Revised Benefits and Costs of Eradicating the Red Imported Fire Ant[1]

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1 Introduction

Kompas and Che (2001) have assessed the expected costs and benefits of eradicating the red imported fire ant (RIFA) from Australia. They concluded that the total value of the potential cost of RIFA over 30 years would be around $8.9 billion, or $2.8 billion in present-value terms. An eradication effort costing $110 million in present value would allow this cost to be avoided, resulting in a benefit-cost ratio of 25:1.

Due to lack of data since the discovery of RIFA in Australia, Kompas and Che (2001) based their analysis mainly on costs experienced in the US. There was also no quantitative assessment of potential environmental impacts.

The objective of this study is to extend the Kompas and Che (2001) analysis. The first extension is to establish quantitative indicators of the potential environmental impact. The second extension consists of parameters assessed in the original report being re-evaluated and updated in light of accumulated evidence and changed costs.

The study has two major components: the spread modelling carried out by Joe Scanlan, Biosecurity Queensland; and the impact analysis conducted by the remaining authors at Innovation and Biosecurity Investment[3].

2 Method

This report uses cost-benefit analysis (CBA) as its core method (Treasury 2006). The costs and benefits of the proposed option are compared to those of the alternative course of action. Incremental costs and benefits are discounted and shown as net present value (NPV) and benefit-cost ratio (BCR).

To accommodate the composite perspective of economic, social and environmental objectives of the decision problem, a social cost-benefit analysis (SCBA) is employed. A SCBA aims to derive Total Economic Value (TEV), not merely a financial or economic value, where:

TEV = use values + non-use values

and

Non-use values = existence value + vicarious value + option value + quasi-option value + bequest value

The impact assessment uses as its inputs quantitative indicators of:

- the impact of the pest in specific environments and on specific components of the human value system,
- the expected dispersal from the initial infestation over the timeframe of the analysis, and
- the costs and likely impacts of alternative control strategies.

The report provides:

- indicative discounted cash flows of impact associated with alternative scenarios (eg, attempted eradication vs management without eradication),
- an assessment of the incremental value of the eradication option, and

Response options to the RIFA infestation compared in this report are:

- *Eradication* – a concerted effort to remove RIFA from Australia.
- *Management* – provision of public information only, at minimal public cost.

[3] Assistance and comments by Craig Jennings, members of the National Tramp Ant Advisory Committee, Shuang Liu and Trevor Wilson are gratefully acknowledged. Remaining errors are the authors' responsibility.

As recommended by FAO (1998), impacts of the dispersal of RIFA in this report are considered against the 'management' alternative, that is, in the absence of a central, coordinated attempt at eradication or containment. It is assumed that any isolated alternative measures taken by individuals will not hinder the natural dispersal of the ants.

3 Spread modelling

Due to limitations in computing resources, the spread of RIFA was modelled in a spatial window of 180 km by 180 km centred on the current infested areas to the west, south and east of Brisbane. This square covers much of what is commonly referred to as South East Queensland (SEQ), plus a part of northern New South Wales. Within this area, rates of spread can be assumed to be constant and equal to those used previously by Scanlan and Vanderwoude (2006).

The spread model is a cellular automaton model with a grid cell size of 1 km by 1 km (100 ha). There are 4 categories of RIFA density – Free; Present; Common; and Dense. At each time step (1 year), each cell was examined and the probability that it would remain in the same category or move to another category was estimated from its current class as well as a set of probabilities that varies depending on how many surrounding cells have RIFA. Among the assumptions in the Scanlan and Vanderwoude (2006) model was that all cells within the area covered by the model were equally likely to have RIFA. In the current version, this was adjusted according to the habitat suitability model (need a reference here). This modification did not change the overall rate of spread, but it did reduce the rate at which the Common and Dense categories were achieved once a cell has some RIFA in the Present category. The habitat model has a much finer resolution (25 m by 25 m) than the spread model (1000 m by 1000 m).

The distribution of RIFA used as a starting point was the location of all nests found in the 2007/8 financial year. Any cell (unit of 100 ha) in which RIFA was found was assumed to have RIFA in the 'Present' category in those areas of high suitability, but absent from those with low suitability. A series of decision rules was developed to describe the distribution of RIFA with the large 1 km by 1 km cells. The probabilities of spread used in the current modeling were the same as those used in Scanlan and Vanderwoude (2006).

The area with some RIFA present is 8,405 ha in 2008. In 15 years, spread is expected to reach the boundaries of the modelled square, and by 2038, RIFA practically fills the 180 km square area, with some variation in density. Out of the total land mass of 2,624,828 ha RIFA are predicted to occur on 2,585,076 ha, of which infestation is 'dense' on 2,114,924 ha, 'common' on 79,313 ha, 'present' on 390,839 ha, leaving only 39,752 ha free. Figures 1 to 3 illustrate the spatial spread in 15-year intervals, while Figure 4 charts the numerical change in the various categories over 30 years. Note that the five-yearly information from the spread model has been linearly interpolated to obtain the intervening years.

