Implementing Economics into Biosecurity Risk Analysis: Avoiding the Pitfalls of Uncertainty
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Abstract
The development of user-friendly economic models allows for greater communication and interaction between the disciplines involved in biosecurity. By creating a decision support platform that allows users to critique the assumptions and processes involved, greater faith is then placed in that system as it develops into a living and breathing tool, whose accuracy improves through time, rather than just delivering a static report. By opening the economic black box, greater effort can then be put into the economic content and also tightening up the bio-economic assumptions. This approach minimise the issues of risk, uncertainty, and communication problems between disciplines.

Key words: modelling, risk, uncertainty and state contingent approach

Introduction

Biosecurity risk analysis is a multidisciplinary issue that attempts to predict the impacts of exotic species on the environment, production systems, and society as a whole. The economics of biosecurity is an attempt to attach dollar values to the potential outcomes of either a change in trade policy (Import Risk Analysis (IRAs)) or the economic loss caused by a new species entering as a by-product of existing trade, a deliberate act and/or natural movement. The last issue can also be expressed as what is the economic benefit from eradication or preventing the infestation from occurring or establishing.

The issues associated with dispersal patterns, seed banks, density to damage ratios, and dynamic versus static time snapshots pose a raft of complex scientific, social, and economic issues to deal with in regards to risks and uncertainties. In order to minimise the communication misunderstandings within a multidiscipline environment, effort must be placed into developing a framework that allows for rigorous debate of the economic, scientific, and social assumptions used. Modelling can provide this transparent platform for communication to question the assumptions and the economics tools used thereby negating the economic black box. By providing a common platform to test alternative opinions there is a greater scope for sensitivity analysis and acceptance of the results increases amongst a wider audience. Such a system also explicitly states the parameters used in the decision making process.

The aim of this paper is to discuss whether current policy restrictions on economic tools is constraining the economic debate in biosecurity in Australia; propose a way to deal with risks and uncertainty by utilising a state contingent approach; and provide practical examples of how modelling provides a communication strategy to devolve the economic black box for other disciplines to help the decision making process.

The paper is organised as follows: Section 1 provides a brief look at the role and limitations of economics in biosecurity; Section 2 provides a discussion on dealing with risk and uncertainty by harnessing a state contingent approach; Section 3 outlines the benefits of using modelling as a communication strategy to unravel the economic black box; and finally some concluding comments are provided.

1. Economics of Biosecurity

Economic investigations of biosecurity generally concentrate on the direct market impacts thus avoiding issues associated with non-market evaluations. Despite Australia having unique fauna and flora and the resulting environmental and economic loss associated with a biosecurity outbreak potentially being considerable, if not irreversible, the techniques involved in determining non-market goods and assets are still developmental. Many of the current tools and techniques are regularly challenged and are resource hungry in terms of time and cost when applied. Consequently this paper focuses on market evaluation techniques used when dealing with biosecurity issues.

Two principal constraints exist in the economic debate in biosecurity. The first is the policy environment (national and international requirements) that the economic studies operate in. For example

> "3.6
> In keeping with the scope of the Quarantine Act 1908 … and Australia's obligations as a member of the WTO, economics considerations are taken into account only in relation to matters arising from the potential direct and indirect impact of pests and diseases that could enter, establish or spread in Australia as a result of importation.
>
> The potential competitive economic impact of prospective imports on domestic industries is not within the scope of IRAs" (Biosecurity Australia 2003).

Such limitations mean that issues such as compensation, long term economic industry viability, and resource relocation are generally ignored.

The second is the lack of a transparent standardised economic approach to biosecurity evaluations within Australia, despite the need being identified in the last review of quarantine matters (Nairn etal 1996). Most economic reports into biosecurity issues are either commissioned by state departments and/or industry groups, or done in house by government organisations. Therefore the reports are often limited to political boundaries; argue the impact to one R&D body; are actually often just financial evaluations; investigate one species only so ignore the impacts of multiple species entry; ignore the benefits and costs to other non-target species from a change in management practices; are based on management projects; and often used after the event to justify spending and are consequently done on a shoestring budget.

Hinchy and Fisher (1991) suggested the two economic approaches used to determine the impact of biosecurity issues: partial or general equilibrium analysis (i.e. economics of trade) and tools that are developed from pest management economics.

General or partial equilibrium analysis focuses on the how producer and consumer surplus alters given a change in demand and supply curves. If the change in consumer surplus (elasticity of demand) is greater than the loss in producer surplus (changes to management costs, prices, and output) then the IRA decision should be for trade liberalisation. Expanded versions may look at other impacts on society as a whole (e.g. impact on abattoir staff, Dent 2002) but this normally the exception to the rule. James and Anderson (1998) for example discussed but did not examine compensation issues impact on net economic benefits and Cook (2001) provides a list of the limitations in the approach. Practical on-ground production impacts and how biological issues affect producers in time and space are poorly defined.

