africa, where there are minimal barriers to market access because they do not impose stringent controls on the import of fruit. However, many destination market countries, including Japan, the USA, Australia and New Zealand, are free of at least some destructive pest fruit-fly species, and enforce strict quarantine restrictions on imports of tropical fresh fruit and leafy vegetables to minimise the risk of introducing exotic pest fruit flies. To gain access to these markets, a potential exporting country must negotiate access protocols to the satisfaction of the importing country.

Historically, fumigation of exports of fresh fruits and leafy vegetables with ethylene dibromide was accepted by most importing countries as an effective way of killing fruit-fly pests. Starting in the mid 1980's, safety concerns resulted in most premium-price countries progressively banning fumigation with ethylene dibromide as an acceptable postharvest treatment. Hence, and countries wishing to export fresh fruit and leafy vegetables to these markets had to negotiate an alternative SPS protocol for market access. This prompted the search for alternative market access technologies to overcome some of these constraints and facilitate export trade, such as:

- area freedom—proving that NO pest fruit flies occur in locations in which export fruit is produced. In theory, this would obviate the need for post harvest disinfestation treatments, but it has not proved possible for ACIAR partner countries to establish area freedom since one or more pest fruit-fly species are endemic in all of them.
- non-host status—proving that a specific commodity is not a host for endemic fruit-fly species in a country, and proving area freedom for pest fruit flies that do infest the commodity, obviates the need for post harvest disinfestation treatments. In a few

cases, non-host status protocols also have been negotiated for import of immature fruit where it can be established that it is NOT a fruit-fly host at early stages of its maturity cycle. For example, green banana is not a host for most pest fruit-fly species.

- equivalently effective post-harvest disinfestation treatments, such as cold temperatures, high temperature forced air (HTFA), irradiation, etc. for fruit-fly host fruits.

Traditionally, importing countries determined their own terms and conditions for import of fresh fruit and leafy vegetables in response to market access requests from aspiring exporting countries. Thus, negotiation of access protocols is on a bilateral basis. Because postharvest disinfestation treatment is a relatively expensive process, negotiating for market access on the basis of non-host status is the preferred option since there are no ongoing additional costs once the necessary conditions have been scientifically established. However, this is not an option for most tropical fruits, since they are hosts for pest fruit-fly species that are endemic in most exporting countries. For these fruits, such countries are required to prove the efficacy of disinfestation procedures on a fruit-by-fruit, and pest-by-pest basis, and then to incur ongoing costs for post harvest disinfestation treatment of all fruit exports.

Since completion of the Uruguay Round of Multilateral Trade Negotiations in 1995, quarantine regimes must conform to World Trade Organization (WTO) requirements, including in particular a science-based approach to setting trade restrictive quarantine measures that is commonly described as import risk analysis (IRA) (Binder 2002). Notwithstanding subsequent gradual moves to standardise import protocols, whether a country gains access for its fruit exports into any given market is still determined on a bilateral country-to-country basis.

Potential Benefits

The same first group of seven large ACIAR projects that produced necessary outputs to establish effective quarantine surveillance systems also generated the scientific knowledge that potentially could be used to negotiate market access on the basis of non host status for selected fruit exports. In the Cook and Fiji Islands, Samoa and most notably in Tonga, these projects established directly that some potential export commodities were not a host for endemic fruit-fly species, and also were instrumental in proving area freedom for pest fruit flies that do infest these commodities. These are examples where ACIAR research contributed to establishing non host status.

These seven projects also established laboratories for fruit fly breeding colonies that subsequently were used for rearing economic fruit fly species to provide a consistent supply of insects for use in quarantine treatment research by the partner countries. Some of these quarantine treatment projects were funded by other donors, but three were funded by ACIAR. The primary contribution of these three ACIAR research projects on post harvest heat treatment was the generation of research data on the heat tolerance of pest fruit fly eggs and larvae to certify commercial quarantine treatments based on HTFA. Staff in the Philippines, Thailand, Malaysia and Vietnam also were trained how to generate the data needed to negotiate market access protocols for exports to Japan of mango treated with HTFA. Subsequently, these research outputs provided the basis for the commencement of mangosteen exports from Thailand to Australia.

Access to markets in countries such as Australia, New Zealand, the USA, and Japan for fruit exports that are based on satisfying their stringent import protocols results in premium prices relative to fruit sold in domestic markets, or exported to more open markets. This is the primary source of potential additional benefits relative to exports to more open markets.

Whatever the basis for gaining market access, the nature of the benefits are essentially the same, as are the considerable fixed costs that need to be incurred to satisfy stringent quarantine regulations. However, fruit exports based on non host status do not have to incur ongoing costs for post harvest disinfestation treatment.

In the With R&D scenario, it is assumed that access to a premium price market such as Japan is restricted, with the permitted quantity being small relative to total production in the exporting country. Hence, it is assumed that the additional volume of exports is at the expense of domestic sales, so any resultant price increase and loss of consumer surplus in the domestic market will be small. If supply in the exporting country is highly elastic, then any diversion from the domestic market will be offset by expansion of production for domestic sale with negligible price consequences. Calculation of the resultant benefit is based on estimates of world export prices for the premium price achieved in the restricted market, and projected export volumes.

Figure 4 illustrates the benefit from gaining access to a premium price market by overcoming a quarantine restriction. Producers in the exporting country can sell at wholesale price (Pw) to the rest of the world. Prior to gaining access at *Pw*, quantity sold was *Q1*. The restricted market access can be viewed as a limited opportunity to sell a fixed amount at a premium price. Conceptually, once access is achieved, this can be considered the first block of exports. Thereafter exports are sold to the rest of the world at *Pw*. In effect, with no supply response producers divert this amount from existing export markets and receive the price premium on offer as additional producer surplus of (*Pr A1 A2 Pw*).