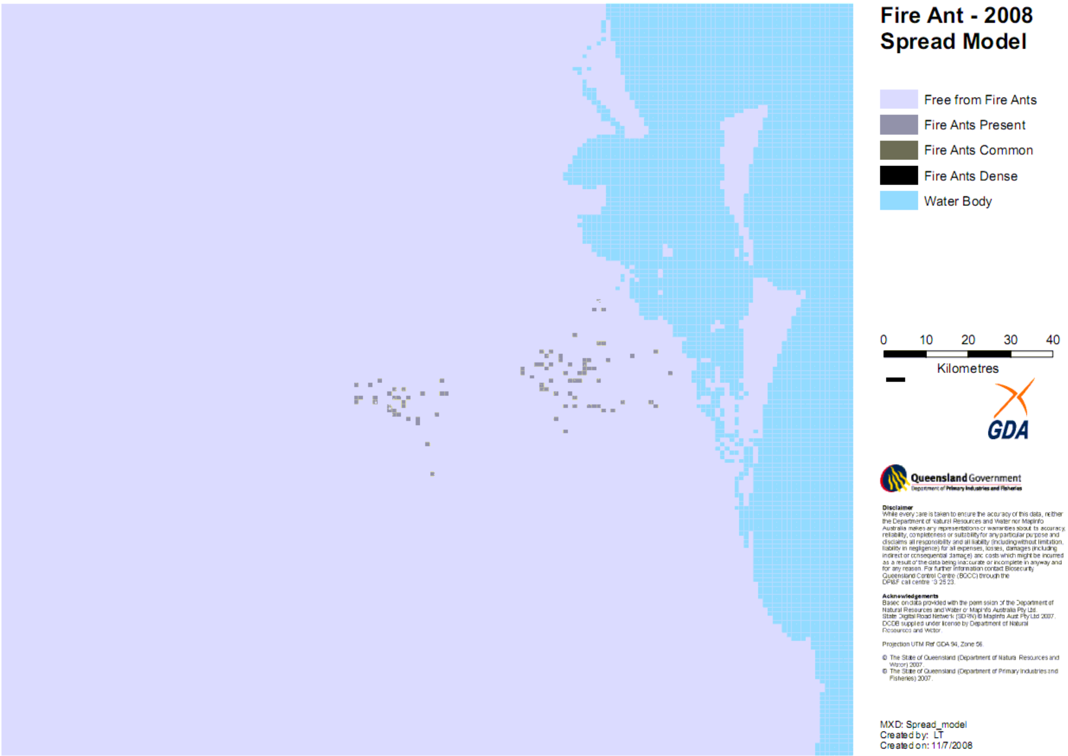

Figure 1 Extent of RIFA infestation in 2008

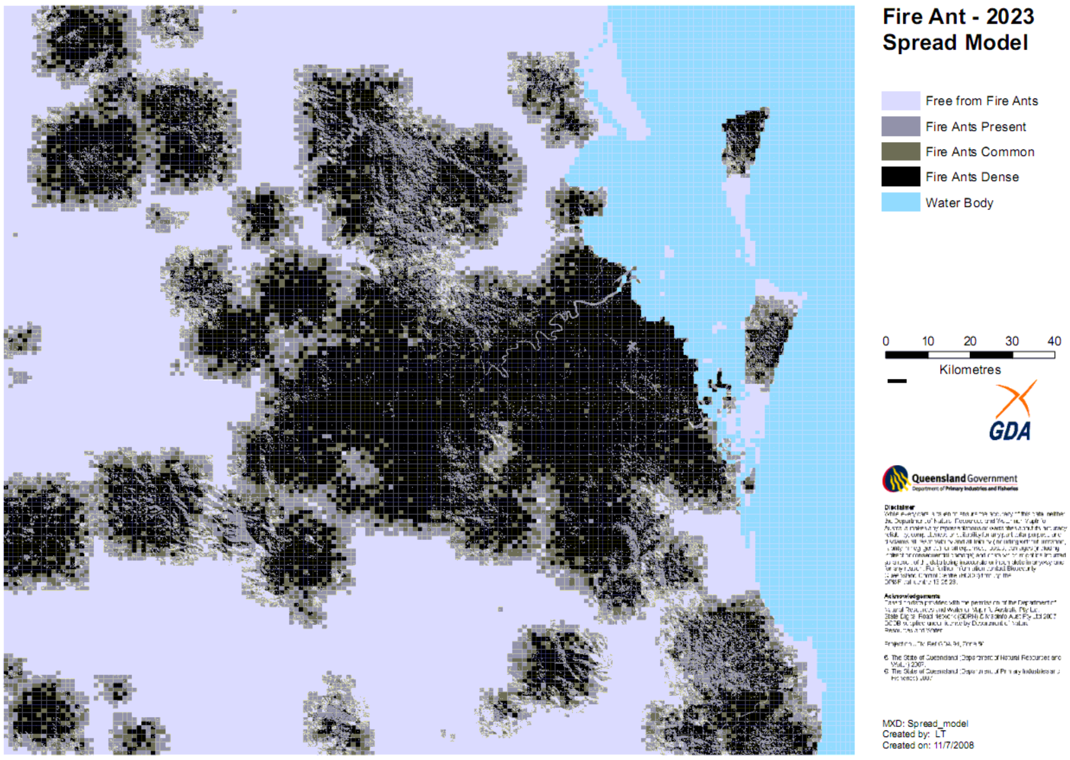

Figure 2 Modelled expected spread of RIFA in 2023

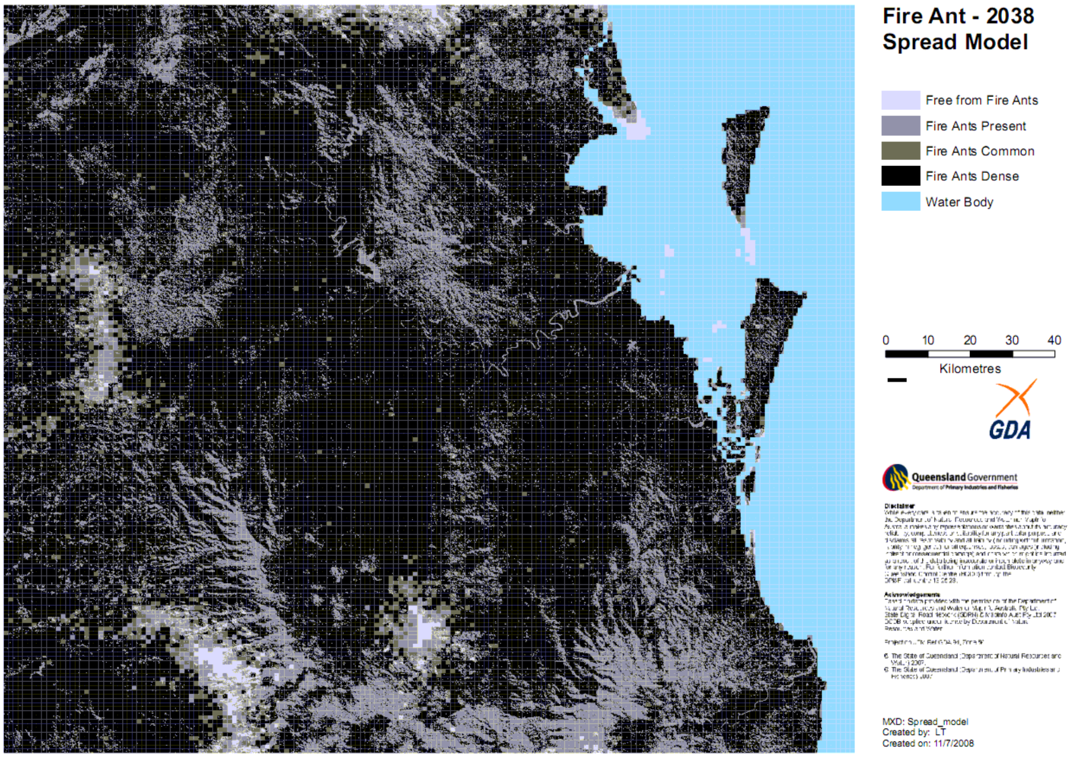

Figure 3 Modelled expected spread of RIFA in 2038

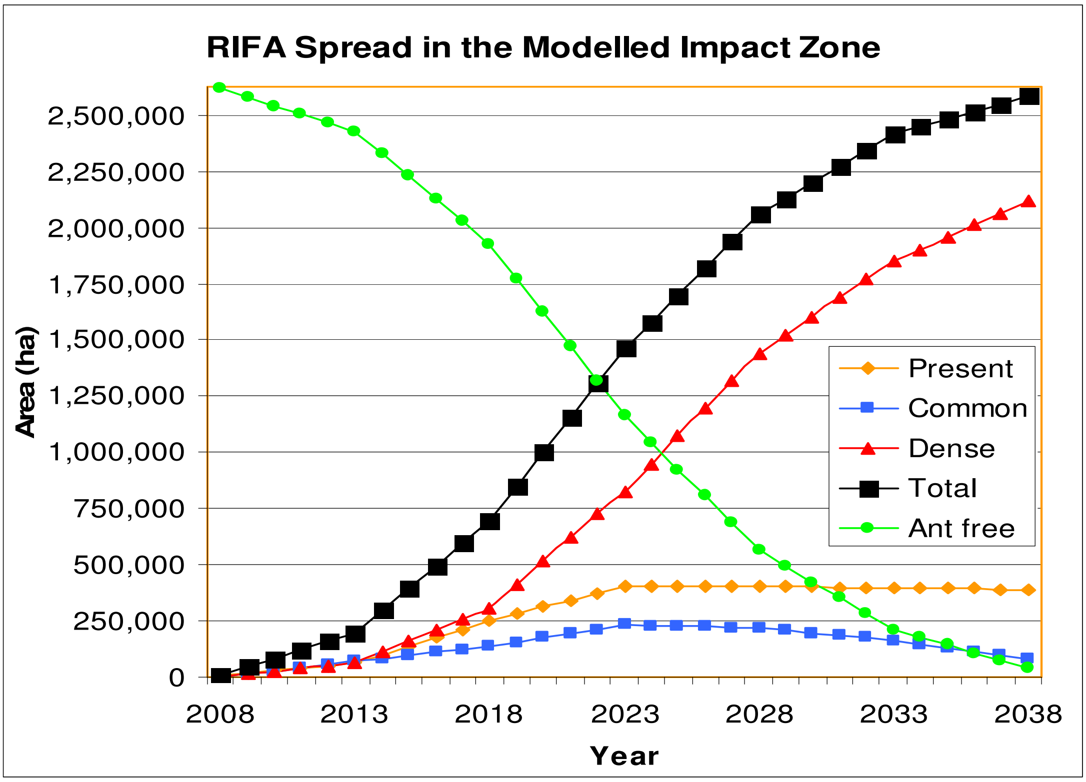

Figure 4 Modelled areas of RIFA spread 2008 to 2038

While it is not known how much beyond the modelled zone RIFA would spread, the spread pattern suggests that it may be up to double the modelled area by year 30.

Over the last seven years, long-distance human-assisted spread of RIFA hasn't been a major factor. While ants have been discovered in material transported to Melbourne, they did not form a colony. This is attributable as much to reduced translocation opportunities through continuous monitoring and control, as to unfavourable conditions for the establishment of translocated ants. If further control measures were abandoned, the probability of human-assisted translocation would once again increase. However, long-distance human-vectored transmission is purely a matter of chance that cannot be predictively modelled. Hence, spread modelling for the revised analysis used natural means of spread only. This, and the limited size of the zone, results in a substantial underestimate of the predicted spread.

4 Direct social impacts of RIFA

This section develops quantitative forecasts for the impact of RIFA on land areas used by residential dwellings, agriculture, parks and recreation and schools. From that information, predictions are made about the potential extent of economic cost incurred in the non-systematic suppression of RIFA, and dealing with its impacts, in the absence of eradication. The range of potential impacts is much wider than those enumerated in this analysis, hence the impact figures must be considered an underestimate. This section constitutes essentially an update of Kompas and Che's (2001) analysis. Single-figure estimates of the most likely expected values are used, and no sensitivity analysis is carried out on these values.

4.1 Treatment and spray rates

This analysis, like the ABARE's in 2001, assumes that uncoordinated private treatment has a negligible effect on the overall spread and eradication of RIFA.

The costs of nest injections were used as the proxy of RIFA control in the absence of eradication. Treatment rates were quoted by Amalgamated Pest Control in Gladstone, and projected using the future density suggested by the spread model. This analysis assumes that as RIFA spread and become more common, they will be increasingly difficult to eradicate, despite regular treatment.

