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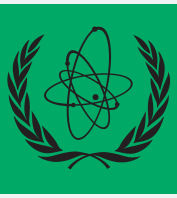

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ENVIRONMENTAL BENEFITS OF MEDFLY STERILE INSECT TECHNIQUE IN MADEIRA AND THEIR INCLUSION IN A COST–BENEFIT ANALYSIS

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FOREWORD

Agriculture remains important to the island of Madeira and integral to other sectors including the tourist sector where landscape and rural life play a key role in attracting visitors.

To prevent the decline of agriculture, rural development and agricultural policies are increasingly designed to promote sustainable agricultural production systems that may reduce pressure on and adequately manage natural resources. For many years the fruit industry in Madeira relied on banana production and exports to the European Union. However, this activity is no longer profitable because of high production costs (expensive hand labour), excessive pesticide use and low prices on the international market. In an attempt to stimulate the fruit industry, agriculture polices encouraged farmers to diversify fruit production. Despite some increase in areas of subtropical fruits such as custard apple, fruit diversification and the rate of increase of new areas of production has been very low.

One of the main factors restricting the development of the fruit industry in Madeira is the Mediterranean fruit fly (medfly), which has over 50 hosts in the island alone. Ecological conditions and the structure of property (small plots with a variety of hosts maturing at different times) favour the development of medfly, which contributes to the intensity of the damage. Calendar insecticide cover sprays are carried out both by the Division of Fruit Production of the Madeira Regional Government and producers, but despite insecticide applications the damage caused by medfly is very high (residual damage); thus the quantity of locally produced fruit is not sufficient to meet the demand of the local population and that of the thousands of tourists that visit the island every year. Insecticide costs make up a large portion of production costs and consequently producer revenue is low. Conventional insecticide applications cause health and environmental problems and the use of high residual and wide-spectrum insecticides affect access to the market because of the long harvest intervals and residues in fruit. High damage to fruit crops leads to the abandonment of agriculture, which has negative social and environmental consequences.

In 1998, the Regional Government of Madeira, with the support of the IAEA and FAO, through a technical cooperation project implemented the Madeira-Med project aimed at controlling the medfly using an integrated approach based on the sterile insect technique (SIT). A mass rearing and sterilization facility with a production capacity of 50 million sterile males per week was built and is currently in operation. Madeira-Med was referred to as an essential stepping-stone for Madeira fruit production to be able to withstand future challenges.

The present study sets out to quantify the different categories of benefits that would be obtained by effectively controlling the medfly using SIT and the costs of the control programme. The economic analysis will evaluate how Madeira-Med benefits society as a whole and not only fruit producers. It includes gains from increase in production volumes and the reduction of production costs, which are direct benefits for the farmers. In addition it includes improvements in environmental quality and health that will benefit both farmers and fruit consumers. Recent cost benefit analyses for proposed insect pest eradication or suppression programmes have included some environmental factors, but a systematic valuation of these factors is new to this study.

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Financial and logistic support to conduct the study was kindly provided by the Madeira-Med Programme of the Regional Government of Madeira (A. Brazão, L. Dantas and their collaborators). J. Andrade conducted the Contingent Valuation and producers surveys. Stakeholders kindly agreed to participate and provided valuable information for this evaluation.

The IAEA officer responsible for this publication was W. Enkerlin of the Joint FAO/IAEA Programme of Nuclear Techniques in Food and Agriculture.

EDITORIAL NOTE

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SUMMARY

In the last few decades the tourism industry in Madeira acquired a prominent role in the economy. Despite infrastructure and development to accommodate ever larger numbers of tourists, efforts have been made to protect the environment and to follow the path of sustainable development. The medfly control programme based on the Sterile Insect Technique (Madeira-Med) represents an important step in this direction.

Medfly control based on the sterile insect technique (SIT) brings various benefits. One of the key benefits is that it would lead to an increase in locally produced, pesticide free fruits.

This study shows insecticides fail to control medfly effectively and that Madeira-Med can save an extra 2.2 million kg of fruit. This represents an increased revenue for producers valued at 1.6 million euros annually.