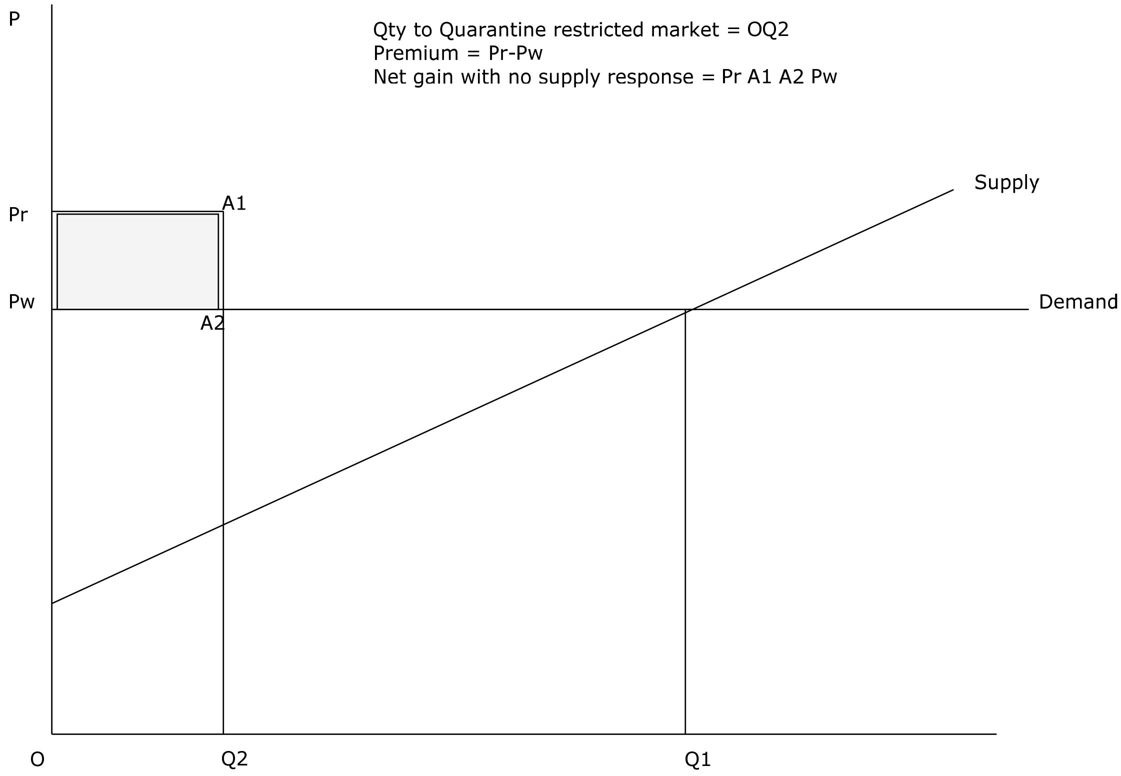


Figure 4: Producer gains from achieving market access to a restricted market

Impact pathway

The following outputs from the ACIAR projects on post harvest heat treatment were necessary to enable exports of fruit-fly host fresh fruit and leafy vegetables to premium-price markets were as follows:

- research data on the heat tolerance of pest fruit-fly eggs and larvae to certify commercial postharvest quarantine treatments based on HTFA
- staff in partner countries trained in methods to generate the necessary data to meet SPS requirements for fruit exports to a number of countries.

Furthermore, in order to carry out scientific research to test for heat tolerance of fruit-fly life stages, it is essential to have access to:

- laboratories for rearing economic fruit-fly species to provide a consistent supply of insects for use in quarantine treatment research.

The ACIAR pathways template is used in Figure 5 to indicate how research undertaken in the various postharvest disinfestation treatments fruit fly projects leads to market access benefits. The pathway shown in Figure 6 shows the way that projects associated with documenting non host status generated market access benefits.

ACIAR projects produced research outputs and research capability necessary to achieving market access. Without the sort of capabilities contributed by the ACIAR projects, partner countries would have found if almost impossible to participate in the processes required for market access to restricted countries.

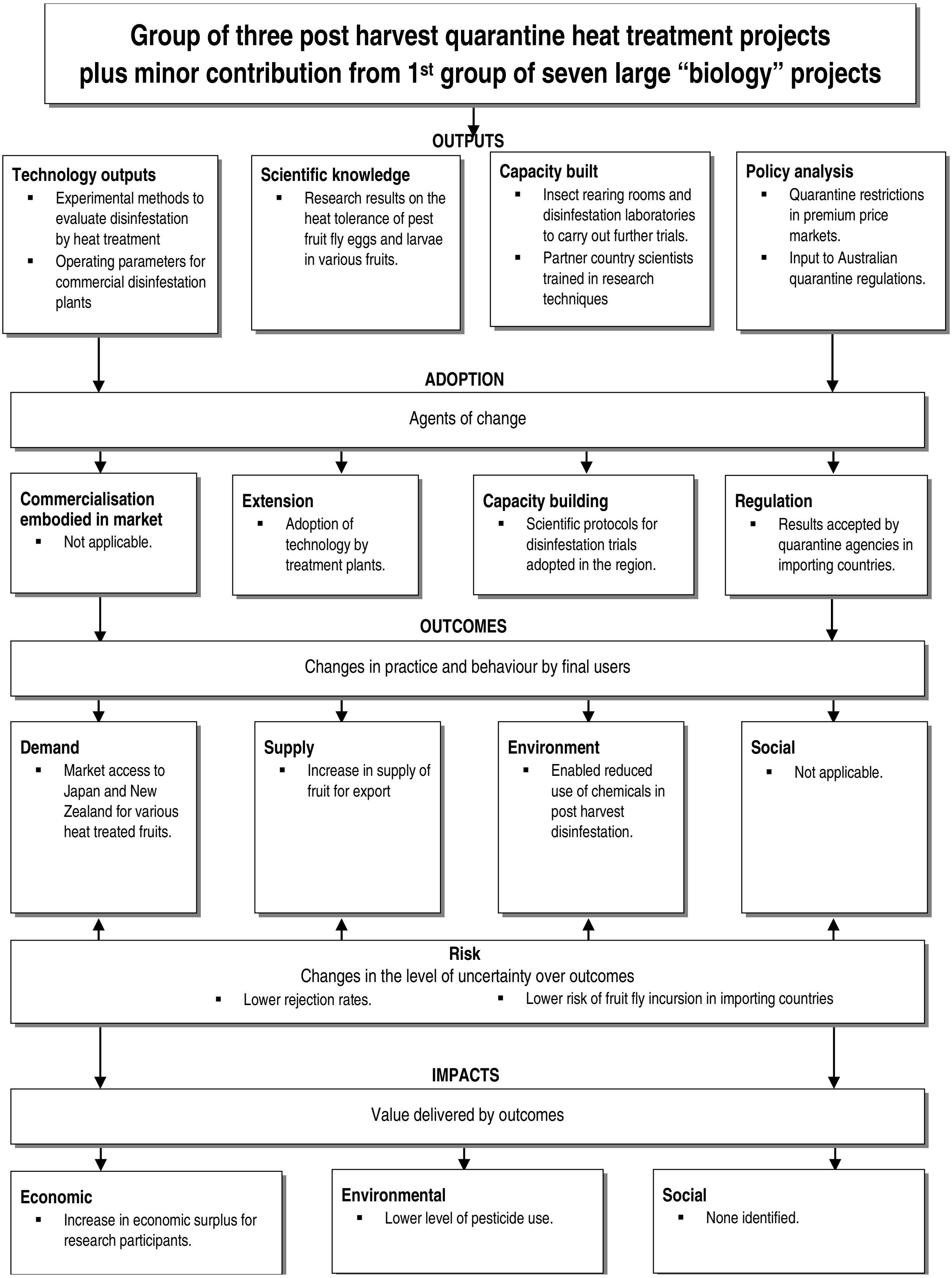


Figure 5: Pathways to benefits from post harvest heat treatment and market access