While baiting is a cheaper form of control for higher nest densities, it is quite likely that RIFA may become resistant to current control methods, and other, potentially more expensive methods will have to be found.

Generally, it is assumed that the costs of direct impacts on society are proportionate with those of spraying.

Table 1 RIFA treatment costs per hectare

Time period	Average nest numbers nests/ha	Yearly treatment costs $/ha
2008-10	1	83.58
2011-13	2	143.28
2014-16	3	214.92
2017-19	4	238.80
2020-22	5	298.50
2023-25	6	358.20
2026-28	7	417.79
2029-31	8	477.60
2032-34	9	537.30
2035-38	10	597.00

Treatment costs for residential households amount to one-tenth of the above figures at the assumed residential density of 10 dwellings per hectare. RIFA density data were generated for the years 2008, 2013, 2018, 2023, 2028, 2033 and 2038 in the spread model. The data for the periods in between were derived using linear interpolation.

4.2 Residential impacts

Calculating total dwellings impacted by RIFA

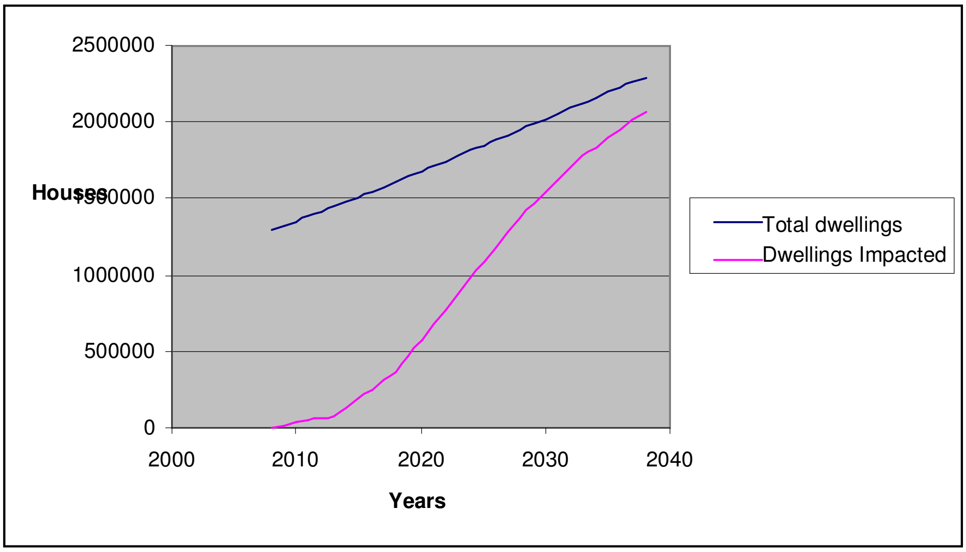

Figure 5 Residential dwellings impacted by RIFA

Dwellings Impacted= ({Total dwellings * % area impacted} / Total area impacted) **–** [({Total dwellings * % area impacted} / total area impacted) * density of residential impact/ density of total impact]

HI = ({TH* %AI}/TAI) – [({TH* %AI}/TAI) * DRI/DTI]

The trend for the total number of dwellings was derived from data in the 2006 Census on the number of dwellings and house approvals over the period 1998-2006. The same trend was assumed to continue for the duration of the impact analysis.

Calculating total hectares of residential land impacted by RIFA

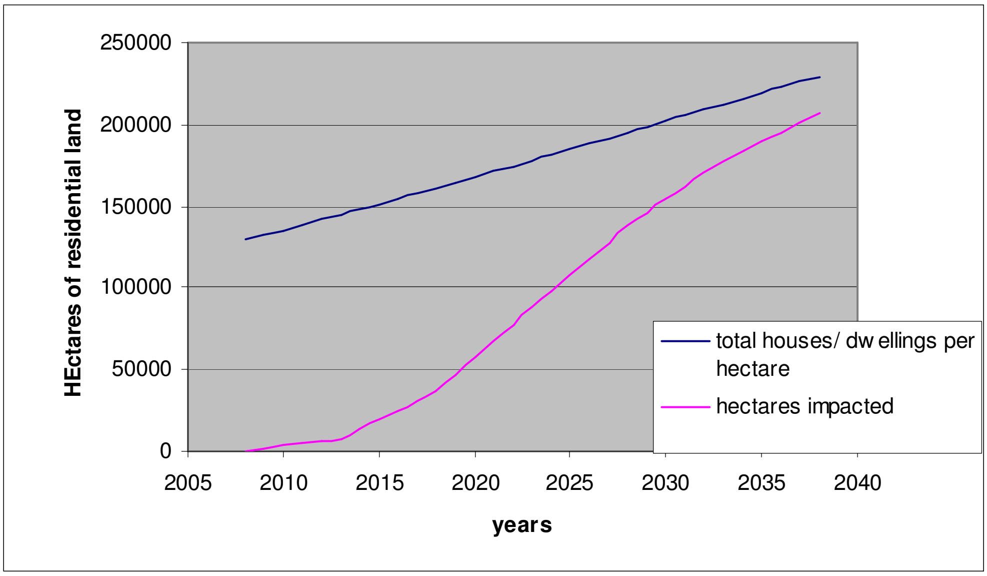

Figure 6 Residential land area impacted by RIFA

Hectares Impacted={ ({Total houses * % area impacted }/ Total area impacted) – [({Total houses * % area impacted }/ total area impacted) * density of residential impact/ density of total impact]}/dwellings per hectare

HI = {({TH* %AI}/TAI) – [({TH* %AI}/TAI) * DRI/DTI]}/dwellings per hectare

The average dwelling was assumed to occupy an area of 1/10 ha. This figure was kept constant for the duration of this analysis.

