PRATIQUE

Deliverable 5.2

A protocol for the cost: benefit analysis of eradication and containment measures during outbreaks

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PROJECT OVERVIEW: PRATIQUE is an EC-funded 7th Framework research project designed to address the major challenges for pest risk analysis (PRA) in Europe. It has three principal objectives: (i) to assemble the datasets required to construct PRAs valid for the whole of the EU, (ii) to conduct multi-disciplinary research that enhances the techniques used in PRA and (iii) to provide a decision support scheme for PRA that is efficient and user-friendly. For further information please visit the project website or e-mail the project office using the details provided below:

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SUMMARY

CBA PROTOCOL: Key steps in conducting a Cost Benefit Analysis of one or more scenarios for the control of a pest

Table 1 provides an overview of the key steps of a CBA. On the following pages, a brief description of each step provided.

Step	*Task*	*Outcome*
1	**Define the problem in terms of:**	
1.1	Purpose	Objective, e.g. one or several control measures, one or several scenarios
1.2	Perspective	Level of analysis, e.g. society or individual stakeholder groups
1.3	Scope and scale	Horizontal (spatial) and vertical (supply chain) system boundaries
1.4	Time	Time horizon of the analysis
2	**Define the baseline scenario**	
	Set the default or reference situation	Baseline scenario relative to which the cost-effectiveness of alternative scenarios is expressed
3	**Select control scenarios**	
3.1	List available control options	Overview of potential control measures; depends on objective and pest
3.2	Select appropriate control options	List of feasible and cost-effective measures (filtered from output of 3.1)
3.3	Define scenarios	One or several scenarios including the control measure(s) identified in 3.2
4	**Predict the effects of each control scenario**	
	Describe expected effects on the pest	Effects of each scenario on the pest, in terms of incidence, spatial distribution, etc.
5	**Estimate Costs and Benefits of each control scenario**	
5.1	Identify costs and benefits	List of changes in costs and benefits resulting from each scenario
5.2	Estimate direct costs and benefits	(Avoided) costs of applying the control measure(s), e.g. costs of pesticides, monitoring costs, reduced yield loss
5.3	Estimate indirect costs and benefits	(Avoided) costs of second level effects, e.g. effects on environment, trade, or tourism
6	**Consider the time aspect of costs and benefits**	
6.1	Determine period in which costs and benefits occur	Specification of costs and benefits over the period covered by the CBA
6.2	Discount annual costs and benefits	Costs and benefits expressed as present values in the base year
7	**Calculate decision criteria**	
	Quantify the overall cost-effectiveness of each scenario	Cost-effectiveness of each scenario expressed as e.g. NPV, B/C ratio, payback period
8	**Perform a sensitivity analysis**	
	Determine the effect of changes in key variables on outcomes	Insight into robustness of outcomes to assumptions and uncertainties
9	**Report on CBA**	
	Describe the CBA in terms of methodologies, assumptions etc.	Report in which the CBA is documented

1 Define the problem

Specify the problem in terms of:

1.1 Purpose

Is it to compare the costs and benefits of a single, proposed response to a pest or to compare the net benefits, or net costs, of a range of control options? In other words, which strategy is the most cost-effective?

1.2 Perspective

Is it in terms of costs and benefits to different stakeholders (particular individuals, businesses, groups, industries or sectors of the government) or from the perspective of the national economy and to society as a whole?

1.3 Scope and scale

Is it in terms of the supply chain (to the farm gate or business door only, inclusive of effects on upstream and downstream industries and related sectors) or extending throughout the economy?
Is the analysis conducted at a local, national or international scale?

1.4 Time

Is it performed over a number of days, months, years? What is the time horizon; when does the campaign start and when does it end?

2 Define the baseline scenario

This is usually the status quo position (i.e. no change in policy, no intervention or a minimum level of intervention) and normally reflects conditions in the absence of the control options.
All options should be assessed relative to the same baseline scenario.

3 Select control scenarios

3.1 List the available control options

These will depend on the objective (e.g. prevention, eradication, suppression) and the type of pest (e.g. insect, plant, nematode).

3.2 Select appropriate control options

If necessary, make a selection from the list resulting from step 3.1 on the basis of expected (cost-)effectiveness and feasibility [To assist with this task, please refer to the Decision Support Module, Deliverable 5.3].

3.3 Define scenarios

Define one or several control scenarios you wish to compare. Each scenario may include a single control option or a combination of several measures.

4 Predict the effects of the different control scenarios

Describe the expected effects of the control measures on the pest, such as changes in pest or disease incidence (including any change in impacts or effects) over the specified time period for each scenario. Even if these are based on assumptions, it is important to make them explicit.

5 Estimate Costs and Benefits of control scenarios

5.1 Identify costs and benefits

Estimate the changes in costs and benefits likely to occur as a result of the introduction of the management (or control) options in each scenario, compared to the baseline scenario.

5.2 Estimate the direct effects of each control scenario as costs and benefits

These include the costs of the action itself as well as the costs incurred by the application of the action(s). They may occur both on farm and at the NPPO level. Consider how estimated costs and benefits depend on pest incidence.

5.3 Estimate indirect effects of each control scenario as costs and benefits

Indirect costs include second level effects such as the indirect effects of pesticides on the environment, effects on trade of agricultural commodities, or effects on tourism and recreation. It may be sufficient to qualitatively estimate such costs

6 Consider the time aspect of costs and benefits

6.1 Determine the period in which costs and benefits occur

When do the costs and benefits related to the control measures (i.e. pest management) commence and how do they develop over time? Estimate full annual costs and benefits for each control scenario as a time series, combining the results of steps 4 and 5.

6.2 Discount annual costs and benefits

Discount annual cost and benefit values to present values in the base year. At present discount rates of 4-5% are commonly used.

7 Calculate decision criteria

Calculate one or more decision criteria (e.g. NPV, B/C ratio, payback period) using present values. Evaluate the control scenarios on the basis of their absolute and relative (compared to other scenarios) cost-effectiveness.

8 Perform a sensitivity analysis

Test the robustness of conclusions with respect to (uncertain) assumptions and key values by varying uncertain elements individually (one at a time) and evaluating the extent to which this alters the findings of the CBA. The sensitivity analysis can be qualitative or quantitative.

9 Report on the CBA

Draft a report which documents the methodologies, decisions and results for each step in the CBA protocol.