A further 130 000 kg/year can be saved in backyard production. This would represent a further gain of 170 000 euros annually (average of the first 10 years) for backyard owners. Although they may not place their fruit on the market this value corresponds to a saving for the household as less fruit has to be bought. It represents equally an increase in the nutritional quality of the food consumed by the household.

Additionally, if medfly is controlled, Madeira has the potential to increase its fruit production areas. The potential for increase in fruit production is strong as the industry benefits from favourable conditions which include:

- Favourable climatic conditions: Climatic conditions allow the production of high quality subtropical fruits such as custard apple, pitanga, carambola, guava and also the production of some temperate fruits such as persimmons, figs and loquats.

- Potential access to new exports markets: Custard apples benefit from certification of quality that confers on them a market advantage in the international arena and others, such as pitanga, benefit from the fact that worldwide production is still at a low level thus there is a window of opportunity to enter the market before other competitors.

- Political support: There has been strong political support for agriculture which has allowed the development of infrastructure, better organisation of production and, ultimately, better revenues for producers.

Considering these favourable circumstances, and provided that medfly was successfully controlled, it was estimated that:

- An extra 2.4 to 5.3 million kg/year of fruit could be produced in 10 years time in Madeira resulting from an increase in the production area.

If we consider that:

- Madeira's production of medfly hosts was estimated at 8.6 million kg/year and
- imports amount to almost 16 million kg/year,

it becomes clear that such an increase in production can play an important part in redressing the trade balance.

As a result of the decrease in medfly damage and the expansion of production areas, production could reach 13.5 to 16.3 million kg (4.8 to 7.7 million kg more than the actual production). This increase

would be a contribution towards meeting the needs of the local population estimated at 18 million kg per year.

More importantly, the value of this extra production is likely to be high as there is growing demand for local products: interviews conducted showed that consumers believe that the quality of local fruit is higher than that of imported fruit and they are willing to pay 15 to 16% more for local fruits:

- This means that consumers are willing to pay almost two million euros more than what they pay now for locally produced fruit.

Furthermore, this increase in production and quality may also benefit the tourist industry. Both tourists (in the willingness to pay survey) and hoteliers and restaurateurs have expressed their interest in consuming locally produced fruits. Considering that the fruit consumption by the tourist industry was valued at almost five million euros per year, this is an important market for fruit producers. Some hotels even pledge, as part of their environmental application, to consume locally produced food as often as possible. With an increasing number of hotels in Madeira applying for environmental certification, the demand for local fruit is bound to increase even further.

Adding to the extra production benefits, Madeira-Med contributes to a decrease in pesticide use:

- Almost 2000 litres are applied by the Fruit Production Department at a cost over 700 000 euros per year.
- If applications by individual farmers are included the cost of pesticide application in Madeira increases to over 2 million euros per year.

Madeira-Med would not only lead to a decrease in pesticide costs but would also limit negative indirect impacts of pesticides. Pesticides cause environmental and health costs, which include: (1) health costs for pesticide users and consumers, (2) costs incurred by the state in pesticide monitoring and preventing pesticide damage and (3) extra costs of controlling other pests that proliferate due to the destruction of their natural enemies by pesticides.

- Environmental and health saving resulting from Madeira-Med were estimated, conservatively at more than 690 000 euros annually.

This value includes important social benefits in terms of capacity building that result from Madeira-Med and which include the role of Madeira-Med in technology transfer to other countries interested in SIT application, in the international scientific arena through development and validation of SIT technologies and the capacity to tackle other potentially invasive species through the strengthening of its plant protection infrastructure.

The benefits that Madeira-Med provides to the tourist industry have also been highlighted in this study. Not only will the programme contribute to the provision of high quality produce to tourists, but to the maintenance of agriculture and the rural heritage.

The tourism development plan for Madeira highlights the fact that tourism depends on the conservation of natural and cultural heritage, which includes rural landscape and the rural life. The analysis of the contribution of agriculture to tourism, carried out by close consultation with stakeholders in the tourist industry, identified the following benefits:

- savings in costs of conservation of agricultural landscape;
- increase in tourism spending to the increased opportunities for development of new activities;
- increased number of tourists by increased attractiveness of the destination.
- The contribution of Madeira-Med to these benefits was estimated at more than 500 000 euros per year.