Dwellings treated for RIFA

It is expected that the proportion of dwellings treated for RIFA may increase as time passes. This is due to the primary infestation of fire ants being in Brisbane's south-west suburbs, typically categorized by households with lower financial means. The RIFA spread model assumes that as time passes, fire ants will eventually disperse to metropolitan regions of Brisbane, where residents are more likely to have the capacity to pay for fire ant eradication services. It was estimated that 60% of households would initially pay to eradicate RIFA in 2008. As RIFA spread to metropolitan regions, this figure was estimated to grow to 80% by 2038. It is also foreseeable that the number of people treating RIFA would increase as the problem receives more attention and worsens.

Impact on property values

Kompas and Che (2001) assumed a reduction in property values due to RIFA. For this study, interviews were conducted with real-estate agents in infected suburbs of the Brisbane agglomeration. They were unanimous in the opinion that there has been no perceptible difference in property values due to RIFA infestation.

4.3 Health impacts

It is assumed that the source of ant stings is households remaining untreated. To arrive at the yearly cost of treating stings, the number of untreated dwellings is multiplied by half the amount it costs to treat a dwelling in a given year, reflecting the ant density in Table 1. This is based on the consideration that if a household decides not to control RIFA, the perceived cost of ant infestation (including health costs and reduced lifestyle values) is less than the cost of chemical treatment of a residence.

4.4 Agricultural impacts

Calculating total hectares of agriculture impacted by RIFA

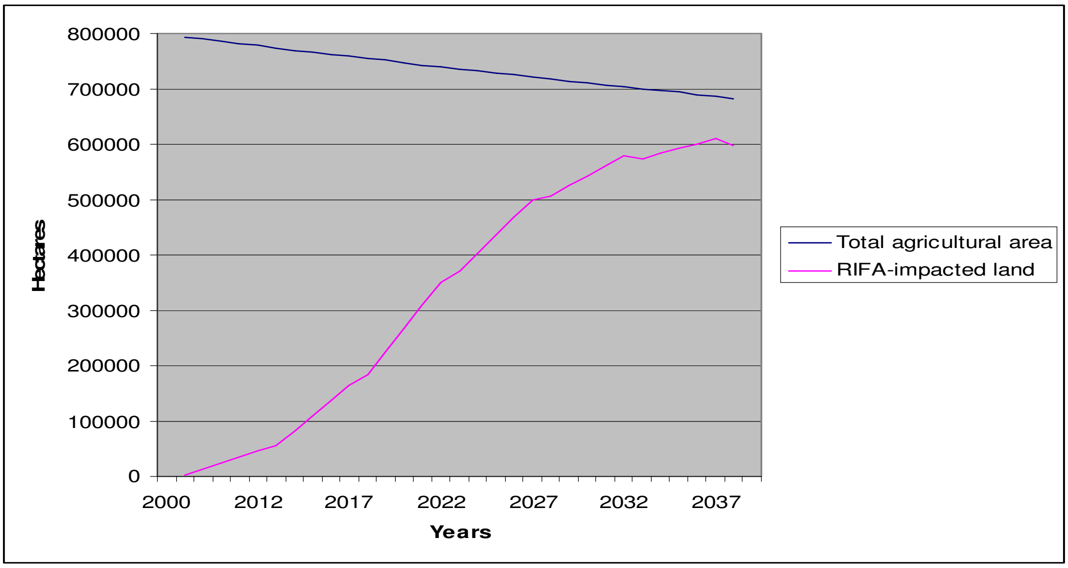

Figure 7 Agricultural land area impacted by RIFA

Agriculture Impacted (ha) = ({Total Agriculture * % area impacted }/ Total area impacted) - [({Total Agriculture* % area impacted }/total area impacted) * density of agricultural impact/ density of total impact]

AI= ({TA* %AI}/TAI) – [({TA* %AI}/TAI) * DAI/DTI]

The total area allocated to agriculture in South East Queensland is assumed to decline from 793,241 ha in 2008 by 0.5% per annum.

It is assumed that 100% of impacted agricultural land will be treated on an annual basis. Although treatment costs are large at high densities, evidence from the US indicates large potential for crop losses and impacts on agricultural workers. Thus, if agricultural establishments decide not to treat their land, they may well incur losses of similar magnitudes anyway, either from crop/stock losses or the opportunity cost of abandoning land.

4.5 Impacts on parks and recreation areas

Calculating total hectares of parkland impacted by RIFA

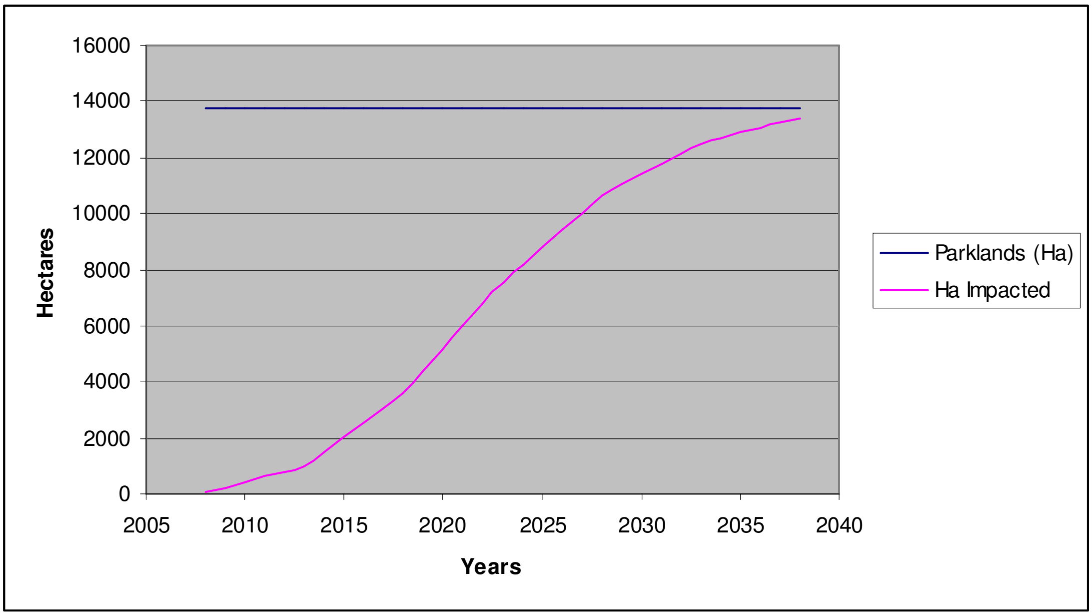

Figure 8 Parks and recreational land area impacted by RIFA

Parklands Impacted (ha) = ({Total Parklands * % area impacted} / Total area impacted) - [({Total Parklands impacted * % area impacted }/total area impacted) * density of parkland impact/ density of total impact]