INTRODUCTION

Cost benefit analysis (CBA) provides a framework for the collection, collation and presentation of data necessary to conduct an economic analysis (which may include considerations of the social and environmental impacts of plant pests'[1] introduced to an area) of the evaluation of control measures for use in a Pest Risk Analysis (PRA). However, it is often difficult for those unfamiliar with the process to know how and where to start, what to do and when to stop. The purpose of this protocol is to offer risk managers / decision makers, with limited experience of CBA, clear guidelines for collating and structuring relevant data in order for them to be able to conduct a cost benefit analysis in a consistent and transparent manner. This guidance for CBA broadly follows the approach outlined in a cost benefit analysis which was compiled by one of the authors (Mumford) for a non-native species (NZ MAF, 2002) and is in line with the procedure more recently described in Boardman *et al*. (2006). Pearce *et al.* (2006) also provide an easily accessible description of CBA basics. Supplementary advice and additional references to examples and methods used for quantification of costs and benefits are provided in an accompanying document: 'Review of literature on Cost Benefit Analysis: Technical analysis'.

COST BENEFIT ANALYSIS: A PROTOCOL

1 Defining the problem

The first step is to clearly define what you are aiming to achieve by specifying the purpose, perspective, scope, scale and time horizon of the analysis.

1.1 Purpose

What is the CBA for? Clearly define the objectives of the CBA exercise. For example, is it to compare the costs and benefits of a single, proposed response to a pest, or to compare the net benefits, or net costs, of a range of control options? In other words is the CBA to inform managers of which strategy is the most cost-effective? Appropriate decision criteria are the net present value (NPV), the cost/benefit ratio or the payback period of a management strategy (see 7).

1.2 Perspective

For whom is the CBA being done, and what do they require? Alternatively, who has to be considered and how will they be affected, e.g. will the CBA be carried out in terms of the costs and benefits to different stakeholders (particular individuals, businesses, groups, industries or sectors of the government) or from the perspective of the national economy and to society as a whole?

1.3 Scope and scale

Will it be conducted at a local, national or international (i.e. pan-national) scale? Will it examine costs and benefits in terms of the supply chain at a farm business level, e.g. that of a representative cucumber grower, or at a higher industry sector level, such as protected horticulture and will it include “knock on” (second order) effects on any other industries and related sectors or extend throughout the economy? Definitions of scope and scale depend on the region(s) threatened by the pest, stakeholders possibly affected by the pest (e.g. seed or primary producers, industry, environment), and the level at which control measures may be enforced. All CBA exercises are limited by time and expense and defining the scope of the exercise determines the area of interest and the level of detail that can be realistically achieved within the time and budgetary constraints. All necessary assumptions should be transparent and clearly described for the chosen scope.

1.4 Time

The time horizon considered within the CBA can be organism-dependent, since, without control measures, pests differ in terms of the amount of time that occurs before potential damage or loss occurs. This variation occurs as a result of differences in the rate of damage expression and geographical spread. For example, it may be many years before the impacts on forest trees by plant pathogens such as *Phytophthora cinnamomi* or *P. ramorum* become obvious, whereas, in the case of a pest on a rapidly growing seasonal crop, such as *Tuta absoluta* on tomato, crop losses are immediately apparent. Thus, it is necessary to take account of these different time periods when evaluating the impact of the applied measures, and an appropriate time scale should be defined at the start of the CBA.

2 Define the baseline scenario

Costs and benefits in a CBA can only be estimated in comparison to a defined reference system or baseline scenario. This is usually the status quo position (i.e. no change in policy, no intervention or a minimum level of intervention) and reflects conditions in the absence of specific control options. However, in the special case where CBA is used to estimate the consequences of deregulating a pest, the baseline would include costs of current control / management measures and an important scenario to be examined would be the impacts if statutory action were to cease and hence save regulatory costs. If the CBA is part of a PRA, it is recommended to use the impact assessment as the baseline scenario. In a situation involving the (unforeseen) introduction of a pest species into an agricultural, horticultural or forestry situation, a PRA may not be available yet. In such a case, the baseline scenario would usually be assumed to be the outcome under the current best practice in that sector. In other words, no official (quarantine) measures are in place and growers would only be applying control measures to avoid losses caused by existing pests. This assumption implies that no 'extra' expense has yet been taken to control the pest within the PRA area, although the management of many crops may involve standard pest management procedures such as pesticide applications, crop rotations and so on, that may exert some level of control on a newly established pest. It is important to consider the estimated level of control on the pest imposed by the pre-existing pest management methods – together with the costs associated with this – so that the additional costs of more specific, or targeted, control measures against the new pest can be correctly incorporated at the 'Cost estimation' stage of the analysis. The baseline scenario for control in many hosts is only likely to be zero in situations where:

a. no control methods are currently used to control other pests, e.g. in broadleaf amenity woodlands, or where there are alternative hosts that have no intrinsic commercial value; or
b. controls used on other pests have no impact on the losses caused by the pest under consideration.

3 Select control scenarios

3.1 List the available control options.

Options may include measures aimed at prevention, eradication, containment control or no action. The 'available options' will vary according to the objective and the pest in question (see Box 1 for examples). For instance, if the aim is to eradicate Western corn rootworm, *Diabrotrica virgifera virgifera* LeConte, available actions include different combinations of pesticide applications (adult control or larvae control), crop rotation and movement controls. A combination of mechanical, chemical, cultural and phytosanitary control measures may be needed to achieve the ultimate goal of eradication. Alternatively, if the objective is to analyse the cost-effectiveness of a single action, only one option is selected (possibly with variations, e.g. inspection using different sample sizes). Management options for different types of species are provided in the risk management module (see the Decision Support Scheme, WP 5.3).

3.2 Select appropriate control options

If the previous step results in a long list of control options, it may be necessary to make a selection of those that seem the most appropriate. Collect information on the following: the effects of the different options on the pest, their probable usefulness in achieving the aim of prevention, their probable acceptability by stakeholders and the time needed for success. If necessary, consider the most appropriate control options for detailed consideration: a single proposed response, a range of control options or combinations.

Appropriate control options are selected on the basis of two criteria:

a. (Cost-)effectiveness. At this stage, a rough screening is sufficient.

b. Feasibility. Before selecting a control measure for its cost-effectiveness, it is necessary to evaluate whether its implementation is a realistic and practical option. (Note: the feasibility of control options is addressed in more detail in the Decision Support Scheme, Task 5.3).

3.3 Define scenarios

Define one or several scenarios, which you want to compare with the baseline scenario. Each scenario may include a single control measure or a combination of several measures. The scenarios may also include the same set of measures, but vary in terms of implementation (e.g. they might differ in terms of the frequency of pesticide application or monitoring intensity).

For policy makers, it may be sufficient to describe the chosen action in general terms, e.g. eradication via physical control (manual removal and burning of infested or invasive plants); or containment via biological control (biological control agents). In this case, it may be useful to include an estimate of the time needed for success in order to help decide which management method should be used.