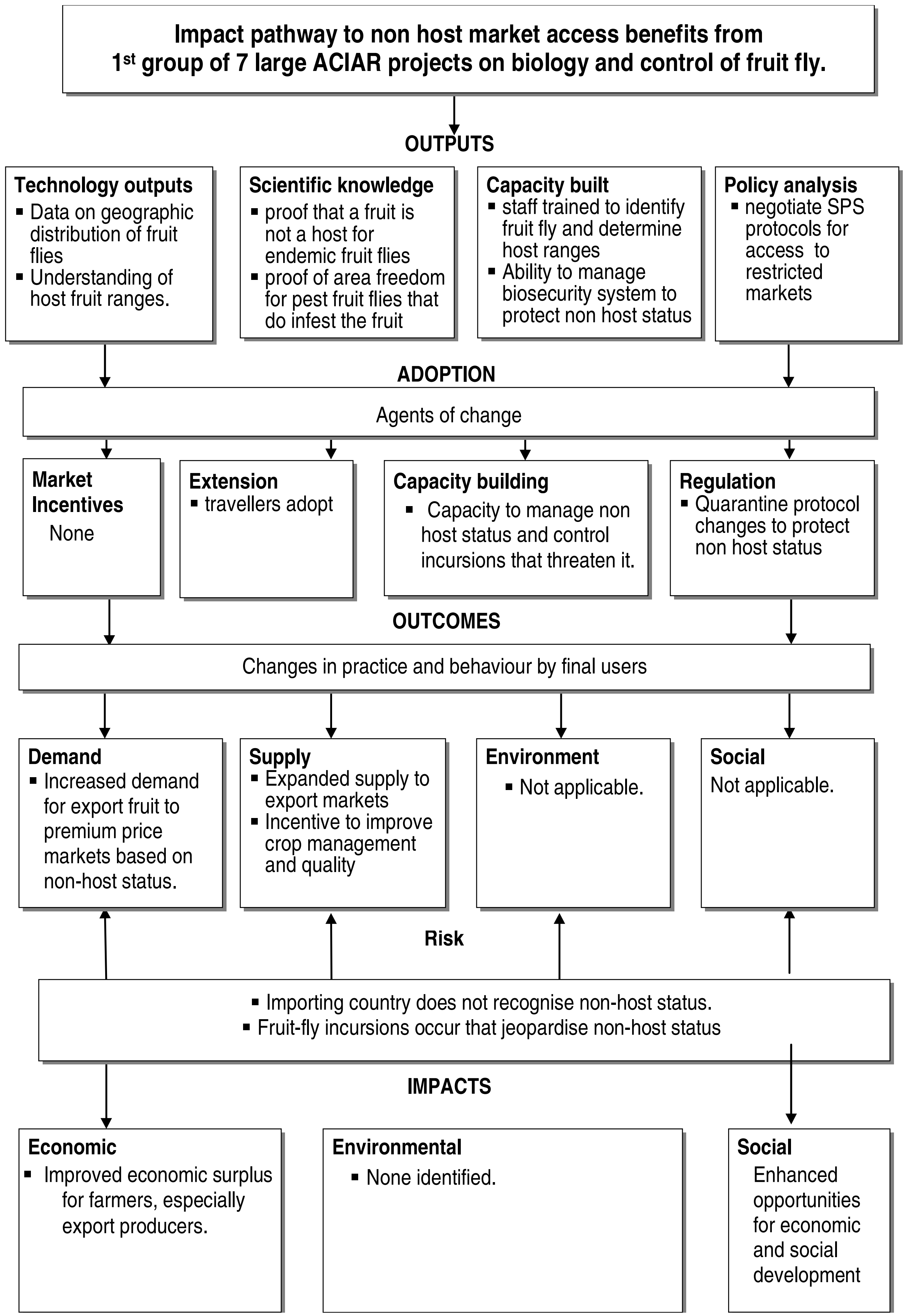


Figure 6: Pathways to benefits from market access based on non host status

Other necessary conditions to realize market access benefits

To gain market access to each potential market, firstly the potential exporter must make a formal application. Typically the application will join a long queue of applications that require a pest risk analysis to be carried out. The number of years that an application stays in the queue will depend, *inter alia*, on the resources available to conduct such pest risk analyses, and on the relative importance that each importing country attaches to facilitating trade in this particular commodity vis-a-vis other commodities. A decade or more would not be unusual. When the importing country decides to conduct a pest risk analysis for importation of a fresh fruit or leafy vegetable, the exporter will need to supply all required information to satisfy the importer that granting market access will provide the appropriate level of protection against an exotic pest fruit fly incursion. However, while the ACIAR research outputs provided some of the necessary information with regard to fruit fly, the applicant also will need to address concerns about the appropriate level of protection against the introduction of other exotic pests and diseases. Once a pest risk analysis is completed, further requirements might need to be negotiated before market access is granted.

For applications based on non-host status for fruit flies, it is necessary for a potential exporting country to provide credible evidence that the commodity is not a host for endemic fruit-fly species in the partner country and also that pest fruit flies that infest the commodity do not occur in the production region of partner country. Such information alone is by no means sufficient to be granted market access. As noted above, the importing country will need to be satisfied that there is an appropriate level of protection against the introduction of other exotic pests and diseases. The import of mangosteens into Australia is a case in point. For many potential exporting countries, it is a relatively straightforward matter to supply the required information to establish non-host status for fruit fly, but there also is the risk of introduction of other potentially more damaging pests that needs to be considered in an import risk assessment. Thus the import conditions for import of mangosteen from Thailand to Australia require fumigation to protect against the introduction of pests other than fruit fly. Similar comments also apply to applications based on postharvest disinfestation treatments for fruit flies.

Finally, for market access benefits to be realised and attributed, at least in part, to the ACIAR-funded projects, it is necessary that exports of fresh fruit and leafy vegetables to importing countries have grown after the introduction of import protocols negotiated using project outputs. Such export growth may not eventuate for a number of reasons that have nothing to do with successful project outcomes. For instance, in an insightful article, McGregor (2007) discusses a number of reasons for the failure of many Pacific island countries to realise their considerable potential for export of fresh fruit and leafy vegetables. In contrast to the rapid growth in the value of horticultural exports from other developing countries, he notes that exports of these commodities from the Pacific island region are lower now than they were in 1980. He lists the main factors that determine capability to export horticultural products successfully as:

- suitable agronomic conditions to produce products with identified markets
- ready access to an international airport or seaport
- availability of air and sea freight capacity to target markets at reasonably competitive freight rates
- private sector marketing capability
- quarantine pest status and management, particularly for fruit flies

- ability to resolve phytosanitary and other market access issues.

Most Pacific island countries have suitable agronomic conditions and, while the various ACIAR project outputs made important contributions to quarantine pest status and management for fruit flies, few Pacific Island countries have ready access to an international airport or seaport with ready availability of freight capacity at competitive rates. Arguably most are weak in terms of private sector marketing capability and ability to resolve phytosanitary and other market access issues. It is doubtful whether the ACIAR projects could have done much about the latter factors even if it had been an objective to so.