PI= ({TA* %PI}/TAI) – [({TA* %PI}/TAI) * DPI/DTI]

Data for public parks and recreation areas were obtained from Brisbane City Council. This area was projected to the whole RIFA impact zone in proportion to population outside the land managed by Brisbane City Council.

Unlike the scenario in residential regions, it is assumed that 100% of impacted parklands will be treated, due to liability implications of not doing so. This is also a reflection of the fact that an outdoor lifestyle is an essential part of Australian social life, and its protection would be attempted even at a high cost.

4.6 Impacts on schools

Calculating the land occupied by schools impacted by RIFA

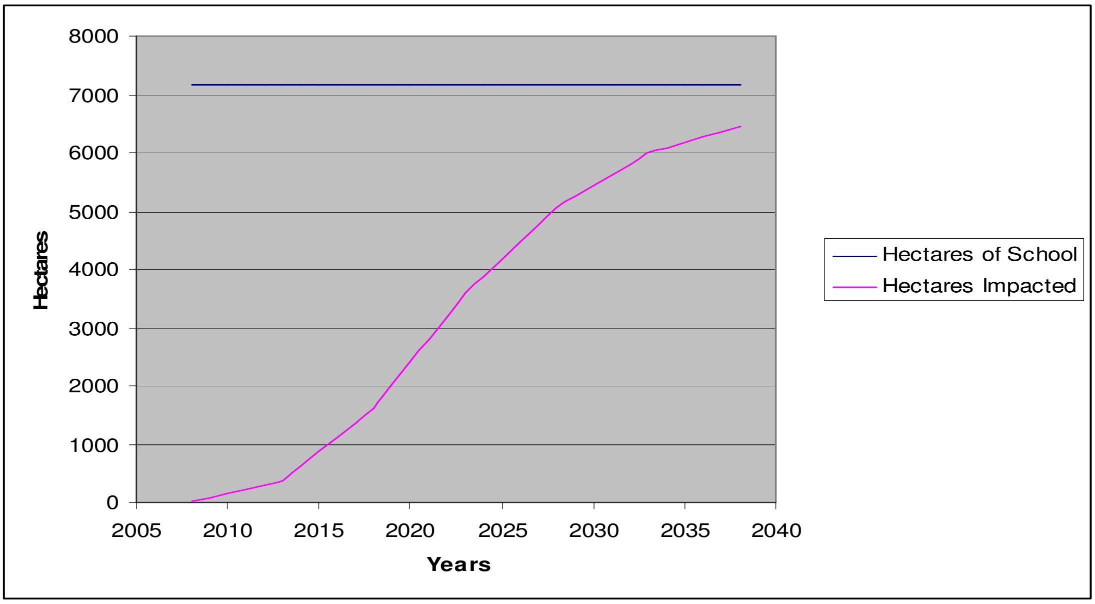

Figure 9 School land area impacted by RIFA

Schools Impacted (ha) = ({Total Area of Schools * % area impacted }/ Total area impacted) - [({Total Area of Schools impacted * % area impacted }/total area impacted}) * density of school (residential) impact/ density of total impact]

PI= ({TA* %SI}/TAI) – [({TA* %SI}/TAI) * DSI/DTI]

The total hectares of schools was calculated by determining the average number of hectares per school and multiplying that figure by the total number of schools in South East Queensland. The number of schools in South East Queensland was estimated to be 1192. This was found by scaling down the number of schools in Queensland (obtained from Education Queensland) in proportion with SEQ's share of the Queensland population.

Although population numbers are projected to grow in the RIFA impact zone, school numbers are kept constant in this study, on account of ongoing amalgamations and a general aging of the population.

The area of each school was assumed to be 6 ha. This is equivalent to approximately three football fields. The density of the RIFA spread in schools was assumed to be in proportion with the density spread in residential areas. It is expected that all schools are treated against RIFA regularly.

5 Environmental impact valuation

5.1 Expected RIFA impact on the environment

There is much evidence of the environmental effect of RIFA in the United States. Due to the control measures in Queensland, applied relatively soon after introduction, RIFA could not build up sufficient numbers in environmentally sensitive areas. This limits the extent of direct evidence of RIFA's damage to Australian ecosystems. Instead, studies were trying to predict impact on the basis of overseas evidence and the workings of Australian ecosystems (Moloney and Vanderwoude 2002, Greenland 2003).

While there are a number of endangered species within the 30-year impact area, none of them are restricted to that area. No sighted reference has raised the potential of species extinction due to RIFA within the expected extent of spread during the 30-year time scope of this analysis. Therefore, no extinction is likely within the accounting period of this study due to RIFA incursion.

Instead, RIFA's impact is likely to be more graduated and, thus, difficult to assess. Ecosystem impacts will occur in a number of subsequent rounds:

- *Primary*: reduction of biodiversity and thus compromised ecosystem functions due to RIFA replacing some local species and hampering the activities of others
- *Secondary*: "collateral" impact of control measures on species other than RIFA, assuming that RIFA become resistant to the current low-impact bait
- *Tertiary*: potentially poor restoration of ecosystems cleared of RIFA and other species

While there are a number of national parks in the impact zone, no specific reference could be found to how and to what extent their values would be compromised by being overrun by RIFA. Also, some wetter and higher-lying areas within those national parks are unlikely to be suitable environments for the establishment of RIFA. Thus, significant areas of natural values may never be subject to RIFA impact in SEQ and perhaps in northern NSW. Nevertheless, RIFA is expected to alter ecosystems in much of the impact zone. It is likely to reduce biodiversity in most locations, and thereby affect ecosystem processes.