4 Predict the effects of the different control scenarios

What are the effects of each control scenario over a specified time period? The effects of control on pest or disease presence are often more or less 'ignored' in CBAs. This is because such information is often lacking, so managers are frequently obliged to make assumptions which are not always made explicit. However, it is important to explicitly describe the expected effects of control measures on the pest (including any change in impacts or effects) in order to justify estimated costs and benefits and interpret the results of a CBA correctly. The robustness of the conclusions from a CBA with respect to these assumptions should be evaluated by qualitative or quantitative sensitivity analysis (see below).

Depending on the decision criteria, it is possible to predict:

a. Pest or disease incidence for all scenarios including the baseline (decision criterion: lowest total losses) or
b. The *reduction in* pest or disease incidence for all control scenarios *relative to* the baseline scenario (decision criterion: highest benefit/cost ratio).

Pest or disease incidence should be described in time and space, using the most appropriate indices (e.g. hectares, number of glasshouses, fields, or lots infested) and consider the entire period and area for which the CBA is done. In particular cases, it may also be relevant to estimate pest density at infested units (e.g. percentage of plants with disease symptoms; numbers of insects per plant; numbers of invasive weeds per unit area, or at a larger scale the percentage of farms or regions infested could be estimated). Population density is an important parameter in outbreaks where control measures may suppress the population of a pest to a size at which damage is avoided or greatly reduced. Within the phytosanitary arena, the aim is often eradication or containment of a quarantine pest; but for some quarantine pests suppression (e.g. significantly slowing the spread) may still be beneficial and cost-effective.

5 Estimate Costs and Benefits of control scenarios[2]

5.1 Identify costs and benefits

In a CBA of quarantine plant pests, costs and benefits are estimated in terms of the changes likely to be caused by the introduction of the pest management options envisaged in each scenario, compared to the baseline scenario.

a. Costs of pest management options are the additional costs that occur due to the introduction of the measures.

b. Benefits of pest management options are usually the avoided costs (i.e. the estimated losses or impacts) induced by the pest of concern, compared to the baseline scenario. Therefore the data for benefit estimation can be derived from the impact assessment part of the PRA.

If costs and benefits are assessed in absolute terms, i.e. not relative to the baseline scenario, the losses in each scenario should be included under costs. In that case, scenarios are compared for their total costs and the benefit of a scenario would be the lower cost of that scenario (if a difference is estimated).

Costs of a scenario	*Benefits of a scenario= “avoided impact”*
• *Costs from direct effects of control measures: growers’ level (e.g. control costs or yield losses) and NPPO level (e.g. monitoring costs) (see 5.2 and table 1)*	• *Avoided costs arising from direct effects of pest presence: e.g. avoided yield loss, avoided costs of pest control (see 5.2 and table 1)*

• *Costs from indirect effects: e.g. effects on natural enemies, restrictions to recreation (see 5.3 and table 1)*	• *Avoided costs arising from indirect effects of pest presence: e.g. avoided market shifts (see 5.3 and table 1)*
∑ *costs in €*	∑ *benefits in €*
Result: ∑*benefits* - ∑ *costs = net benefits (NB)* *After discounting : present value benefits – present value costs = net present value (NPV)*	
Or: ∑ *benefits* / ∑ *costs = benefit / cost ratio*	

5.2 Estimate the direct effects of each control scenario as costs and benefits

The direct effects of a control scenario are those positive and negative effects (expressed in monetary terms as benefits and costs), that occur expectedly or are wanted outcomes of the introduction or deregulation of a management option. Direct effects reflect the effects of controlling a particular pest on the host plant that is to be protected. The costs of the chosen action(s) should include the costs of the action itself (including associated activities) as well as the costs incurred by the application of the chosen action. In other words, if the chosen action is removal of the host plant, e.g. trees, the costs will include the costs of cutting down trees together with the costs of removal of the dead wood, plus the loss of the tree (market and/or amenity value) and any other activities required to restore the habitat. Or, if the chosen action would require changes in the cropping system, e.g. crop rotation against *Diabrotica v. virgifera,* the losses in yields and income due to growing other crops would have to be considered as costs.

In order to determine the costs over time (see next step), it is necessary to consider how costs depend on pest incidence. A declining pest population is likely to reduce certain costs of control. What expenditure will be necessary for each scenario? How will this expenditure change as the pest population declines? Express costs in real terms where possible (N.B. real values need to be corrected for inflation, for example: if a company's revenues have increased by 4% over the previous year, but prices were [on average] 2% higher than in the previous year, then its revenues have only increased by 2% in real terms), e.g. using market values for material, labour and overheads. Indicate the extent of any on-going or subsequent variation in year-to-year expenses.

For quarantine pests the *cost of control* might include those listed in Box 2. It may be useful to separately examine the costs which will be incurred by different stakeholders, e.g. the costs to the farmers, growers, businesses or private property owners, and to the NPPO (official authority). In other words, to gain support for (or acceptance of) the selected control measures, it is important to know who is going to pay for them and who is going to benefit. In evaluating this, it is worth identifying both the private and public costs and benefits, to get an indication of the degree commitment of/from stakeholders that can be expected in a given campaign.

Some types of expenditure are worth breaking down into their unitary cost (€/unit/year or €/hectare/year). This is appropriate for costs that recur regularly (e.g. sprays) or where many similar units are required (traps). The unit cost can then be multiplied by the number or density required and the area over which they are to be applied.

To estimate *the benefit of the control scenario* (i.e. arising from direct effects, which are the avoidance or decrease of impacts), check for the availability of an economic impact assessment for the species concerned. If available, check whether the underlying assumptions of the impact assessment correspond to the baseline scenario (which usually should be the case). The benefit of the management scenarios can then be estimated as follows:

a. If the management scenario is almost or 100% efficient in avoiding the expected impact (e.g. successful eradication is possible), the benefit would be equivalent to the economic impact avoided.
b. If the management scenario is only partly efficient (e.g. suppression of the pest) in avoiding the expected impact (e.g. impact avoided by 50-60%), in this case the benefit would be equal to a proportion of the economic impact avoided.
c. If the management scenario in not efficient or successful in avoiding the expected losses, there will be no benefit from this scenario.

In circumstances where there is no quantitative economic impact assessment available, the expected economic impact for the baseline scenario must be derived from one's own estimations.