In contrast, countries such as Thailand, the Philippines and Vietnam, where ACIAR also contributed to post harvest research, have well developed trade infrastructure.

Realized and prospective benefits in partner countries from market access projects

Table 2 summarises the estimated benefits from market access achievements attributed almost entirely to the three post harvest treatment centred ACIAR projects. In this case, realised benefits dominate due mainly to the early success in gaining access for export of mangoes from Thailand and the Philippines to Japan since 1993/94. Fiji also has had success at exporting fruits to New Zealand and Australia based on heat treatment. Other heat treatment facilities in Cook Islands, Samoa and Tonga have been less successful than Fiji, at least in part because they not are as well served with frequent international flights as the heat treatment facility at Nandi Airport.

Table 2: Realised and prospective market access benefits in those partner countries where ACIAR post harvest treatment projects produced the necessary R&D outputs. (Present Value A$million 2007).

Host Country	Realised	Prospective	Total
	$million	$million	$million
COOK ISLANDS*	0.063	0	0.063
FIJI ISLANDS*	0.073	0.275	0.347
MALAYSIA	0	0	0
THE PHILIPPINES	16.284	1.278	17.563
SAMOA*	0.001	0	0.001
THAILAND	10.353	3.155	13.508
TONGA*	0	0	0
VIETNAM	0	0	0
TOTAL	**$26.773**	**$4.709**	**$31.482**

Legend: 0 = no evidence of uptake/impact
* Attribution to ACIAR projects small because they only produced one minor research output. All other necessary R&D outputs from complementary projects funded by other donors.

To date, the only outstanding success in realising significant market access benefits from exporting non-host fruit has been the export of squash from Tonga to Japan. The ACIAR projects provided significant assistance to Tonga in establishing that squash is not a host for fruit-fly species in Tonga, and that pest fruit flies of squash do not occur in Tonga.
In addition, New Zealand agreed to harmonise the standards that Pacific island countries had to meet to establish non-host status for some tropical fruits and vegetables. The Fiji islands, Cook Islands and Samoa successfully negotiated non-host SPS protocols for the export of chillies and pre-colour break bananas to New Zealand. The ACIAR projects played a key role in this success by participating in fruit-fly trapping and host survey programs that established that these fruits are not hosts for endemic fruit flies in these countries, and that the countries are free of fruit flies that might infest these fruits. Table 3 shows the realized and prospective benefits associated with non host projects.

Table 3: Realised and prospective market access benefits in partner countries where ACIAR non host status projects produced necessary R&D outputs. (Present Value A$million 2007)

Host Country	Realised	Prospective	Total
	$million	$million	$million
COOK ISLANDS	0.003	0.001	0.004
FEDERATED STATES OF MICRONESIA	0	0	0
FIJI ISLANDS	0.067	0.031	0.099
INDONESIA	0	0	0
MALAYSIA	0	0	0
PAPUA NEW GUINEA	0	0	0
SAMOA	0.260	0	0.260
SOLOMON ISLANDS	0	0	0
THAILAND	0	0	0
TONGA	14.561	1.930	16.491
VANUATU	0	0	0
VIETNAM	0	0	0
TOTAL	**14.892**	**1.962**	**16.854**

Legend: 0 = no evidence of uptake/impact

Lessons

Negotiating market access is a complex and difficult activity that can take many years and requires considerable resources.

Market access based on area free pest status appears virtually impossible given the environment on Asian countries with long land borders traversing areas where pest fruit flies are endemic and where within the large area of eradication needed, farm sizes are small and there is a general lack of on farm sophistication.

The market access case based on non host status is clear cut but requires robust documented evidence and the capability and resources to pursue and negotiate access on this basis, especially in situations where other pests may still have to be treated as part of any export activity.

Tonga is the only country that has realised substantial market-access benefits based on non-host status. While other countries hope to do so in the future, the realities of negotiating access to premium-price markets are such that these aspirations are unlikely to be realised, especially as conditions for gaining market access are becoming more stringent and standardised as more countries join the World Trade Organization (WTO), and technology developments are overtaking previous requirements. The problems of realising such benefits seem to have been underestimated in the research.

Market access based on post harvest disinfestation is more consistent with the way global trade in fruit and vegetables is progressing. Importing countries require exporters to meet all their quarantine requirements regarding pest. The most stringent quarantine rules effectively operate a zero tolerance to the presence of pests such as fruit fly larvae in imported fruit.

Gaining access to markets is dependent on the importing countries accepting the scientific results and treatment protocols established in the exporting country. However, this is only the start of a long application, evaluation and negotiation process that can take many years and is influenced by a variety of bilateral trade issues. Consequently some countries that have the relevant scientific evidence and have developed acceptable post harvest treatment systems may still be unable to get into the queue for evaluation. As with non host and pest free status, researchers appear to have underestimated the difficulty of negotiating access in this case.

The treatment landscape is also changing. In particular, the move to irradiation for post harvest treatment, which is now a requirement imposed by some importing countries, has the potential to make some existing technologies such vapour heat treatment obsolete. Post harvest treatment technologies are continuously monitored by importing countries and quarantine requirements revised as needed to reflect the new technologies.

The large market access benefits in ACIAR partner countries are based on the Philippines and Thailand achieving market access for mangos into Japan based on post harvest heat treatment. Post harvest projects also have occurred in Vietnam although access is yet to be achieved in any restricted market based on their completed research and documentation. In part this can be attributed to fruit exports not being as a high a priority as industrial exports and the lack of negotiating resources. In the South Pacific, only Fiji has been able to continue to grow exports of fruit under SPS protocols negotiated with assistance from the Regional Management of Fruit Flies in the Pacific (RMFFP) and complementary ACIAR projects.

A particular issue arises when the research funding country is one that also has strict quarantine rules. The funding country makes no commitment to the partner country in respect of trade opportunities. Even when acceptable post harvest research and documentation is completed there is no commitment to evaluation and partner countries take their place in the queue like any other applicant. The effect of this is to reduce the estimated potential benefits from successful research.

Field control benefits

Overview

Numerous methods to either control fruit-fly infestations, or mitigate their effects predate the ACIAR projects. Practices to reduce fruit-fly populations include cover sprays of insecticides, protein bait sprays mixed with insecticide, and field sanitation. Male annihilation, by luring flies into traps baited with an insecticide and containing a para-pheromone able to attract fruit flies from more than 300 metres, can be particularly effective method of reducing fly populations. However, due to cost, it is normally only used as a monitoring tool for surveillance purposes and in eradication programs. Bagging fruits is used to protect some high-value fruits from fruit-fly infestation, while ‘cultural’ avoidance practices include production during periods of relatively low fruit-fly activity, early harvest before fruit is fully ripe and susceptible to infestation, and growing less susceptible varieties.