5.2 Approaches in environmental impact valuation

Incorporation of the environmental impact of invasive species in an economic assessment framework, such as cost-benefit analysis, requires the quantification and valuation of those impacts in a way that is compatible with the valuation of traded goods and services. This means valuation in dollar terms, something that is still not without controversy but is by now a standard method.

Valuation is becoming routine, based on the concept of society being willing to pay for a basket of physical and nonphysical, traded and non-traded goods and services. Non-market valuation of the non-traded good and services, particularly contingent valuation, is the best known, but not only, technique. Table 2 summarizes the range of methods available.

Table 2 Environment valuation techniques

	Use values		Non-use values			Use & non-use values
	Direct evaluation	**Indirect evaluation**	**Direct evaluation**	**Indirect evaluation**		
	Financial valuation	*Economic valuation*	*Simulated market methods*	*Conventional market methods*	*Substitute / related market methods*	
Cardinal, monetary evaluation techniques	Market pricing	Shadow pricing	Contingent valuation Dichotomous choice method Choice modelling (= polychotomous choice method)	Dose-response techniques Replacement cost technique Cost-avoidance or damage cost	Hedonic pricing Travel cost method Household production functions Benefit-transfer methods	
Ordinal, non-monetary evaluation techniques			Contingent ranking/rating			Multi-attributed indices Multi-criteria analysis (née scoring models) Qualitative approaches

The environmental impact most conducive to valuation is the extinction of a native species, as there is evidence about the perceived loss from countries with similar cultures, income levels and social preferences to those of Australia. This allows relatively simple benefit transfer whose implications can be expected to be close to Australian social preferences. However, such an outcome is not expected for RIFA in the modelled impact zone for the period of the analysis. Hence, the more subtle environmental impact needs to be assessed.

Environmental values go beyond environmentally sensitive, protected areas. Ecosystem functions are essential for life even in such highly artificial environments as urban centres. Ecosystem goods (eg wild-gathered food and materials) and services (eg, nutrient cycling, recreational values), together referred to as ecosystem services, are of direct and indirect benefit to humans. This is a utilitarian, anthropocentric approach that gets around the philosophical arguments about the intrinsic, hence unquantifiable, values of ecosystems. Since the practical assessment of ecosystem services uses Total Economic Value as its measurement device, it does include, among others, social perceptions about the existence value of ecosystems. At the same time, as it is compatible with conventional financial/economic analysis, it provides a basis for comparison, valuation and priority setting.

In their seminal study, Costanza et al. (1997) have put the value of 17 selected services provided by ecosystems in 16 of the world's biomes at $16-54 trillion, against the total world GDP at the time of $18 trillion. Their method was further developed in the extensive Millennium Ecosystem Assessment conducted under the aegis of the United Nations (MEA 2003).

A recent study by Costanza et al. (2006) estimated the value of ecosystem services produced within the state of New Jersey, pooling numerous studies that used the methods in Table 3. They have estimated the total value of ecosystem services at US$19,803/acre on average across all the ecosystems of the state:

Table 3 Total Annual Ecoservice Values in New Jersey

Ecoservice	Value 2004 US$/yr/A	Share per cent
Nutrient cycling	5,074	25.6%
Disturbance regulation	3,383	17.1%
Water regulation	2,433	12.3%
Habitat/refugia	2,080	10.5%
Aesthetic/recreational	1,999	10.1%
Waste treatment	1,784	9.0%
Water supply	1,739	8.8%
Cultural/spiritual	778	3.9%
Gas/climate regulation	246	1.2%
Pollination	243	1.2%
Biological control	35	0.2%
Soil formation	8	0.04%
Totals	**19,803**	**100%**

Source: NJDEP (2007)

An assessment of the goods and services provided by SEQ ecosystems is under way as part of the research activities aimed at the SEQ region (SEQC 2008). Initial project outputs include the preparation of a register of ecosystem services and their GIS matching to specific ecosystems. At the time of writing this report, the SEQ Ecosystem Services project is not sufficiently advanced to be relied on for valuing the impact of RIFA in the region.

The only option available for this study was to transfer the findings of the New Jersey ecosystem services assessment to the RIFA impact zone. The map presented by Costanza

(1997) indicated that the RIFA impact zone has overall ecosystem values (in terms of providing ecosystem services) at least as high as those of New Jersey.

Average values for New Jersey were applied to the RIFA impact zone, without distinguishing between land-cover types. For the various types of ecosystem services, a subjective assessment was made as to the extent of RIFA impact: either light or heavy. Similarly, a subjective assessment was made as to the extent of loss in ecosystem services under the three degrees of RIFA presence: present, common and dense. These assumption are summarized in Table 4. Values from Table 3 were updated to 2008 US dollars through the application of US inflation rates of the intervening years, then converted to Australian dollars with an exchange rate of US80c/A$ and expressed on a per-hectare basis.

At the suggestion of peer reviewers, an adjustment has been made on account of differences in capacity to pay between the US and Australia, as well as New Jersey and the RIFA impact zone[4]. Australia's per-capita GDP is around 79% of that of the US at purchasing-power parity (IMF 2008). While the land area of New Jersey (22,500 km^2) is comparable to that of the RIFA impact zone, the latter has only 32% of New Jersey's population. Thus, even with comparable social preferences, the potential "budget" in SEQ for "buying" ecosystem services is around one-quarter of that in New Jersey.

A subjective assessment of the extent of RIFA impact was made on specific ecosystem services, corresponding to the extent of ant infestation. The implied values are shown in Table 4.