5.3 Estimate the indirect effects of each control scenario as costs and benefits

Indirect effects follow from direct effects. Whereas direct effects of a control scenario relate directly to the host plant or crop that is to be protected, indirect effects are non-host specific. They also include externalities, i.e. positive or negative side-effects, not transmitted through prices, to parties not initially involved. For example, the use of pesticides may lead to the potential loss of beneficial arthropods or have negative effects on non-target vertebrate species and human health (applicators, ground water pollution, residues *etc*.). Other examples of indirect effects are possible effects on trade of agricultural commodities, effects on crop management (e.g. change in crop rotation plan, effects on product certification), or effects on income from access fees of recreational areas. (See Table 1 and the Decision Support Scheme in Task 5.3 for more examples). Indirect effects are often, but not necessarily, borne by society as a whole. They may be difficult to identify, and might be contentious, but failing to recognise and apportion them will result in inappropriate balances of net costs and benefits from management strategy decisions (see Leach and Mumford, 2008)

What are the monetary values of each effect (i.e. the annual value of the effects of each control option)? Value the effects in real terms, allowing for any changes in unit costs over time. Calculate market values, or where available, measures of cost value (i.e. costs saved, avoided or incurred). Some effects may have no market value, or are difficult to value (e.g. ecosystem function, see also Table 1); in such cases where an accounting approach is not applicable it may be appropriate to calculate the benefit value using contingent valuation (i.e. willingness to pay or willingness to accept changes in the quantity or quality of a nonmarket resource). It may be sufficient for policy makers to briefly consider in qualitative terms whether or not there is any potential for such costs to be incurred, whereas risk managers may wish to attempt to capture such costs more precisely using environmental accounting tools such as that produced for pesticide applications by Leach and Mumford (2008). There is a growing body of literature that describes methods for valuing non-market environmental goods (e.g. Hanley & Common, 1987; Hanley, 1989; Garrod & Willis, 1999; Bateman, *et al*., 2002). Such methods can also be used to monetize impacts on such goods, e.g. see Areal & MacLeod (2007).

6 Consider the time aspect of costs and benefits

6.1 Determine the period in which costs and benefits occur

When do the costs and benefits related to the control measures commence and how do they develop over time? Determine how many days, months, or years of costs and benefits are involved. N.B. the time over which control scenarios are envisaged can vary from less than one year to over 50 years, depending on circumstances. Estimate full annual costs and benefits for each control scenario as a time series, combining the results of steps 4 and 5. For example, a chemical spray programme may involve the use of chemical(s) x, y and z, applied once or twice a week for N weeks. In the case of an on-going suppression campaign, such as the 'Slow the Spread' campaign for the introduced European gypsy moth in the USA, control measures may be applied every year until such time as the pest has spread to all available areas.

6.2 Discount annual costs and benefits

Differences in timing of costs and benefits affect their current value. To allow direct comparisons of the different options, convert annual costs and benefits to present values. Discount (annual cost and benefit) values to present values in the base year.

Present value of costs or benefits = $C_0 = \sum_{t=1}^{N} y(t) \cdot q^{-t}$

where:
q = 1+d with d = discount rate, i.e. interest rate minus inflation;
N = number of years until total potential costs or benefits will be reached;
y(t) = potential costs or benefits within the single years;
t = years
C_0 = value of total costs or benefits during number of years (N) from the point of view of today

Annual Net Present Value (Annuity) of the costs or benefits = $C_0 * (q-1)$
The annuity represents the annual costs or benefits of the harmful organism concerned within the single years.

The discount rate d reflects the rate of return that could be earned on an investment of the hypothetical money for costs or benefits in the financial markets with a similar risk. In reviewed published CBAs, discount rates of between 3.5 and 5% are common, although in practise smaller or larger values may be used within Europe. Lower discount rates have been proposed for some public good investments, such as for climate change mitigation and other broad social benefits[3]. Mumford (2001) discussed discount rates for environmental cost and benefit estimates in quarantine decisions. In the sensitivity analysis (see below) the effect of the discount rate can be estimated and can be of major influence on results, particularly for long term campaigns.

7 Calculate decision criteria

Calculate one or more decision criteria using present values. Examples of decision criteria are:

a. Net present value (NPV) provides a measure of the absolute difference(s) between costs and benefits (PV (B) – PV (C)) of each scenario and is usually the primary criterion as it indicates which option generates the largest net benefit.
b. The benefit-cost ratio (B/C ratio, total PV benefits divided by total PV costs) provides a measure of the relative difference(s) between costs and benefits. Benefit-cost ratios are often calculated in a CBA; scenarios with ratios higher than 1 are considered cost-effective, while those with a ratio between 0 and 1 are not. The B/C ratio provides additional information to the NPV as it informs about the relative investment required to realize benefits. For instance, two scenarios with a similar NPV may have a very different B/C ratio because one scenario has much higher costs (and equally higher benefits), and also the other way around (two scenarios with similar B/C ratio may have very different NPV).
c. The payback period represents the number of years required for sufficient benefits to accrue to offset the costs incurred (or the period it takes until the cumulative costs equal the cumulative revenue foregone if the costs hadn't been incurred).

Rank the control scenarios according to the chosen decision criteria and/or compare them with the baseline scenario. Control scenarios should not only be interpreted on their relative cost-effectiveness (compared to other scenarios), but also in absolute terms. For instance, minimal criteria or threshold values with respect to cost-effectiveness may have been defined beforehand, which must be met in order for any scenario to be acceptable.

8 Perform a sensitivity analysis

How sensitive are the findings to variation in the key values chosen for uncertain coefficients and variables? Particularly when little information is available for performing the CBA and many assumptions have been made, there may be considerable uncertainty. Perform a sensitivity analysis by varying uncertain elements individually (one at a time) and evaluating the extent to which this alters the findings of the CBA. A sensitivity analysis can be quantitative (e.g. by calculation or use of models, such as Monte Carlo simulation), but if the required data are lacking, qualitative analysis will also provide information. Two approaches can be applied:

a. Determine for each element the range of values over which the findings remain robust, and by default, the critical values at which the findings change significantly.
b. Determine for each element a plausible range of possible values it can take, including the worst case scenario, and evaluate whether the ranking of the scenarios will change if the value of the element changes within this range. (Usually, taking the minimum and maximum value will already provide a reasonable indication of the potential range).

Discover which particular variables are most sensitive in terms of altering the findings. Revisit previous steps in the CBA and where necessary refine the values (or modeling technique) used in the analysis. Take into account the risk attitude of the stakeholders for whom the CBA is being carried out; the option with the highest expected net benefit might not be the most preferable option if the probability of success is lower than a less risky alternative.

9 Report on the CBA

What is required by the stakeholders in terms of reporting on the CBA? Draft a report which documents the methodologies used and the main finding s of the analysis. The report can be structured by describing the choices, methodology and/or results for each step of the CBA protocol.

NOTES

1. The term ‘plant pest’ is used to refer to any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products (IPPC definition).