Many of the indirect benefits identified could not be attributed a monetary value but are equally important to the analysis. These include the social and economic importance of supporting environmentally-friendly agricultural production methods for the sustainable development of Madeira. Such methods can lead to the production of high quality and high value products (such as those from organic agriculture) that will give Madeira's agriculture a competitive advantage. They may also promote an image of Madeira as an all-organic destination that would confer the island a competitive advantage in the tourist market.

Based on the benefits resulting from the programme, the economic analysis compared three different control strategies: maintaining the *status quo,* maintaining the same production level of sterile flies but targeting selected areas in the East of the island, and expanding the programme by doubling the sterile male production capacity of the programme. To the present costs of the programme were added costs of initial suppression operations which are essential to reduce population to the required levels for SIT to be effective.

The key results of the analysis are the following:

- The expansion of the programme is the most favourable scenario. The costs of expansion were calculated at 2.9 million euros, including around 700 000 euros to upgrade the current mass rearing facility. The extra costs of operating this programme are limited: in 2004, these would be around 120 000 euros more than in the *status quo* scenario (assuming that a few bottleneck in production are achieved). This scenario allows control of the medfly in all the island, thus the benefits are very high. The savings in production amount to an average of four million euros/year (twice as much as the *status quo* scenario). The total benefits for this scenario including benefits from increased production area and environmental and health savings, amount to 5.4 million euros/year (considering the average of the first 10 years of programme operation).

  The economic analysis shows that the net present value (NPV) for the expansion scenario is only negative in the short-term projection and without indirect benefits. If a longer timeframe is considered or if indirect benefits are added, the economic indicators become positive demonstrating the interest of the project. The internal rate of return (IRR) including indirect benefits is 11% and 31% respectively in the six year and 12 year projections.

  The robustness of this scenario was demonstrated in the sensitivity analysis. For the sensitivity analysis, the parameters producing a larger variation on the final economic result were selected: these included the discount rate, the yearly increase in fruit prices, the yearly variation in SIT costs, the costs of SIT expansion, the potential for increase in planted area, the value of environmental and health costs and the level of control achieved with SIT. The selected parameters were attributed a distribution of probabilities based on an estimation of their minimum and maximum value. Subsequently, the results were tested using a risk analysis software — Crystal Ball™.

  The simulation showed that even if variables varied between the selected limits, there was 90% probability that the NPV for the expansion scenario (including indirect benefits) would be positive in the long term. However, it is important to note that this result is based on the assumption that the population suppression efforts prior to the release of sterile flies are effectively conducted throughout the island by public authorities, farmer cooperatives and backyard owners as explained in the report.

- If the programme continues operating at a weekly capacity of 50 million sterile males (*status quo*), the returns obtained, without indirect benefits, are negative. The average programme costs, estimated at an average of 2.7 million/year, outweigh the benefits, calculated at 2 million euros/year. Both the NPV and the IRR are negative in this scenario.

  However, if indirect economic, environmental and health benefits are included, the benefits increase to more than 2.3 million euros/year. In this case the IRR becomes positive in the long

term reaching 5% in the 12 year projection and 8% in the 15 year projection. The NPV also become positive in the 15 years projection reaching 13 million euros. This result indicates that, although the financial gains are not large enough to justify the costs of the programme, the societal gains are substantial in the long term. This result is, however, not very robust and the risk analysis shows that with the new mean distribution resulting from the probabilities of distribution assigned, the economic indicators become negative.

- Finally, the East Madeira strategy, that required the same level of production of the *status quo*, but entails a change in the control areas and strategy, yields much better results than the *status quo* without the need for substantial additional investment.

  Although the costs remain the same as in the *status quo* scenario, the average yearly direct benefits of this strategy increase to 2.5 million euros/year. The extra benefits are enough for this scenario to give positive returns. Although in the first years the net-benefits are low this strategy gives positive returns after five years without indirect benefits and after four years including indirect benefits. In the 15 year projection the IRR reaches 2% and with the inclusion of the indirect benefits, the IRR increases from –2% to 21%.

  Adding to these more favourable economic returns, the probability of obtaining favourable results are higher with this scenario. The sensitivity analysis demonstrated the robustness of this scenario: there is an 80% probability that the NPV is positive in 12 years.