Pest management economics generally looks at potential changes in production (costs and yield, i.e. impact on gross margin budgets) from the target species on a per hectare basis. Then the numbers are multiplied up to a farm, region, state, or country scale. Evaluations concentrating on the changes to the gross margin of production are more financial evaluations rather then economic approaches as they ignore capital investment, operator labour, and potential benefits to consumers.

In reality both approaches are needed and should be used to complement each other to improve rigour during an evaluation. As illustrated in Table 1 both processes generally avoid economic issues such as impact on capital, operator labour, and compensation. This is in part because of the policy environment, the terms of reference, and the inability to actually get quality data. Biological issues such as distribution and density through time, resistance management, and density/damage ratios are generally lacking in detail.

Table 1 Assumptions needing rigour

• probability of entry, establishment, survival and detection • distribution • density • damage/density ratios/commodity • resistance management • benefits flowing to consumers	• time • environmental impacts • changing environmental conditions (climate change) • impacts on society • range of scenarios • capital costs

A lot of these issues have already been incorporated into economic evaluations in the past and some of the classic texts in this field are: Auld et al 1978/79, Auld et al (1987), Hone (1994), Dent (2002). The following example illustrates why turning financial evaluation into economic evaluations and looking at long term economic viability is important for biosecurity issues.

Turning Financial Evaluations into Economic Evaluations: The case of Fire Blight
There are three economic reports to consider: Hinchy and Low (1990), Bhati and Rees (1996) and Arthur (2006). These studies concentrate on the changing producer and consumer surplus from freeing up Australian markets. However, in depth analysis of the impact of a change in biosecurity protocols on farm return have not been conducted to date although the need for such an evaluation was identified by Hinchy and Low in 1990.

In 1990 Hinchy and Low estimated that the loss to the Goulburn valley alone was in the magnitude of $39 million for apples, however that Australia even under the most unfavourable assumptions would be better off by $0.2 million a year. Bhati and Rees 1996 estimated that if fire blight infested all of Australia the cost to the apple and pear industries would be around $125.7 million. While Arthur (2006) estimated that Australia, at the lowest levels of benefits, would be better off by $90 million even if fire blight became established across all areas, yield decreased by 20%, and management costs were raised by 6%. All three reports only looked at the financial on-ground impacts to producers and not what would happen to the economic investment rationalee.

Financial evaluations generally require the inclusion of capital and operator labour in their assumptions and calculations in order to turn them into economic evaluations. The inclusion of capital and labour is important for commodities that require time to pay off capital investment (e.g. perennial horticultural commodities that have a production maturity lag). By including these two variables we can then determine if a change in quarantine protocols could alter a rationalee economic investment decision.

Table 2 details the costs and benefits of two production systems once maturity has been reached (packed apples which require a packing shed and loose apples where a packing shed is not purchased) and what could happed to their profitability ‘with’ and ‘without’

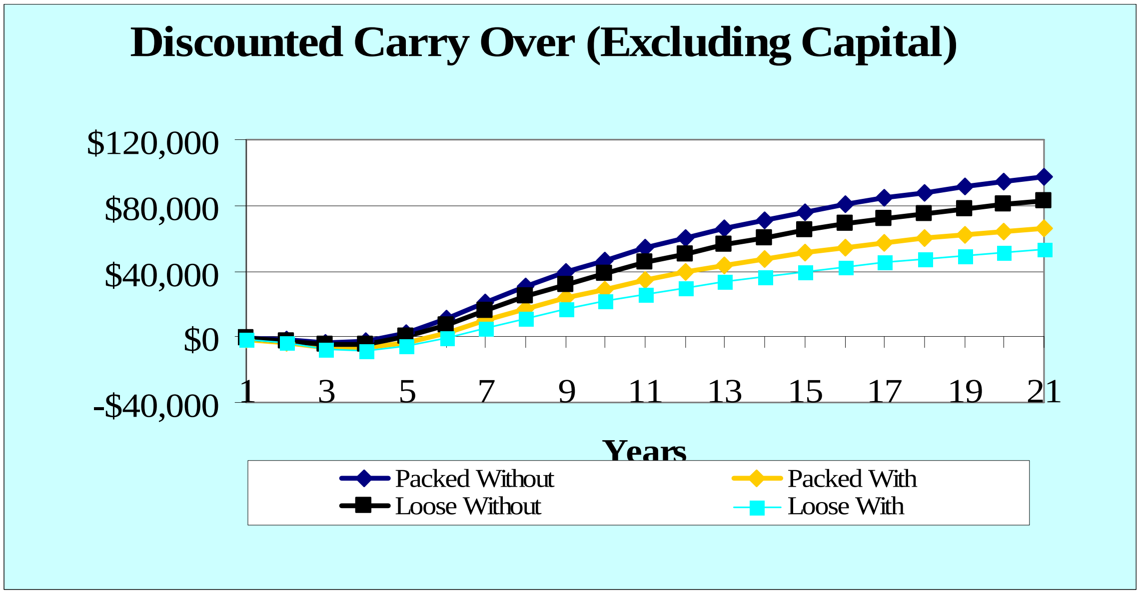
Table 2 Economic Return by Commodity ('with' = 20% yield loss+ management costs) per Ha