2. In identifying and valuing costs and benefits, it may be useful to check the impact assessment that has been done as part of the PRA (if this has been done). The impact assessment includes economic, environmental and social impacts occurring in absence of any control measures (baseline scenario). PRATIQUE has also developed the Invasive Risk Impact Simulator (IRIS) which provides risk based estimates of impact (€/year) for individual species. The benefits of control actions could be framed in terms of the proportion of IRIS estimated losses averted.

3. Monthly official discount rates of member states are regularly published by the European Commission (see, for example, http://eurlex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ-:C:2011:004:0004:0004:EN:PDF for rates of 2010). For an example of discounting public good investments, see http://webarchive.nationalarchives.gov.uk/+/http://www.hmtreasury.-gov.uk/stern_review_report.htm.

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TABLES & BOXES

Box 1. List of management methods for different types of invasive organisms

Types of measures, for unintentional introductions and invasions of unintended habitats by intentionally introduced species:

Terrestrial Invertebrates

- physical control (trapping, host destruction)
- biological control (biological insecticides, parasitoids, predators)
- chemical control (pesticides, pheromones, natural products)

Diseases

- physical control of host plants(cutting and burning)
- biological control (biological fungicides,
- Chemical control (fungicides)

Plants

- physical control (cutting and burning)
- biological control (herbivore release)
- chemical control (herbicide)

Other general measures (principally for intentional introductions that have not yet invaded unintended habitats)

- Restriction on sale
- Restriction on holding
- Notification before import
- Restriction on movement
- Prevention of movement to specified areas
- Prohibition to release in unintended habitats
- Required growing/rearing conditions
- Surveillance and establishment of a contingency plan with eradication, containment and control measures as appropriate when the species is found outside its intended habitat

Other measures for all invasions

- Publicity
- Obligations to report findings
- Research

Box 2. Examples of different types of costs associated with eradication or containment campaigns.

I. Costs incurred by official authorities (NPPOs)

Labour
- Monitoring (e.g. trap servicing, field walking, pilot time, laboratory services/identification)
- Control actions (spraying, bio control releases, tree injections, fruit stripping)

Capital investment
- infrastructure (quarantine buildings, incinerators
- storage sheds (pesticides, spraying equipment)
- bio-factories
- labs (QA, testing)
- eclosion facilities
- transport (dedicated vehicles for monitoring *etc*.)

Materials
- pesticides
- traps (monitoring, mass trapping)
- pheromone (mass trapping, mating disruption)
- bio-control organisms
- equipment (sprayers, office)

Publicity
- pamphlets
- fliers
- mass media (radio spots, newspaper)
- hand-on training

Research
- emergency research (resistant varieties; novel detection, monitoring and control technologies)

Administration
- Management
- Communication

II. Costs incurred on the farmers/growers/business level

Losses
- Yield and income losses due to destruction of crops and plant material
  Yield and income reduction due to changes in cropping system (e.g. obligatory crop rotation)

Control costs
- Plant Protections Products (e.g. Pesticides, biocontrol agents)
- Labour costs
- Machine costs

-

III. Costs incurred by private owners of properties where actions have to be taken

- Loss of property values in case of cut down of host plants (e.g. big old trees)
- Costs of the action if not covered by NPPO

Table 1. Examples of direct and indirect pest effects with and without commercial or market impacts

	Market Impacts	Non-Market Impacts
Direct Pest Effects	• Losses in commercial crops (quantity and quality) • Losses in timber products (quantity and quality) • Control costs • Monitoring costs • Materials • Labour (some types)	• Urban ornamental • Wildlife habitat • Reduction of keystone plant species
Indirect Pest Effects	• Government research • Administration • Publicity • Capital investment • Labour (some types) • Trade • Tourism	• Nutrient cycle • Hydrology • Ecosystem function

ANNEX I

CBA Protocol: Key steps in conducting a Cost Benefit Analysis of one or more options for the control of *Thrips palmi* in the UK

1. Define the problem

1.1. What is the purpose of the analysis?

1) to calculate the financial impact (costs) of eradicating an outbreak of *T. palmi* on a crop of ornamental chrysanthemum flowers in the UK;
2) to estimate the potential economic impact of *T. palmi* on horticulture in England had eradication not been achieved (i.e. benefit).

The paper also examined the value for money of an exclusion policy towards *T. palmi* based on a qualitative benefit: cost analysis.

1.2. From whose perspective is the analysis being carried out?

From the perspective of the UK Plant Health Service, but both costs to i) the crop production Industries at risk (cucumber, sweet pepper, aubergine and protected ornamentals) and ii) the official government agencies, were calculated.

1.3. What is the scope of the analysis?

Geographical: National (Defra's remit covers England & Wales) B.
Two potential scenarios were considered:

1) *T. palmi* spreads sigmoidally to all areas at risk within 3 years, and
2) Linear spread to affect 62.5% of the area at risk over 10 years.

2. Define the baseline scenario

2.1 Identify the baseline scenario

No official intervention, i.e. no requirement for statutory eradication measures; in other words no additional control measures beyond those carried out by the industry to suppress pests and diseases below economic injury levels.

3. Select control scenarios

3.1 How many control options are there? List them.

One: chemical control (N.B. there is the possibility of IPM in salad production nurseries, but biological control is not normally used in ornamental plant production).

3.2 Select and define the most appropriate control options

Chemical control in this case, but CBA could be used to 1) compare chemical vs. IPM control scenarios; or 2) consider the cost benefit of applying additional (thrips) controls as contingency plans for the pest.

4. Predict the effects of the control scenarios

4.1 What are the effects, or impacts, of each control option?

Identify all significant effects, i.e. the likely consequences and implications of each option (even if not quantified of valued).
Define the effects in terms of specific outcomes. Identify direct and indirect effects of control options (N.B. It is often easier to estimate control costs than to evaluate the effects of control options).

The monetary values of each impact (i.e. the value of annual effects of each control option) were negligible, in the sense that normal pest control measures would control the pest to the extent that yield was not affected. However, the potential impact on other glasshouse (i.e. salad) crops was potentially much more serious, and so the CBA had to be calculated in terms of the costs and benefits to horticultural crop production as a whole (including exports).

5. Estimate Costs and Benefits of control scenarios

5.1 Identify costs and benefits

The costs were the annual expenditure on control measures (incurred by the grower) together with surveillance (largely government) and management costs (also mainly government). The benefits were the economic impact of the pest, in terms of costs saved, avoided or incurred as a result of the action.

5.2 Estimate the direct effects of each control scenario as costs and benefits

COSTS: Annual expenditure, including associated surveillance and management costs, increased by up to UK £2,190 per 0.1 ha (up to 6 times higher than the baseline scenario). This consisted largely of the extra cost of insecticides plus a range of additional measures (including materials for physical control methods and labour costs).