  From an operational perspective, this strategy would consist of initially concentrating resources in selected areas in the eastern part of the island where custard apple growers are organized in a cooperative and to gradually expand to the whole of the East of Madeira, after demonstrating the feasibility of SIT. The advantage of this option is that the likelihood of achieving an effective population suppression would be higher compared to the expansion option since the scale of the operation would be smaller (although large enough to be effective) and would target a more concentrated production area where producers are more organized.

Finally, in analysing the results of the analysis it is important to note that the conclusions are only valid under the set of assumptions described in the analysis. Moreover, the medfly control programme is part of a larger system and, for the potential for development of the fruit industry in Madeira to be fulfilled, broad governmental support to the fruit industry is needed. This includes concentrating efforts in organising production and marketing in order to develop a profitable fruit industry based on the quality of local produce. Support for research, for instance in selecting the most favourable varieties, developing modern and effective extension systems, providing training and incentives for the formation of cooperatives are of great importance. Other constraints such as decreased labour availability, low profitability resulting from high input cost and low market prices due to competition, lack of quality and lack of private investment need also to be addressed if the potential is to be fulfilled.

1. INTRODUCTION

The Portuguese archipelago of Madeira, situated 630 km west of the Moroccan coast, comprises several islands but only two inhabited ones: Madeira and Porto Santo. Madeira, with its capital Funchal, is where most of the population lives. Its volcanic origin and a combination of temperate and subtropical climate give the island its extraordinary and diverse scenery including precipitous valleys, sheer cliffs and cultivated terraces.

FIG. 1. Madeira and Porto Santo islands (adapted from www.mapquest.com).

Throughout the centuries, the key economic activities in Madeira ranged from sugar trade, to wine and shipping trade. From the 1960s onwards, and especially after Portugal's entry into the EU in 1986, tourism became the main source of income. It now represents 77% of Madeira's economic output. However, the sustainable development of tourism is closely linked to other sectors of the economy such as agriculture which plays an important role in the conservation of the landscape, the key resource of tourism in Madeira.

Agriculture has lost some of its economic importance, but is still an important activity to maintain rural life. Many people depend on subsistence agriculture and 65% of the people have at least some relationship with agriculture. Traditional farming methods are still used in the numerous terraces where mechanisation is extremely difficult. The small property size (the average farm size at 0.38 ha (INE, 2001) also contributes to the maintenance of traditional production methods.

However, these farming conditions carry high production costs and led to the abandonment of this activity. To contravene the decline of this activity, agricultural policies have been implemented that contributed to better organisation of the production and the modernisation of the sector. There are, henceforth perspectives for growth in some sectors of production. This is the case for fruit production and especially for subtropical fruit production. In recent years the areas of subtropical fruits increased. This increase was due to favourable agricultural policies aimed at decreasing the reliance on banana, and to the potential for exports of some subtropical fruits.

Support for subtropical fruit producing also comes from the need to redress the trade imbalance in fruits: Madeira imports twice what it produces although it has the potential to produce much more than its current production.

However, for the fruit industry to collect the full benefits from these favourable factors, it is of paramount importance that the key pest of fruit crops, the Mediterranean fruit fly (medfly), is effectively controlled.

Medfly has more that 50 hosts in Madeira and is a key limiting factor in fruit production (with the exception of banana and avocado) (Vieira, 1952). The ecological conditions and the structure of property (small plots with a variety of hosts maturing at different times) favour the development of the pest and explain the intensity of the damage. To control this pest calendar insecticide cover sprays are carried out by the Division of fruit Production and by producers.

However, the use of insecticides causes several problems. Firstly, they cause environmental and health problems. Secondly, insecticides are not solving the problem, the damage occurring despite the use of

pesticides (residual damage) is still very high and the quantity of fruit locally produced decreases. Pesticide costs take up a important share of the production costs and, consequently, producers revenue is low. The quantity of fruit available for auto-consumption also decreases which can affect the quality of the diet of the populations that traditionally rely on this source of fruit. In addition, high damage encourages the abandonment of agriculture which has serious negative social and environmental consequences. Further to the environmental and health problems, the use of insecticides also poses marketing problems due to the long harvest intervals. To aggravate the problem, the intensity of the attacks is increasing every year probably due to favourable climatic conditions and the abandonment of agriculture. The importance of medfly in custard apple was low 10 years ago but it has now become a key pest. It is feared that other fruit crops and vegetables may be attacked in the future.