	‘Packed Apples’		**‘Loose Apples’**	
	‘Without’	**‘With’**	**‘Without’**	**‘With’**
Income	$63,850	$51,080	$34,035	$27,228
TOTAL VC	$43,787	$37,853	$21,101	$20,060
Gross Margin	**$20,063**	**$13,227**	**$12,934**	**$7,168**
Operators Labour	$1,778	$1,778	$1,778	$1,778
Capital Repayments	$4,738	$4,738	$4,325	$4,325
Economic Return	**$13,548**	**$6,712**	**$6,831**	**$1,066**
				Source Adamson (2006)

fire blight being present. From the data provided the annual capital costs per Ha is approximately $6,500 and $6,100 for 'packed apples' and 'loose apples' respectively. So if the evaluation considers the financial and not economic data the continuing investment decision may be flawed.

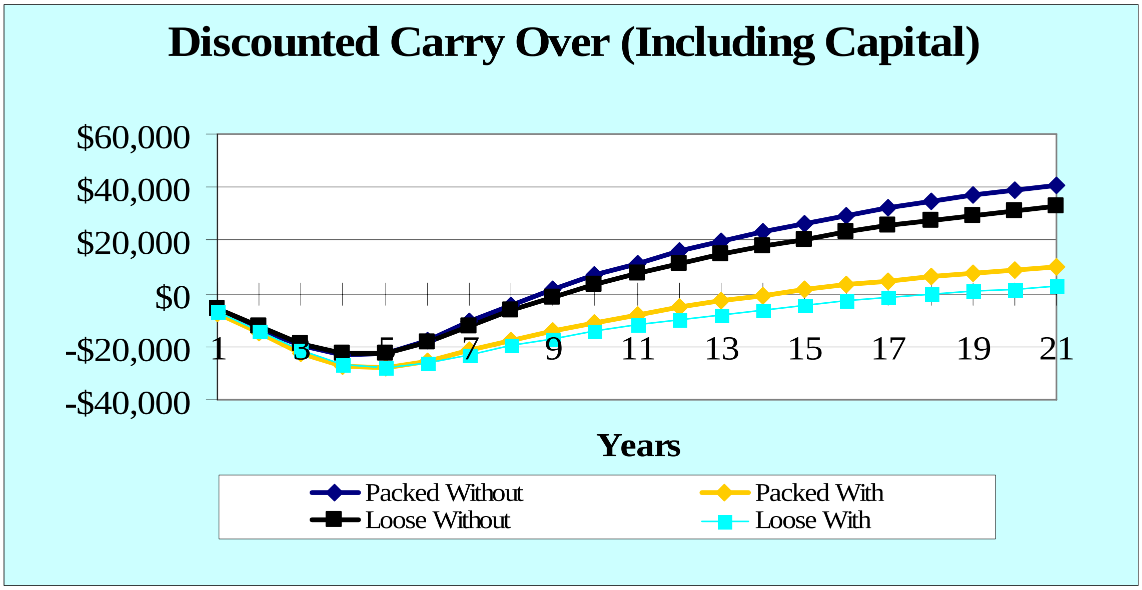
In order to understand the impact of an IRA decision the long term viability of the industry needs to be investigated. Apples trees have a production life of 20 years and they do not reach production maturity until about seven years. Figure 1 and 2 illustrate the impact fire blight could have on production systems with and without including capital costs respectively. In Figure 1 the investment broke even after 4 years despite increased management costs and a 10% yield loss every 2 years costing each investment approximately $30,000. The continuing investment in apples trees is a very sound decision.

Figure 1 Excluding Capital (Management Costs + 10% yield loss every 2 years+10% discount rate)