This figure equates to an annual total of £14,705,000 for all (99 ha) of protected ornamentals in production at the time (2000/01), but the potential losses in this sector were very small (1%). In contrast, the potential losses to cucumber production were very large (i.e. 10% of £39m = £3.8m).

BENEFITS: The economic impact of the pest - in terms of costs saved, avoided or incurred – was estimated at between £16.9 and £19.6M (depending on the rate of spread and the severity of the damage). This is the impact of the pest that would occur as a result of lower quality and yields, increased control costs and loss of export markets. Average crop losses of 15% were assumed based on experience of the pest in similar circumstances in Japan.

N.B. in this particular case *(T. palmi* on chrysanthemums) there were non-negative impacts (i.e. compare gross margins for flower production with and without an infestation), indeed the sales increased as a result of increased quality resulting from better overall pest management as the final consequence of the application of more (statutory) sprays!

5.3 Estimate the indirect effects of each control scenario as costs and benefits

Indirect effects were not estimated.

6. Consider the time aspect of costs and benefits

6.1 Determine the period in which costs and benefits occur

Costs and benefits were calculated over a 10-year period.

6.2 Discount annual costs and benefits

The recommended UK government discount rate of 6% was used to discount future costs and benefits to present values.

7. Calculate decision criteria

7.1 Calculate the chosen decision criteria using present values

The benefit-cost ratios (total Present Value benefits divided by total PV costs) were determined by comparing the costs incurred for eradication and exclusion with the financial benefits resulting from eradication and exclusion. The resulting ratio expresses the efficiency of the policy, and this ranged from 96:1 (fast rate for spread and where export markets were lost) to 5:1 were no loss of exports occurred. Variation in the dates of spread affected these ratios slightly (lowering them to 95:1 and 4:1 at a slow rate).

In this case, there was no threshold value for accepting control options, as prevention of the introduction and spread of this harmful organism (quarantine pest) was a requirement of the EC Plant Health Directive (2000/29/EC).

8. Perform sensitivity analysis

How sensitive are the findings to variation in the key values chosen for uncertain coefficients and variables?

There was considerable uncertainly with regard to the impact of the pest on exports. Los of revenue from loss of exports would be the major impact of the pest, and without these losses, impacts decrease significantly (6+-fold) from between £16.9-19.6M to between £0.6-3.3M, over 10 years.

In other words, the loss of exports was the most sensitive variable in terms of altering the findings.

The risk attitude of the stakeholders (in this case the Plant Protection Service) was determined by the official EC regulations (PH Dir 2000/29/EC).

9. Report on the CBA

9.1 What is required by the stakeholders in terms of reporting on the CBA?

In this case, a scientific publication by A.MacLeod, J.Head, & A.Gaunt (2004): An assessment of the potential economic impact of *Thrips palmi* on horticulture in England and the significance of a successful eradication campaign. Crop *Protection* 23, 601-610.

ANNEX II

CBA Protocol: Key steps in conducting a Cost Benefit Analysis of control options for Asian Longhorn Beetle (ALB), *Anoplophora glabripennis*, in Italy

1. Define the problem

1.1. What is the purpose of the analysis?

1) to calculate the financial impact (*i.e.* costs) of eradicating an outbreak of ALB discovered in summer 2009 in NE Italy;
2) to estimate the potential economic impact of ALB in NE Italy in case eradication will not be performed (*i.e.* benefit).

The annex also examines the value for money of an exclusion policy towards ALB based on a qualitative benefit: cost analysis.

1.2. From whose perspective is the analysis being carried out?

From the perspective of the Italian National Phytosanitary Service, but both costs to 1) the owners of ornamental trees and 2) the official government agencies, were calculated.

1.3. What is the scope of the analysis?

Two potential scenarios were considered:
1) ALB population increases exponentially in the infested areas according to a model based on history of infestation and availability of susceptible host trees.
2) ALB spreads linearly from the infested area to adjacent areas at risk.

The analysis was conducted at local scale (5 x 5 km), in Cornuda (Treviso), NE Italy.

2. Define the baseline scenario

2.1 Identify the baseline scenario

No official intervention, in other words no control measures beyond those carried out in tree nurseries and on ornamental trees to suppress pests and diseases below economic injury levels.

3. Select control scenarios

3.1 How many control options are there? List them.

a) Eradication by mechanical destruction (chipping) of the timber infested by larvae (N.B. chemical control is almost inapplicable as larvae live deep in the wood and the infested trees are often of large size and grow in urban areas).

b) Chemical control for plant protection against adults applied only in summer and only in ornamental tree nurseries located inside the infested area.

3.2 Select and define the most appropriate control options

Only mechanical control by tree removal, combined with inspection of trees from the ground, and, in case of doubt, by tree climbers trained to detect emergence holes, oviposition pits and feeding marks.

4. Predict the effects of the control scenarios

4.1 What are the effects, or impacts, of each control option?

The control option will lead to pest containment and, in the medium-long term, to eradication, depending on the efficiency of the detection system. The action will limit the probability of an expansion to nearby towns. This will modify the local landscape and lead to a temporary loss of the ornamental (aesthetic) function of the trees.

5. Estimate Costs and Benefits of control scenarios

5.1 Identify costs and benefits

The costs are represented by: the monitoring network including tree climbers, the removal of the infested trees, the replacement trees, and the management of the system including the information to the public. All these costs are incurred by the local government. The costs incurred by the owners of the trees consist o of the temporary loss of the ornamental tree functions.

The benefits consist of saving the ornamental function of the trees, the landscape value, and protecting the local tree nursery activity.

5.2 Estimate the direct effects of each control scenario as costs and benefits

COSTS

Annual expenditure includes:
- tree monitoring (about 10,000 trees inspected from the ground, of which 10% inspected by tree climbers), individual tree mapping, total cost: € 23,000
- tree felling, removal, chipping of the infested trees, for an overall cost of € 86/tree
- replacement of trees removed for a cost of € 30/tree
- scientific coordination and information, total cost € 10,000.

In the first year (2009) this figure equates to an annual total cost of about 50,000 € for the whole infested area (5 x 5 km, 567 infested trees).

Note: the salary of permanent staff of the Plant Health Service and University is not included in the estimate as it is not an additional cost.

The temporary loss of the ornamental function of trees is estimated based on the market value of an ornamental tree of medium-large size (€ 585.2). This value has been calculated by asking local tree nurseries. As the loss of the function is about half of the expected lifetime for an ornamental tree in the area (40-50 years), the temporary loss of the tree function is estimated to be 50% of the market value, i.e. € 287.6.