Rural development policies are now designed to promote sustainable agricultural production systems that reduce pressure over natural resources and adequately manage them. The need to transform agricultural systems is also driven by public demand for increase quality and environmental protection. Within this context, medfly problem can only be tackled using environmentally friendly methods such as the Sterile Insect Technique (SIT) and it is for this reason that the Madeira-Med project was set up. Madeira-Med was referred to as an essential stepping stone for Madeira fruit production to be able to withstand future challenges (Jornal da Madeira, 1998). This project, started in 1998, is an integrated control programme based on SIT and included pest trapping and fruit sampling, public relations campaign and cultural control operations and sterile fly rearing and releasing.

The benefits of controlling medfly using SIT include direct benefits such as increasing local fruit production and indirect benefits such as improving conditions for further expansion of the fruit production area and increasing environmental quality and health. The present study sets out to quantify these different categories of benefits provided by Madeira-Med and to include them in the economic analysis.

By quantifying these impacts, the economic analysis will evaluate Madeira-Med benefits for society as a whole and not only for fruit producers. For instance, it will include gains from increase in production volumes and reduction of production costs which are direct benefits for the farmer but also gains in environmental quality and also improved health that will benefit both farmers and fruit consumers. Recent cost benefit analyses for proposed eradication or suppression programs have included some environmental factors however, a systematic valuation of these factors, as will be developed in this study, was not carried out in previous analysis. (Vo *et al.* (2002) in Central America, Enkerlin and Mumford (1997) in the Middle East, Mumford *et al.* (2001) in Western Australia, Mumford (unpublished) Western Cape in South Africa and Larcher-Carvalho *et al.* (2001) in Algarve Portugal.).

The report starts by presenting the economic model and the methods selected for the valuation of environmental benefits of Madeira-Med. Then it focuses on quantifying the key costs and benefits of Madeira-Med. Following that, an economic analysis to assess the economic returns of SIT use in Madeira, including the benefits obtained from environmental savings is carried out.

2. METHODS

2.1. The economic model

A cost benefit analysis model has been developed based on previous similar models created to evaluate medfly control programmes based on the sterile insect technique (SIT)[1]. The model developed comprises several worksheets that can be divided into the following groups:

[1] These included mainly the studies by Enkerlin (1997), Enkerlin and Mumford (1997), Mumford (1996) Mumford *et al* ((2001) and Larcher-Carvalho (2002).

Scenarios: The economic evaluation considers three different scenarios:

> **Scenario 1: *status quo* —** consisted of maintaining the same sterile male production level (50 million flies per week) and controlling medfly in the North/Western part of the island and Porto Santo
>
> **Scenario 2: East Madeira —** consisted of maintaining the same production level but diverting control efforts to selected areas of higher concentration of production situated in the Eastern part of the island (this is apparent in Figure 2); This strategy would proceed in phases, each time concentrating resources in a limited area. The advantage of this strategy is that result would be achieved quicker in the targeted area. After demonstrating the feasibility of SIT in a restricted area the programme could then gradually expand to other areas of concentrated production.
>
> **Scenario 3: expansion** — consisted of increasing production to 100 million flies per week. This scenario would allow expansion of the SIT programme to other relevant fruit producing areas.

SIT costs. In this worksheet the costs of running Madeira-Med under the three different technical scenarios are entered. These include sterile fly production and field operation costs. In addition to these current cost factors an estimate of population suppression costs was considered (more detail in Section 4.2).

Direct benefits of SIT. These include the savings in the losses that occur despite the use of insecticides (residual losses). Several worksheets were developed, in order to accurately estimate potential and residual damage taking into account host type, host quantity, host sequence of maturation and monthly medfly infestation. Finally, the loss worksheet combines damage with monthly prices of commodities to calculate the monthly production losses.

Indirect benefits. These include the savings in production in backyard gardens and the gains from increase in production area that SIT would allow.