Protein bait sprays comprise an attractant and a toxicant, and have been used extensively in Australia for many years. In the mid-1980s, the acid hydrolysate attractant component of bait sprays, which can have phytotoxicity problems, was replaced with a yeast autolysate. The effectiveness of protein bait as an attractant depends on the fact that immature females need a protein meal to develop mature eggs, so ‘spot spraying’ is adequate and cover spraying of the tree canopy is unnecessary. Experiments and experience have shown that bait spraying is most effective in ‘area’ treatment programs, such as in large orchards, or where adjacent properties all use the technique.

Research in the earliest ACIAR projects raised the prospect of developing low-cost protein bait from brewery yeast waste that could be spot sprayed to improve fruit-fly control in developing countries. The objective of developing and testing efficacy of a protein bait spray also was a common thread running through subsequent research in the group of seven larger projects, and also lead to two extra small projects that were funded specifically to further develop a cheap and locally available protein bait spray from brewery yeast waste. Field control using protein bait also is an essential part of other ACIAR funded research into the use of improved temperate fruits varieties and orchard management in North Vietnam.

Potential benefits

Relative to insecticide cover sprays, claimed advantages of protein bait sprays include:

- They lower the costs of insecticide as less is used.
- Protein bait sprays leave less residues in crops and in the environment.
- They do not attract and therefore do not harm beneficial insects, such as pollinators and parasites. Hence, they are suitable as a component in Integrated Pest Management (IPM) programs.
- Spot spraying is less time-consuming and requires less labour input.
- Farmers also may be able to use simpler, cheaper application equipment.
- Protein bait sprays are more environmentally sound. Spray applications can be directed on to foliage and away from fruits to minimise fruit residue problems.
- The use of coarse sprays at low pressure are less hazardous to the spray operator.

A significant disadvantage of protein bait sprays is that control can be inadequate when there is extreme pest pressure, and especially if re-invasion of the treated area is continuous. This is likely to be the case when the treated area is small in relation to surrounding untreated areas. Also, as the season progresses, control may be less effective as female populations at all stages of sexual maturity develop, because gravid females may be less interested in food than in finding suitable egg-laying sites. Hence, for some industries, potential benefits of field control using protein bait sprays will only be realised if area wide control can be organised.

Protein bait spray technology has been included in quarantine protocols developed between New Zealand and Fiji Islands, Samoa, Tonga and Cook Islands for the export of some fruits, and is being used in some of these countries as one component of quality assurance schemes for selected exports. In addition, due to concern about high pesticide levels among tropical fruit producers in South Vietnam, the government may in the future instigate mandated use of protein bait sprays as a way to solve the problem. The Vietnamese government is committed to a pesticide reduction policy.

Figure 7 shows the generic case of benefits from field control in existing industries that arise primarily from the increased yields of saleable fruit that farmers receive. In effect the supply curve is shifted down. Figure 7 illustrates this. Without field control, supply is *S1* and producer surplus is area *a*. After the adoption of field control based on protein bait, supply shifts to *S2* for adopting farmers, and producer surplus grows to area (*a*+*b*+*c*), a net gain of area (*b*+*c)*. The assumption in the diagram is that the adopting farmers will be able to sell fruit at current market prices while the cost of protein bait application is a relatively small proportion of total production costs.