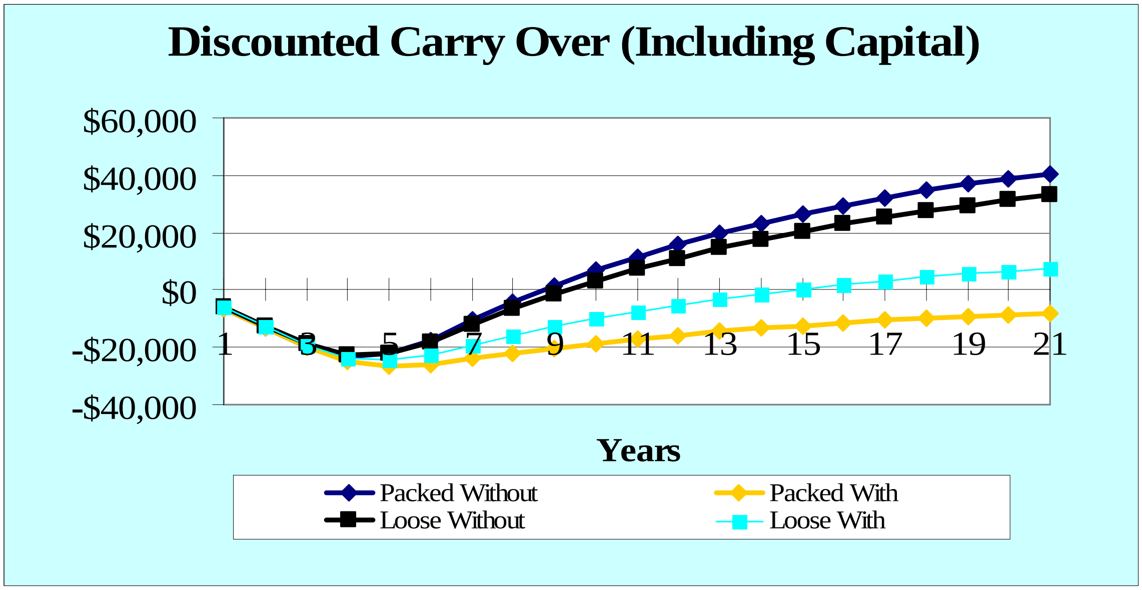
However, by including capital as in Figure 2 the enterprises need 10 years after planting to pay off the investment without fire blight being present. However, in the fire blight scenario of increased management costs and a 10% yield loss occurred every two years then the packed enterprise would breakeven after 15 year and for loose apples around year 19. This leaves very little room for something else to go wrong in the production cycle. So by including capital the investment decision in apples has moved from sound to marginal.

Figure 2 Including Capital (Management Costs + 10% yield loss every 2 years+10% discount rate)



In figure 3, the assumption is that the whole industry receives a price decrease of 15% after liberalisation, fire blight does not enter and management expenses do not increase. In this case there is no economic justification from moving from a 'loose apple' to a 'packed apple' enterprise as there is no rationalee from investing in a packing shed as the extra capital investment would never be returned given the example run.

Figure 3 Fire blight scenario (15% decline in Prices, no Management costs, Fire blight never enters)



What we need to take away from here is that for many producers the investment in an apple orchard would be an unwise decision if the IRA decision was to allow apples in from New Zealand. Therefore anyone considering planting would be well advised of the longer time to pay off the investment and consequently only increases the risks associated with this investment choice.

Such economic information is highly useful for producers as it: one allows them to see the expected increased management costs and changes to price and how it could impact on their production system; and secondly with this information about the increased production risks publicly known issues, such as compensation payments from biosecurity outbreaks can be studied. In this case the maximum time compensation payments for a biosecurity outbreak could only possibly be awarded for about 20 years.

Economics needs to start bringing everything together in a framework that allows for the analysis of production under uncertainty. One approach was first suggested by Arrow and Debru (1954) and furthered by Chambers and Quiggin (2000). It involves the representation of uncertainty by differentiation of commodities produced in alternative states of nature and is referred to as state contingent approach. Hinchy and Fisher (1991) did look at some of the alternative ways of dealing with uncertainty that Quiggin was working on but the ideas were not fully developed.

2. Applying a State Contingent Approach

A state contingent approach can be implemented into the current practices very easily. Norton (1985 & 1994) argues the use of decision trees as the optimal way to highlight the 'technically possible' versus the 'practically feasible' decisions available for pest control which help to set the states of nature. This system of identifying the management responses to alternative scenarios of pest incursions can be furthered by applying a generalised pay off matrix to account for alternative pest pressure. This now can be expanded by utilising state contingent analysis which argues that for every state of nature there is a know probability and that this probability is not dependant upon the expected-utility hypothesis (Quiggin 2005.a) but rather is a known based on past experiences.

The expected utility hypothesis is where all states of nature are merged into one by using a weighted average while a state contingent approach allows you to explicitly define the risk associated with each possible state of nature. By defining each state of nature you avoid loosing the best and worst cases in the noise of an evaluation and you move away from a stochastic model to a non-stochastic model which allows you to negate uncertainty. By stipulating all concerns as a state of nature you end up with a simple but clean model that is easy to explain.

The following is an explanation of state-contingent approach using a hypothetical IRA decision. The decision tree provides the possible states of nature by allowing the importation of a commodity from a previously banned exporter. Here there are two potential paths a pest can have: either it enters or it does not. If it does enter then there are three potential impacts that pest may have. The 'Never Enters', 'Best Case', 'Expected Case' and 'Worst Case' provide us with four states of nature.