BENEFITS

The benefits are represented by the saving of the ornamental function of the trees, calculated as above based on the market value of the trees (€ 287.6). Also, in this case, only the temporary loss has been included as it has been considered that owners would have replanted resistant trees. The benefits have thus been calculated based on the number of trees protected from the infestation each year, and by calculating the difference between the total number of susceptible trees present in the area and the number of trees that would have been attacked in case of no action (effective population growth factor of 4, calculated based on the number of trees infested in 2009 – 641 – and the estimated year of establishment from the dating of the emergence holes, i.e. 2004). The rate of spread of the beetle (1.5 km per year) has been taken from Haack et al. (2010). According to this estimate, in 2014 all susceptible trees in the area would be colonized and for this reason we limited the estimation of the benefits to 2014.

5.3 Estimate the indirect effects of each control scenario as costs and benefits

No precise costs of indirect effects have been considered. However, ecological impacts are negligible as long as the species is confined to ornamental trees, although they could increase considerably if the species moves to forests. Impacts on nursery trade are important but compensated by the switch to resistant species.

6. Consider the time aspect of costs and benefits

6.1 Determine the period in which costs and benefits occur

Costs and benefits were calculated over a 10-year period.

6.2. Discount annual costs and benefits

As in other European countries, the discount rate of 6% was used to discount future costs and benefits to present values.

7. Calculate decision criteria

7.1 Calculate the chosen decision criteria using present values

The benefit-cost ratios (total Present Value benefits divided by total PV costs) were determined by comparing the costs incurred for eradication with the financial benefits resulting from eradication and exclusion, i.e. the commercial value of trees saved from infestation. The resulting ratio expresses the efficiency of the policy, which was 82:1 for the period considered.

In this case, there was no threshold value for accepting control options, as prevention of the introduction and spread of this harmful organism (quarantine pest) was a requirement of the EC Plant Health Directive (2000/29/EC).

8. Perform sensitivity analysis

How sensitive are the findings to variation in the key values chosen for uncertain coefficients and variables?

There is considerable uncertainly with regard to the pest impact. It concerns mainly the estimates made on ALB range expansion rate and population growth factor. The uncertainty will be reduced by refining the estimate based on observations made in 2010 and 2011.

9. Report on the CBA

9.1 What is required by the stakeholders in terms of reporting on the CBA?

A local publication is essential:
Vettorazzo M, Zampini M, Coppe M, A Battisti, M Faccoli, 2010. Infestazione di Anoplophora glabripennis in Veneto. Acer, 3-2010: 57-60.

Other important papers:
Nowak et al., 2001: Potential effect of Anoplophora glabripennis (Coleoptera: Cerambycidae) on urban trees in the United States. Journal of Economic Entomology, 94: 116-122.
Haack et al. 2010: Managing Invasive Populations of Asian Longhorned Beetle and Citrus Longhorned Beetle: A Worldwide Perspective. Ann. Rev. Entomol. 55:521–46.

ANNEX III

CBA Protocol: Key steps in conducting a Cost Benefit Analysis of control scenarios for *Diabrotica virgifera virgifera* in Germany

1 Define the problem

1.1 Purpose

This CBA protocol compares two control scenarios for Western corn rootworm (*Diabrotica virgifera virgifera*) in Germany to the baseline scenario. It aims at selecting the most cost-effective strategy to cope with *Diabrotica v. virgifera* and to provide information on the most appropriate control strategy for the future.

1.2 Perspective

The CBA protocol considers effects at the NPPO level (and also regional PPOs in Germany) as well as for maize growers who have to apply the measures.

1.3 Scope and scale

The CBA protocol is conducted at a national level, taking into account different maize production purposes (grain maize, green maize, biogas production) as well as regional differences within Germany.

1.4 Time

The time period for performing the CBA protocol on *Diabrotica* is a period of 15 years since the beetle needs about five years of establishment before damage will be realized.

2 Define the baseline scenario

The baseline scenario for *Diabrotica v. virgifera* control in Germany is "maize growing without official control measures". This means that there are no restrictions for growing continuous maize and insecticides are not applied to control *Diabrotica*. Growers may observe damage by the Western Corn Rootworm five years after introduction, since this species needs some time to build up to a population threshold that damages maize crops. It is assumed that growers will then start to apply plant protection measures, such a insecticides to suppress *Diabrotica* below the economic injury level. Growers may prefer growing continuous maize.

3 Select control scenarios

3.1 List the available control scenarios

The available control scenarios are listed in table 1. Since *Diabrotica* is a regulated quarantine pest, emergency measures in case of outbreaks are laid down in the EU Decision 2003/766/EG. For Germany, the “Regulation on plant health measures against *Diabrotica*” and the “Guidelines on application of official measures against *Diabrotica*” describe the measures to be taken (both are available at

http://pflanzengesundheit.jki.bund.de/index.php?menuid=60&reporeid=71).
Combinations of control scenarios (e.g. crop rotation + insecticide application) have not been included here.

Table 1: Control scenarios for *Diabrotica virgifera virgifera*

Control Scenarios	Costs per ha and year[1]	efficacy	Acceptance/ availability	Eradication	Containment
Crop Rotation (33% or 50% maize in crop rotation)	Grain maize: ca. 150 € silage/green maize: about 250 € Maize for biogas production: 150-350€	96 - 98% (e.g. in Switzerland very good results)	only partly accepted by growers / depends on regional and farm specific prerequisites	Yes	Yes
Insecticide application			in many cases good acceptance by growers / less by the public		
a) larvae seed coating: Chlothianidin;	about 70€	30 - 60% (economic threshold reached after 7 years, Krügener et al. 2010)	not available due to problems with bees in 2008, therefore no license	No	No
soil application: Tefluthrin)	about 70€	60 - 70% (economic threshold reached after 9 years, Krügener et al. 2010)		No	No
b) adults (e.g. Alpha Cypermethrin, Spinosad, Thiachlioprid, Pyrethroid)	about 80€ for two applications (costs higher for the Pyrethroid)	80 - 90% (under optimal conditions – timing, climate and repeated application)		No	Yes, but depends very much on conditions
Biological control (application of nematodes)	150 € application costs	According to Toepfer et al. (2007) comparable to soil insecticide application or seed coating	Not yet available for application on a broad scale		
Resistant varieties	Not known	Medium to high	No genetically modified varieties allowed in Germany		

[1]estimates based on calculations and data from 2009

3.2 Select appropriate control options

Concerning the efficacy of the control options, those that including crop rotation are the most appropriate. Other options that are not yet available in Germany (biocontrol and resistant varieties) have not been taken any further into account. The crop rotation option with 66% maize was also not pursued due to its low efficacy. Insecticide applications against adults are only efficient if repeated during the growing season.