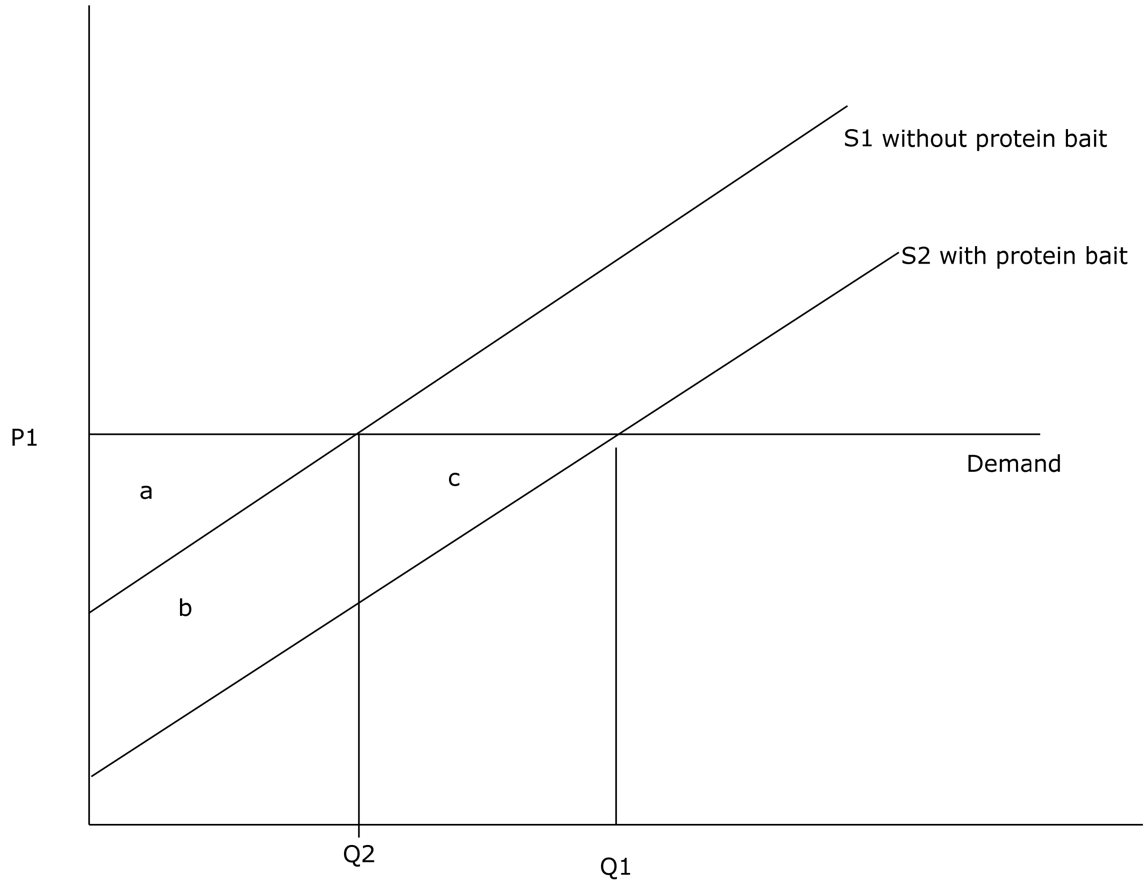


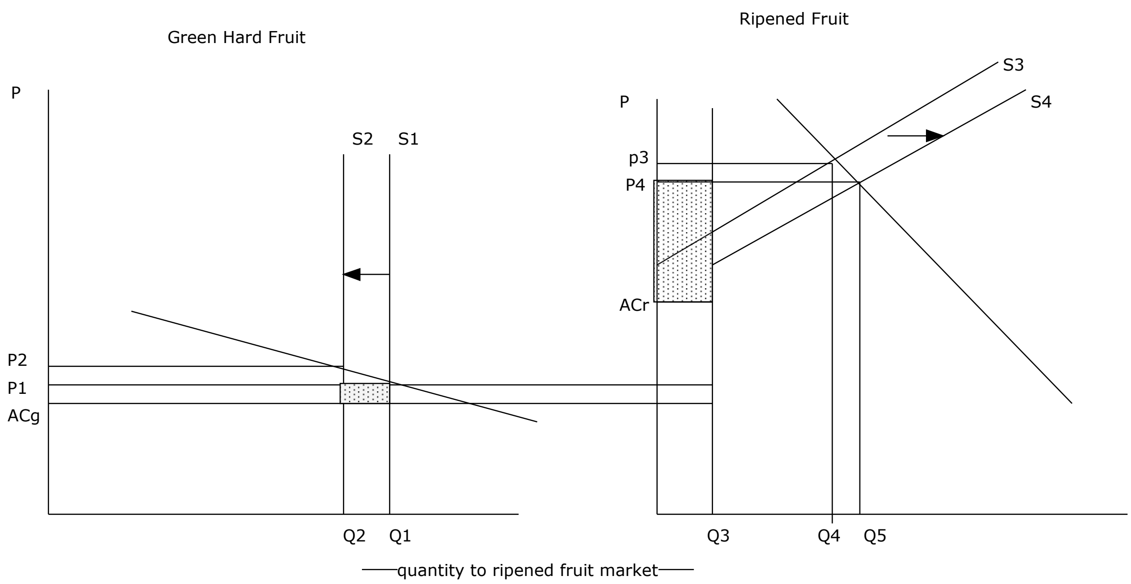
Figure 7: Producer gains from improved field control

In addition to adoption by existing industries, in certain cases, protein bait spray technology might be transformational by enabling the development of new industries, or by opening up new markets. A case in point is the introduction of new temperate fruit varieties, including varieties of plum, peach, nectarine, pear and persimmon, to upland regions of both Laos and Vietnam that was the focus of another ACIAR project.

Growers in these areas suffer because of poor-quality, locally-grown cultivars, lack of resources, and poor farm management and extensive fruit fly infestation. Growers have managed fruit fly infestations in the past by harvesting fruit hard green. A critical element for success with the new potentially more productive crop varieties was the introduction of protein bait into the management regime. Effective field control in the developing orchards was critical to ensuring minimal losses if the new species are allowed to ripen at a later date to ensure much higher quality fruit and extended harvest periods across a range of fruits. Arguably the ultimate success of these projects was heavily dependent on the related ACIAR supported research on protein bait spray.

Where field control using protein bait sprays was combined with new temperate fruit varieties, the benefits arise because farmers can produce greater volumes of high quality fruit at preferred times of the year. In particular, in North Vietnam the potential benefits arise from farmers achieving premium prices in the Hanoi markets in competition with imported Chinese fruits.

Figure 8 illustrates the approach used to measure the benefits from farmers producing higher quality ripe fruit with the new varieties and protein bait based field control.



In green fruit market price = P1 and qty =Q1
Q1-Q2 diverted to ripe fruit market
Price increases to P2
ACg = AC for green hard fruit.
PSg= (P1-ACg) (Q1-Q2)

In ripe fruit market price = P3 and qty Q4
Q3 added from diversion
Price = P4 and qty= P5
ACr = AC for ripe fruit
PSr = (P4-ACr)Q3

Figure 8: Producer benefits from low-chill temperate fruit

Essentially, there are two markets. In the green hard market, farmers follow longstanding practices and harvest green hard, taking whatever yields occur without much orchard management. There is minimal attention to pruning, fertilisers, pest control or drainage. Farmers take whatever they can harvest to market. Prices are low, around *P1*. Average cost is lower *ACg* leaving small producer surplus. There also is a ripe fruit market where higher quality fruit is sold. Currently this is characterised by supply *S3* and price *P3*. In Vietnam this is the Hanoi market area, where currently much of the *S3* supply comes from China.

Farmers who adopt the combined low-chill temperate fruit regime with new cultivars, improved orchard management and protein bait will switch to this market. They lose volume *Q2-Q1* in the green hard market and supply *Q3* to the ripe fruit market. They will not necessarily be the same volumes, as yields (fruits or kg per ha) vary between the two systems.

After the switch, supply is *S2* in the green hard market and *S4* in the ripe fruit market. The farmers lose a small producer surplus in the green hard market and gain a surplus in the ripe fruit market. In the green hard market the surplus lost is *PSg= (P1-ACg) (Q1-Q2)*. The surplus gained in the ripe fruit market is *PSr = (P4-ACr)Q3*. The net gain is the difference between the two.

Impact Pathway

The following outputs from ACIAR projects have been identified as necessary for achieving potential field control benefits in partner countries:

- local staff with expertise in methods of field control of fruit flies
- an effective extension package adapted to local conditions

- a cheap and locally available supply of protein bait spray
- application methods for protein bait spray of proven efficacy
- demonstration of protein bait effectiveness.

The first two outputs are essential for field control benefits from the ACIAR projects, and the other three outputs also are necessary for benefits when use of protein bait spray is a component of field control methods:

To the above can be added the following project outputs in the case where low chill temperate are combined with protein bait field control.

- demonstration areas that show farmers how to plant and manage the new varieties and potential yield and fruit quality improvements
- an effective extension package adapted to local conditions to demonstrate the potential returns to individual farmers
- local extension staff with expertise in propagating and raising the new varieties

The various ACIAR projects where protein bait was a component incorporated farmer and extension (‘train the trainer’) activities. Field experiments documented effectiveness and were the basis for commercial operators to develop application recommendations. In some ACIAR projects, researchers contributed directly to the development process for protein bait manufacturing facilities.

Figure 9 illustrates the pathway to show how the research undertaken in the various relevant fruit-fly projects with a field control component lead to the realisation of field control benefits. Figure 10 illustrates the pathway to achieving benefits in the case where field control is combined with new varieties of temperate fruit.