Figure 4 IRA Decision Tree and the Potential Pest Impacts

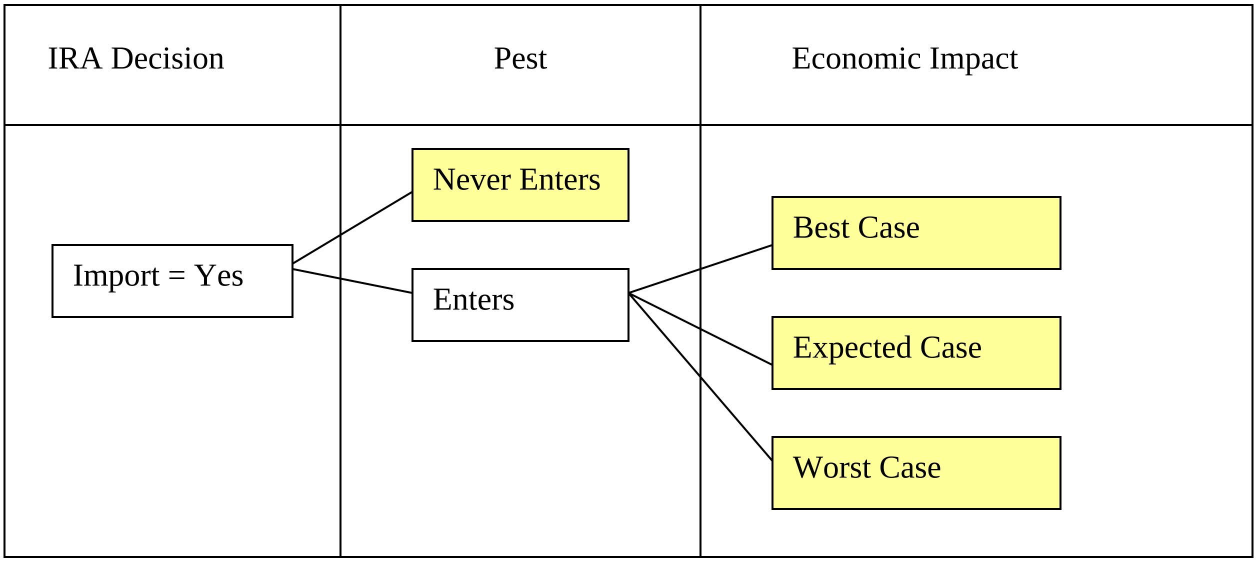


Table 3 then provides the potential pay off matrix for IRA decision and for this example it has been assumed that the net economic benefit of allowing trade in is $100 and then for each state of pest pressure (low, medium and high) a proportion of the potential net benefits of trade are lost. The potential losses should then be able to incorporate the range of viewpoints from the benign to extreme in terms of pest impacts on domestic production and in this case 10 states of nature have been defined: one state where the pest never enters and nine states where the pest enters and causes some level of impact on the potential benefits of market liberalisation.

Table 3 IRA Pay off Matrix

Biosecurity Outbreak	Pest attack (State of Nature)		
	Low	Medium	High
Never Enters	$100	$100	$100
Enters, Best Case	$100	$50	$30
Enters, Expected Case	$20	-$50	-$80
Enters, Worst Case	$0	-$100	-$200

Table 4 provides an example of how to apply a state contingent approach for an import risk assessment on an annual basis. For each state of nature regarding an IRA decision we can determine the economic value and assign a probability of this event occurring. In this case the IRA decision would be to allow trade in this commodity from the given country as the net benefit to the importing country is positive $3.30.

Table 4 IRA Pay off Matrix for year x

Biosecurity Outbreak	Pest attack (State of Nature)		
	Low	Medium	High
Never Enters	40.00%	0.00%	0.00%
Enters, Best Case	2.00%	5.00%	1.00%
Enters, Expected Case	5.00%	15.00%	5.00%
Enters, Worst Case	5.00%	13.00%	9.00%
Sum or Probabilities	100%		
		$3.30	

Table 5 shows how we can expand the basic example by introducing time and implement the whole process within a cost-benefit frame work. This then allows us to deal with assumptions such as alternative distributions, climate change scenarios, density/damage functions, multiple or single commodities impacts, etc through time and space.

The obvious difficulties in such a system are the determination of the probability (weighting) of each state of nature. Although in such a system the subjectivity of the weightings is visible and justification of each position must be made explicit by the decision maker. Obviously using either expert surveys and/or utilising focus groups to reach a consensus does provide one mechanism to limit subjectivity. Then by providing the individuals involved in such a process or external reviews with a copy of the model to play with at their leisure you minimise their residency in accepting the decision. Alternatively as Quiggin 2005.b suggests by utilising the notion of the precautionary principle greater weighting can be applied to the worst case scenarios to compensate for uncertainty.