Table 4 Assumed ecoservice values and losses in the RIFA impact zone

Ecoservice	A$/ha 2008	RIFA impact	Loss at RIFA infestation of		
			Present	Common	Dense
Nutrient cycling	4446	light	1%	2%	5%
Disturbance regulation	2964	heavy	2%	10%	50%
Water regulation	2132	light	1%	2%	5%
Habitat/refugia	1822	heavy	2%	10%	50%
Aesthetic/recreational	1751	heavy	2%	10%	50%
Waste treatment	1563	light	1%	2%	5%
Water supply	1524	light	1%	2%	5%
Cultural/spiritual	682	heavy	2%	10%	50%
Gas/climate regulation	216	light	1%	2%	5%
Pollination	213	light	1%	2%	5%
Biological control	31	heavy	2%	10%	50%
Soil formation	7	light	1%	2%	5%
Totals	**17,350**		**246**	**927**	**4130**

Multiplying the assumed per-hectare loss figures in Table 4 by the hectares of spread for each year, one may calculate approximate values of ecosystem-service loss over time.

The numerical indication is that a dense infestation of RIFA would reduce the value of annual ecosystem services by 24%, from $17,350/ha to $13,220/ha. At the modelled full spread, the annual total value of ecosystem provision in the 2.6 million ha modelled impact zone will be reduced from $45 billion to $36 billion. Discounted at a real 5% rate, the present value of losses thus calculated amounts to around $43 billion over the whole of the infected area modelled in the spread model.

[4] Feedback by Rod Strahan and John Mullen was instrumental in this correction of the earlier draft.

The reader is urged to view this figure with caution, due to the numerous assumptions and approximations used in its derivation. It is not possible to attach a standard error to this figure. Given the understatement of area in the modelling, there is an underestimation bias in the above figure, in addition to the general uncertainty. A sensitivity analysis was carried out, applying -50% and +50% variations to the loss parameters in Table 4. This gave a range of total discounted values of potential environmental values of $31 billion to $55 billion, around the expected value of $43 billion.

6 Summary and conclusions

The key to assessing ecosystem values lost to RIFA in the modelled impact zone is benefit transfer. The original values were for a US ecosystem that is less productive than that of the RIFA impact zone, and assessed for a society whose environmental preferences are similar to Australia's. Subjective measures of the RIFA impact on specific ecosystem values were used to discount the transferred ecosystem-service values according to the expected spread of the ants. The present value of RIFA damage in the modelled impact zone has an indicative figure of around $43 billion dollars, with an unknown error margin. This figure would be significantly higher if spread outside the impact zone were also considered. The flows of undiscounted costs and benefits of RIFA eradication within the modelled impact zone are shown in Figure 10 (note that the environmental benefits are off the scale).

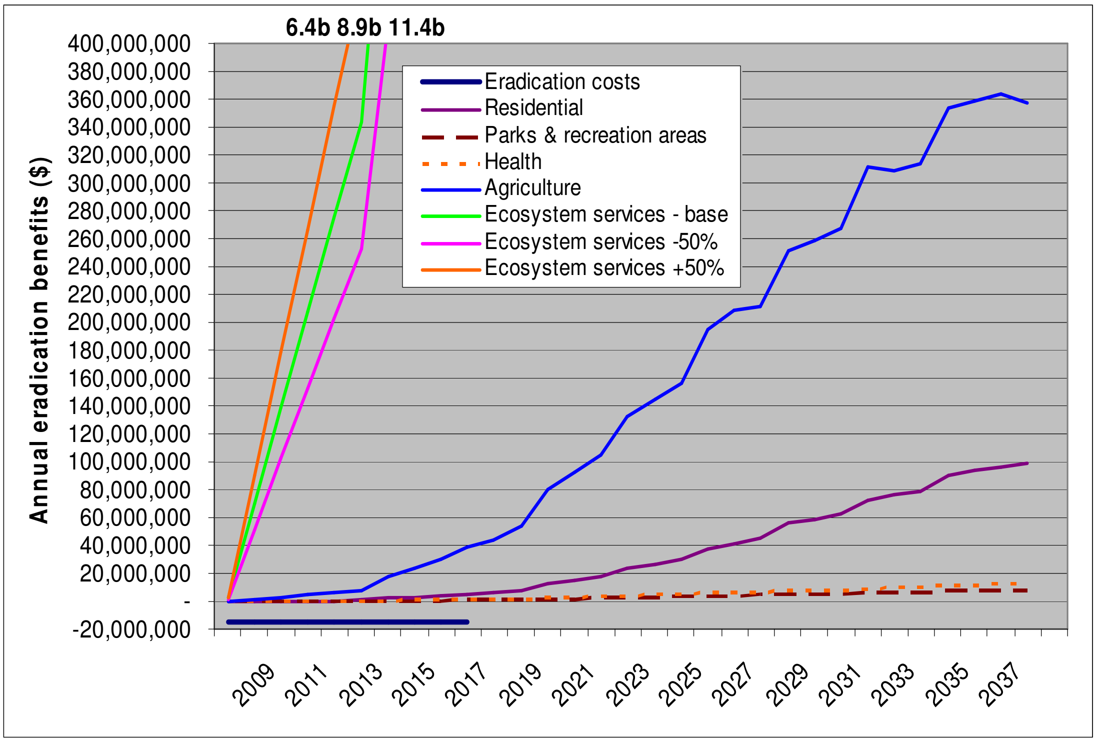

Figure 10 Flows of undiscounted costs and benefits of RIFA eradication

The revised figures are significantly higher than Kompas and Che's original damage estimate: the expected present value of avoided costs is increased from $2.8 billion to $45 billion, and the benefit-cost ratio from 25:1 to 390:1. Alternative values for the ecosystem-service loss parameters change the overall outcomes as follows:

	Most likely ecoservice loss	-50% ecoservice loss	+50% ecoservice loss
NPV	$45 billion	$33 billion	$57 billion
BCR	390:1	289:1	496:1

These large potential impact values, even within a wide envelope of uncertainty, further reinforce the economic case for eradication.

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