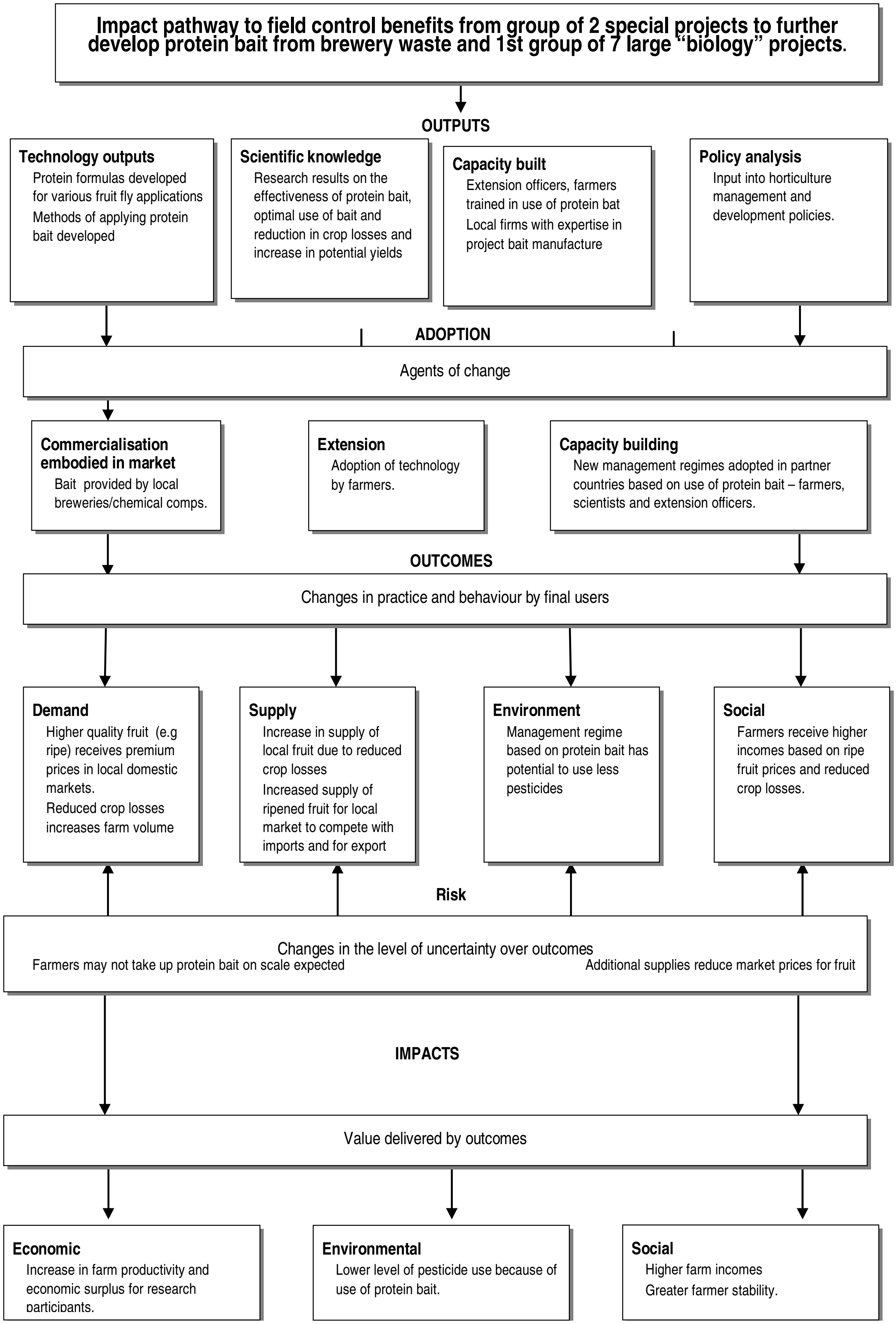


Figure 9: Pathways to benefits from field control based on protein bait

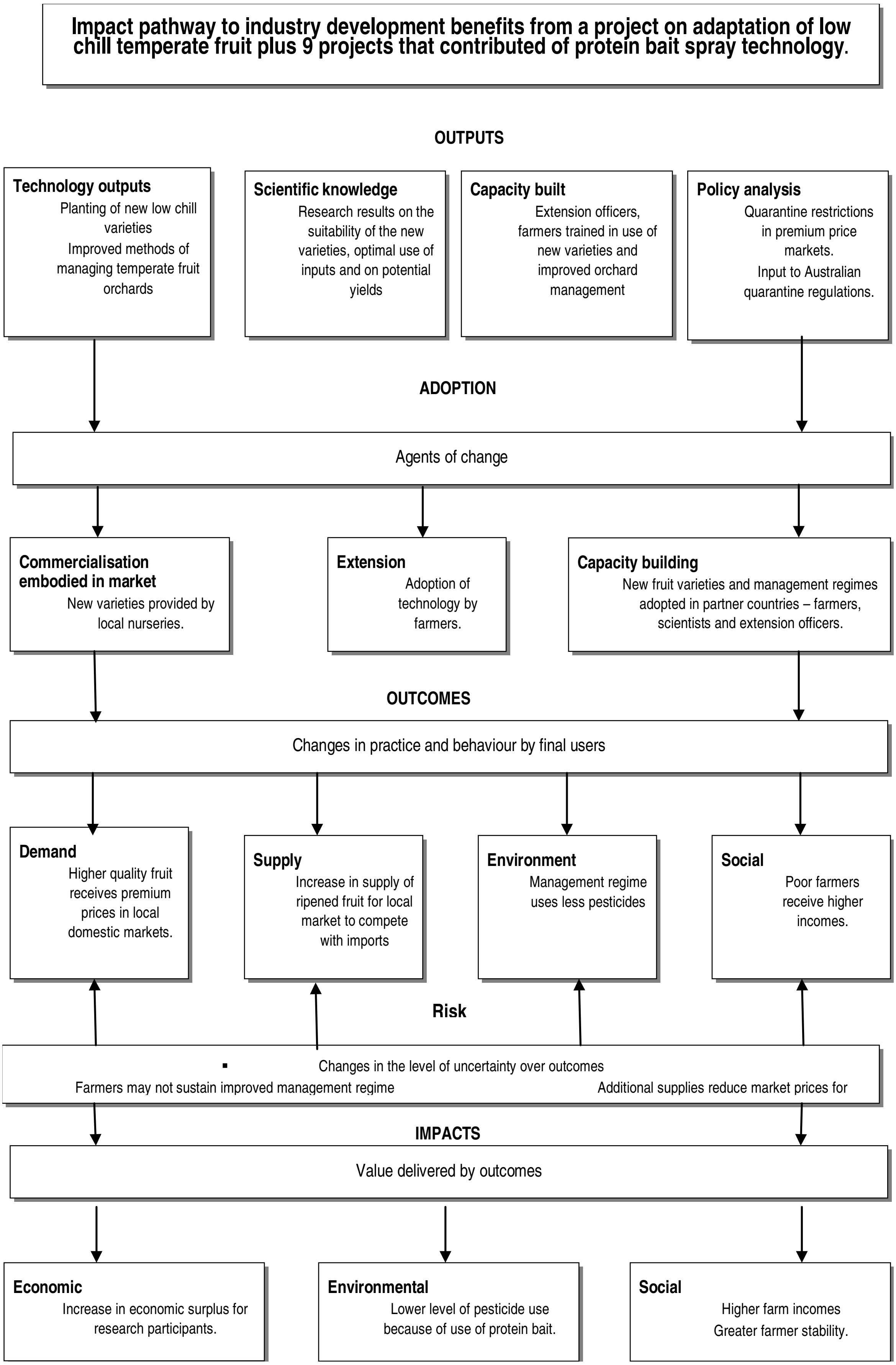


Figure 10: Pathway to achieving benefits from low chill fruit

Other necessary conditions to realise field control benefits

Sustained uptake of all necessary project outputs by potential adopters is necessary, and may be sufficient, for benefits from better field control of fruit flies to be realised. Growers will only lastingly adopt new or different field control methods if there are net benefits from doing so. Adoption of improved methods of field control may reduce fruit-fly infestation and thereby increase fruit quality and/or yields, or may reduce the cost of achieving prior levels of mitigation of fruit-fly infestation.