The process is not about hiding the risks and uncertainty its about expressing them openly for discussion. The more the risks, uncertainties and assumptions are discussed, challenged and tested the more likely that the results will be accepted by the larger audience.

Modelling and using a state contingent approach can provide a platform to visualise and communicate the variables of concern.

Table 5 State contingent analysis: Multi-period Benefit

Year	No Entry	Enters, Best Case Pest pressure			Enters Expected Case Pest pressure			Enters, Worst Case Pest pressure			Benefit of Trade	Discount Rate (10%)	Discounted Benefits
		Low	Medium	High	Low	Medium	High	Low	Medium	High			
1	$20	$20	$20	$20	$20	$20	$10	$20	$0	-$12	$14	0.91	$13
2	$40	$40	$40	$40	$40	$20	$15	$20	-$50	-$50	$15	0.83	$12
3	$60	$60	$60	$60	$60	$20	$10	$0	-$100	-$40	$19	0.75	$14
4	$80	$80	$80	$80	$60	$0	$0	$0	-$120	-$150	$12	0.68	$8
5	$100	$100	$80	$80	$50	$0	$0	$0	-$80	-$120	$28	0.62	$17
6	$100	$100	$80	$60	$40	-$5	-$20	$0	-$100	-$150	$20	0.56	$11
7	$100	$100	$80	$50	$30	-$20	-$40	$0	-$100	-$170	$15	0.51	$8
8	$100	$100	$60	$30	$20	-$50	-$60	$0	-$80	-$250	$3	0.47	$1
9	$100	$100	$50	$30	$20	-$50	-$80	$0	-$120	-$200	$1	0.42	$0
10	$100	$100	$50	$30	$20	-$50	-$80	$0	-$100	-$200	$3	0.39	$1
									TOTAL		**$130**		**$87**

3. D**evolving the Black Box?**

There are numerous questions to ask when undertaking an economic evaluation of biosecurity issues: Where will this pest spread to; how quickly; what commodities are affected; what is the impact on the environment; are there human health issues involved; what management strategies will work and what will they cost; what is the impact of density on the impacts; etc. Often we are dealing in a realm of unknowns and at best partial data. So the question becomes how do we best get the data, display it and utilise it.

By providing a transparent platform that explicitly indicates the model's parameters, the ability to communicate ideas, limitations in approach, questionable assumptions, and the model's results in a clear and concise manor maximises the impact the model has with decision makers.

With the ability to develop a model that is effectively controlled by using a mouse and provides an interface that makes it easy to change the variables in terms of area infected (see Figure 5), alter the density to damage relationship (see Figure 6 where the potentially affected area was constrained by a CLIMEX simulation), gives you the ability to use defined options and the ability to utilise your own assumptions (Figure 7) and can provide the results in a charting (Figure 8) or mimicking GIS mapping (Figure 8) the ability to communicate with a wider audience becomes available.