3.3 Define scenarios

1. Crop rotation (33% and 50% maize)
2. Insecticide application against adults

4 Predict the effects of the different control scenarios

Pest abundance (incidence) for the defined scenarios:

Krügener et al. (2010) calculated the population development for different control scenarios and crop rotation assumptions. Their calculated data are used here for the prediction of the abundance of *Diabrotica* (table 2) for the selected control scenarios.

Table 2: Effects of different control scenarios on Diabrotica abundance

	Baseline scenario	Crop rotation	Insecticide application
Predicted abundance of *Diabrotica*	already after 4 years above the economic threshold (assumption: 80.000 beetles/ha)	66% maize (no maize in the year after detection of the beetle): < 10.000 beetles/ha = low population but no eradication 33% and 50% maize: no population development if no maize is grown in the first year after detection	adult control: < 1000 beetles/ha (assumption: at least two insecticide applications)

5 Estimate Costs and Benefits of control scenarios

5.1 Identify costs and benefits

Table 3 summarizes the costs and benefits resulting from the different control scenarios. While the costs of the baseline scenario are mainly borne by maize growers, costs of the control scenarios have to be paid by both by growers and the NPPO.
The costs arising from the two control scenarios which are borne by growers are caused by:
(a) crop rotation (see table 1) and
(b) remaining yield losses despite the measures taken (calculation based on assumptions of percentage yield loss – e.g. 10%) or as a side effect of the measures taken (insecticide applications late in the season can cause structural damage to the maize crop).

NPPOs will cover the costs for:
(a) monitoring (costs of traps, labour, control and travel); in a former study estimates of150€ per trap location were given; solidarity data from 2008 showed that Baden-Württemberg spent about 41.000 € for 840 auxiliary traps leading to costs of about 50€ per trap.
(b) insecticide applications (material, labour costs, machine costs; estimates for costs per ha see table 1)

Table 3: Costs and benefits arising from the different control scenarios.

Control Scenarios	Costs	Effect on spread	Benefits
Baseline scenario: maize after maize and insecticide application after 5 years	1. costs of the insecticide, costs of spraying 2. Yield losses (10-15%) → to be calculated for the area reached after 15 years	*Diabrotica* is expected to spread rapidly (assumptions: 80 km/year)	---------
(1) Crop Rotation (33% or 50% maize in crop rotation)	Costs of crop rotation (difference in gross margin between maize and alternative crop; see table 1 for costs/ha of different maize production purposes) → to be calculated for 3 years (eradication) Monitoring costs -> to be calculated for 15 years	*Diabrotica* is expected not to spread (eradication can be achieved)	Avoided costs and losses of baseline scenario minus costs of crop rotation

(2) Insecticide application against adults	1. costs of the pesticide, costs of spraying, at least two times during the season, need of special machinery (see table 1 for costs/ha) 2. Monitoring costs -> to be calculated for 15 years 3. Environmental impact of insecticides → to be calculated for the area reached after 15 years	No eradication but containment, *Diabrotica* is expected to spread slowly (assumptions: 20 km/year)	Avoided costs and losses of baseline scenario minus costs of the scenario

5.2 Estimate the direct effects of each control scenario as costs and benefits

To estimate direct effects, the spread of *Diabrotica* was modeled for Germany according to an approach developed by Baufeld and Enzian (2005). It is based on data on maize production data at a district or community level for 2003/2004. Assumptions for the spread distance are indicated in table 3.
Table 4 summarizes the costs and benefits of the two different control options which arise from direct effects.

Table 4: Costs and benefits of control measures for Diabrotica virgifera in Germany assuming an introduction in Freiburg, Baden-Württemberg, calculated over a period of 15 years.

Control Scenarios	Costs in € (present values)		Benefits in € (present values)	
	from	to	from	to
Baseline scenario: maize after maize and insecticide application after 5 years	32,332,244	44,493,697	---------	---------
(1) Crop Rotation (33% or 50% maize in crop rotation)	6,467,389	9,576,490	25,864,855	34,917,207
(2) Insecticide application against adults	6,123.876	7,156,612	26,208,368	37,337,085

5.3 Estimate the indirect effects of each control scenario as costs and benefits

Table 5 summarizes the indirect effects of the baseline scenario and the two control scenarios. The effects are not quantified but have to be considered qualitatively.

Table 5 : Indirect effects of the considered control scenarios for *Diabrotica v. virgifera.*

Control Scenarios	Indirect Effects	Costs	Benefits
Baseline scenario: maize after maize and insecticide application after 5 years	1. side effects of insecticide → to be calculated for the area reached after 15 years	Difficult to quantify	---------
(1) Crop Rotation (33% or 50% maize in crop rotation)	Changes in usage of specific machines possible, changes in delivering maize for biogas production possible – consequences for contracts?	Difficult to quantify	Avoided costs of baseline scenario (avoided negative effects of insecticide application; costs of crop rotation have already been taken into consideration in 5.2)
(2) Insecticide application against adults	1. side effects of insecticide → to be calculated for the area reached after 15 years →are assumed to be considerable	Difficult to quantify	Avoided costs of baseline scenario – application of insecticide on a smaller area but more intensive (repeated application necessary)

6 Consider the time aspect of costs and benefits

<u>6.1 Determine the period in which costs and benefits occur</u>
Costs and benefits were calculated over a period of 15 years.

<u>6.2 Discount annual costs and benefits</u>
Costs and Benefits have been discounted with an interest rate of 4% (see table 4).

7 Calculate decision criteria

Cost/Benefit ratio based on direct effects:

- Control Scenario 1 (Crop Rotation): 1:4
- Control Scenario 2 (Insecticide application against adults): 1:4 to 1:5

Rank the control options

When considering only the Cost/Benefit ratios based on direct effects, there is almost no difference between the two scenarios. When indirect effects are also taken into account, this could lead to a higher Cost/Benefit ratio for the crop rotation scenario since this does not produce side effects from the regular and repeated application of insecticides. Therefore this the crop rotation scenario should be pursued.

8 Perform sensitivity analysis

For the CBA of control scenarios for *Diabrotica virgifera* a range of assumptions had to be made:
- percentage of continuous maize in Germany, Baden-Württemberg (assumed: 20%)
- prices for maize to calculate the monetary losses of *Diabrotica* infestation (these have been taken into consideration within the calculations for a lower and higher price)
- interest rate (used here: 4%)
- yield loss in the baseline scenario (assumed to be: 10%)

They all affect the final result and increase uncertainty.

9 Report on the CBA

The CBA has been reported, presented and discussed at national meetings of representatives of the NPPO and the PPOs of the Federal States in Germany.

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