For the protein bait farmers will need access to sufficient cheap volumes of spray. This depends on the willingness of breweries to continue to provide yeast waste and on the developers being able to make a profit. Of note, in Malaysia, where initial protein bait trials, were undertaken, waste yeast is used in animal food production and it appears that this is a more valuable use in the market place compared to protein bait. This one reason, among others, why protein bait development been slow in Malaysia.

Without correct and consistent treatment, protein bait loses its effectiveness. In addition, because infestations cross farm boundaries and farms are small in partner countries, successful use of protein bait spray depends on a group of farmers (usually many farms) cooperating in the use of and correct application of the spray over a large enough area to ensure maximum control.

Realised and prospective benefits in partner countries

Table 4 shows the estimated realised and prospective benefits attributed to field control ACIAR projects alone, as well as the combined benefit attributed to selected field control projects plus the low chill temperate fruit project.

The realised benefits are small and are largely due to small groups of farmers (villages) in the north agreeing to adopt protein bait sprays as part of the development of the technology and to Barbados cherry farmers in the south using the bait spray. The realised benefits are based on small scale protein bait plants, essentially in the developmental stage. The prospective benefits are based on planned expansions of protein bait production assuming it is all used at required application rates. For low chill temperate fruit, the Vietnamese Government has announced ambitious targets to increase the area of temperate fruit production. However, the estimates for prospective benefits are based on this target discounted by 80% to allow for the expected slow take up of the bait spray technology and new varieties and for the planned production capacity of protein bait.

Table 4: Realised and prospective benefits in partner countries where ACIAR field control and/or low chill temperate fruit projects produced necessary R&D outputs. (Present Value A$million 2007)

Host Country	Realised	Prospective	Total
	$million	$million	$million
field control projects only			
BHUTAN	0	0	0
COOK ISLANDS	0	0	0
FIJI ISLANDS	NE	NE	NE
FEDERATED STATES OF MICRONESIA	0	0	0
INDONESIA	0	NE	NE
MALAYSIA	0	0	0
PAPUA NEW GUINEA	0	0	0
SAMOA	0	0	0
SOLOMON ISLANDS	0	0	0
THAILAND	0	0	0
TONGA	0	0	0
VANUATU	0	0	0
VIETNAM - SOUTH	1.558	54.035	55.594
VIETNAM - NORTH	2.924	45.842	48.766
combined low chill temperate fruit plus field control projects			
VIETNAM - NORTH	0.732	34.487	35.219
TOTAL	**5.215**	**134.364**	**139.579**

Legend: 0 = no evidence of uptake/impact
NE = insufficient information to quantify

Lessons

Low cost protein bait spray emerged from the very early work on fruit fly in the ACIAR projects. An initial plant in Malaysia proved not to be viable, a combination of an unstable formula and waste yeast supply problems. A plant was developed in Tonga. Launched in 1998 the plant has provided little protein bait, arguably because of the high price as compared to imports. Other plants are very recent. South Vietnam (2002), North Vietnam (2007), Indonesia (2008) and a new plant in Malaysia (2006). The benefits are essentially prospective from these developments and notwithstanding the nearly 20 years of research on the development of low-cost protein bait sprays from brewery waste, it still has not been conclusively demonstrated that the use of these sprays is a cost-effective alternative to existing practices in most developing countries.

For both protein bait sprays and low chill temperate fruits, significant ongoing support is required (training, extension, demonstration) to realise the prospective benefits. This goes well beyond the time frame of an ACIAR project. In these circumstances it is debatable whether this ongoing activity should be the responsibility of ACIAR or other aid agencies, or of the partner-country government. Where this is an issue the policy setting and resource commitments by the partner countries need to be appropriate. Arguably some of the potential benefits from low chill temperate fruits and protein bait sprays will not be realised if this not the case.

Conclusions

While the total value of benefits generated from the investment by ACIAR and its partners is impressive, the pattern of benefits is variable by type of benefit and by country. The twin lessons that *ex ante* the returns on individual investments in research are very unpredictable, and *ex post* are highly variable, are not new lessons but ones that are often forgotten. A related lesson from this thematic and wide-ranging impact assessment is that the high returns to research are often serendipitous. One of the most important general lessons, also widely known but reinforced by the results from this study, is that while successful research project outcomes may be necessary to enable potential benefits, they rarely are sufficient for benefits to be realised. In particular, potential benefits will only be realised if there is uptake of project outputs. However, at the time of project formulation, the necessary conditions for adoption of project outputs often seem to receive insufficient attention. Notwithstanding some 20 years of research on the development of low-cost protein bait sprays from brewery waste, it has still not been conclusively demonstrated that the use of these sprays is a cost-effective alternative to existing practices in most developing countries.

References

Binder M, 2002. 'The role of risk and cost-benefit analysis in determining quarantine measures'. Productivity Commission Staff Research Paper, AusInfo, Canberra.

Cantrell B., Chadwick B and Cahill A. 2002 Fruit fly fighters: eradication of the papaya fruit fly. SCARM Report 81, CSIRO, Collingwood, Victoria.

Collins D. and Collins B. 1998. Fruit fly in Malaysia and Thailand, 1985–1993, ACIAR Projects 8343 and 8919. ACIAR Economic Impact Series No. 5., Canberra.

Lindner B. and McLeod P. 2008. A review and impact assessment of ACIAR's fruit-fly research partnerships, 1984–2007. ACIAR Impact Assessment Series Report No. 56, August 2008.

McGregor A. 2007. The export of horticultural and high-value agricultural products from the Pacific islands. Pacific Economic Bulletin 22(3) October 2007 Asia Pacific Press

Monck M. and Pearce D. 2007. Improved trade in mangoes from the Philippines, Thailand and Australia. ACIAR Impact Assessment Series Report No. 50, Canberra

Plant Health Australia. 2006. National Tropical Fruit Industry Biosecurity Plan. Plant Health Australia, Canberra, ACT.

Plant Protection Research Institute. 2007. Report on implementing of ACIAR project 'Management of pest fruit flies to increase productivity of fruit and vegetable crops in Vietnam'. Code CS2/1998/005. Plant Protection Research Institute, Hanoi

Waage Jeff K., Fraser Rob W., Mumford John D., Cook David C., and Wilby Andy. 2004. A new agenda for biosecurity. Unpublished manuscript.