Figure 5 Selecting Areas Manually

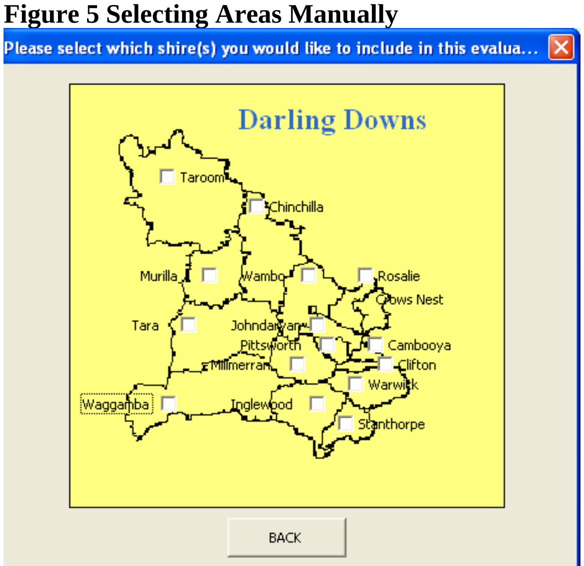


Figure 6 Using Models to select Areas

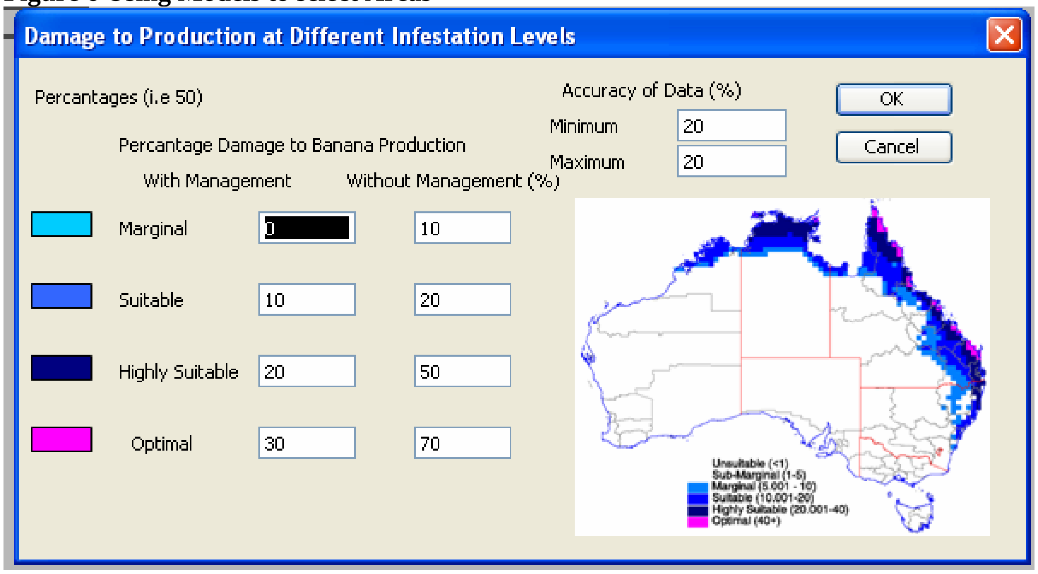


Figure 7 Providing Options for Users

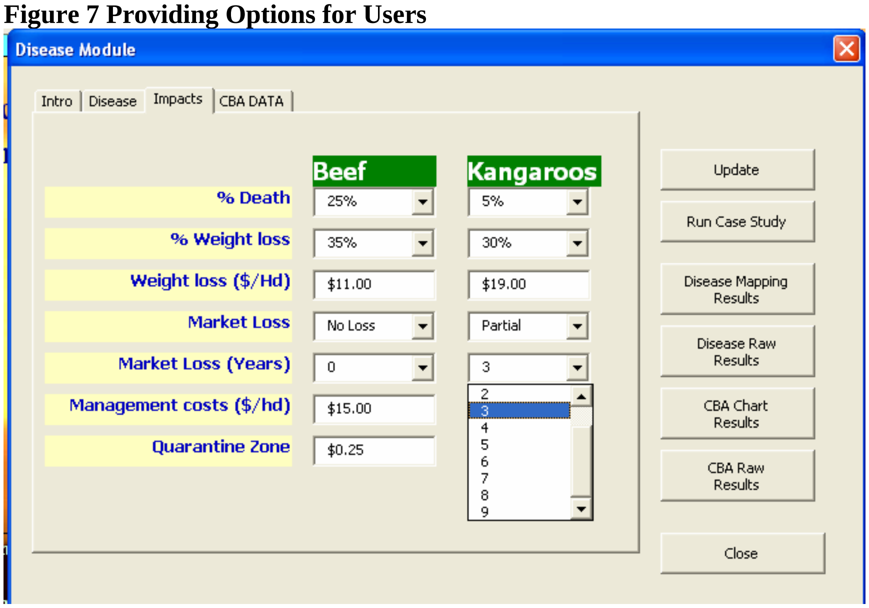


Figure 8 Displaying the Results

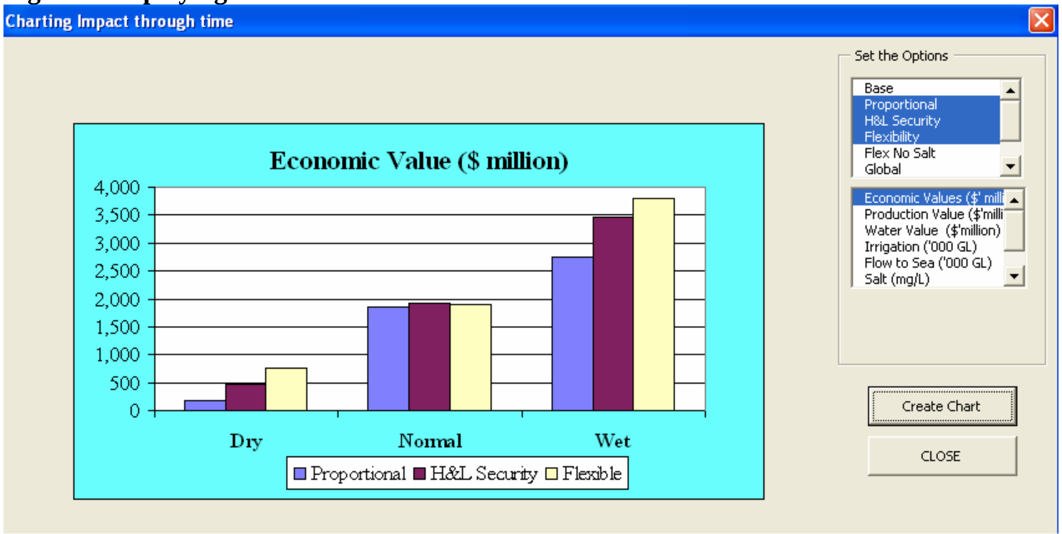
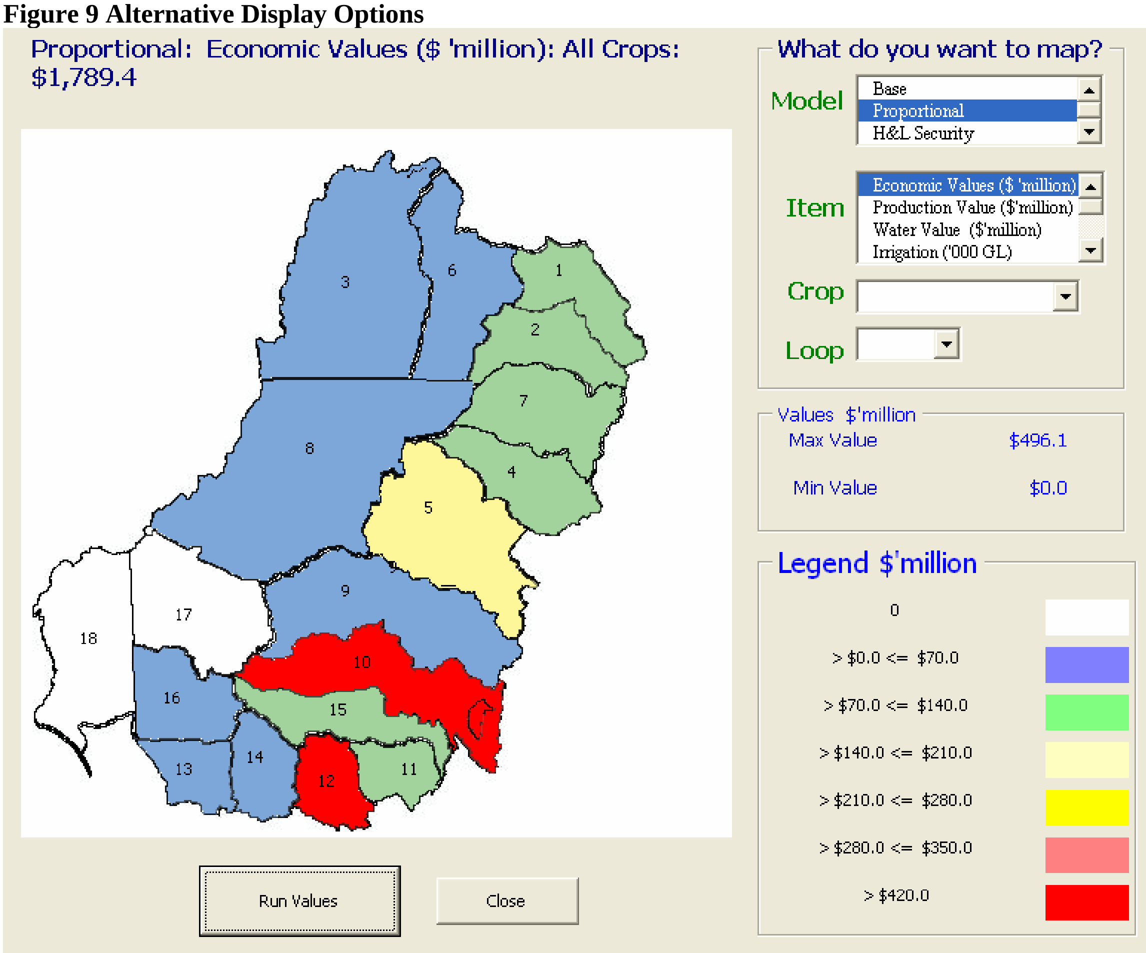


Figure 9 Alternative Display Options



By having the ability to seamlessly change data assumptions within the case studies used, chop and change data sets and import datasets from scientific models, the ability to communicate and take on board alterative viewpoints the model continually evolves and becomes more accurate once better data comes to light. When the assumptions used are made explicit, then the real areas of sensitivity in the model can be identified and studied.

4. Summary

Economic studies of biosecurity need to incorporate both approaches (partial equilibrium and pest management economics) to find out how the whole of society is affected by a biosecurity outbreak and care must be made sure that the basics economics are right.

By providing a common platform to compare and contrast differences in opinions you can see the implications of alternatives viewpoints. This allows you to explore other opportunities and also helps determine the parameters to describe the situation. The utilisation of a transparent systems helps to describe and visualise alternative approaches.

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