Environmental benefits of SIT. This worksheet includes the savings in environmental damage that will be quantified in the valuation exercise.

Cost–benefit analysis. The following economic indices were used in estimating the likely success of the project:

> **Net benefits**: The Net Benefits show the difference between the costs incurred by the SIT project and the associated benefits. Larger figures represent a larger return on the investment and are associated with greater Net Present Value.
>
> **Net present value** (NPV): The NPV gives an indication of the value of the project less any investments adjusted for the prevailing discount rate. If the figure is positive then the project will make a profit, if it is negative, then a loss will be made over the time covered. The base discount rate used for the analysis was 5%[2].
>
> **Internal rate of return** (IRR): The IRR is the discount rate value that zeroes out the net present value of the investment; a higher IRR indicates a greater average return on the investment.

The values of the indirect benefits calculated in Sections 5, 6 and 7 assumed 100% medfly control. However, in the model the benefits are entered as a percentage of the assumed levels of control achieved with SIT. The model considers a short term (six years) and two long term (12 and 15 years)

[2] A 5% discount rate may be a standard benchmark for EU co-financed projects (Massimo *et al.,* 2002).

time horizons. The combination of the three strategies with time horizons gives rise to several scenarios that are built into the model.

2.2. Environmental valuation

The key environmental benefits of SIT derive mostly from the reduction in pesticide use. Therefore, to a great extent, quantifying the environmental benefits of SIT corresponds to quantifying the environmental costs of pesticide. There are a number of possible methods to evaluate these environmental impacts. This study uses two valuation techniques that have been used widely in similar situations.

The first consists in quantifying the costs incurred by society when dealing with the externality caused by pesticides. These include the monitoring costs incurred by public and private authorities to monitor pesticides in the environment and in food and the treatment or prevention costs incurred to restore the environment and human health. Only those costs that can be attributed specifically to the use of insecticides for medfly control in fruit crops are accounted for.

Information was collected during interviews in Madeira with experts qualified in several different fields such as agriculture, environment, health and tourism (Appendix 1). A survey of producers was also carried out to collect information on risk from pesticide exposure and toxicological effects.

The second method used for environmental valuation is contingent valuation (CV). The idea behind this method is that what people want should be the basis for benefit measurement. The way to identify what people want is to analyse how people behave when presented with choices regarding goods and services. A positive preference will show in the form of a willingness to pay (WTP) for it.

Based on this method, an exploratory CV survey, with a small number of respondents (72) was conducted[3]. Respondents were asked to specify the maximum amount they would be willing to pay to obtain fruits produced using environmentally friendly methods (organic fruits). The objective of this exercise is to obtain an average WTP that would correspond to the value to society of this specific environmental improvement (fruit production without pesticides). The average WTP would be a measure of the value respondents give to sustainable production methods, to fruit quality and to environmental protection. The method was also used to assess the WTP for locally produced fruit. This value reflects the value given to fruit quality and also to the social, environmental, economic values attributed to fruit production in Madeira.

3. MADEIRA-MED COSTS

3.1. Present costs of the programme

The costs of running Madeira-Med for the past four years are summarized in this Table I[4]. These include the costs of mass rearing and sterilisation, population monitoring, sterile fly release, staff training, public information campaign and administration. The yearly variation in the running expenses is determined by a number of factors namely the variation in the price of inputs, in the quantities of materials bought and in salaries. Capital investment variation is due to the acquisition of durable goods. For instance, the increase verified in 1999 was due to the acquisition of release equipment and PARC boxes, to the installation of IT network, the acquisition of IT equipment and the installation of refrigeration units amongst others. The acquisition of durable goods such as PARC boxes, field cages, fridge unit and egg sowing device increased capital expenses in 2002. Running expenses also rose due to increase in the aeroplane rental, security services and diet ingredient costs, amongst other. Career progression has also lead to an increase in personnel costs.

[3] All the interviews were conducted by Jordan Andrade, technician in the Madeira-Med Programme.
[4] Estimates by Alexandre Rodrigues and Luis Dantas, Director of the Madeira-Med programme.

Projections were made by programme leaders for 2003 assuming all operations remain the same. A four per cent price increase was assumed for the year of 2003 and it was estimated that only half of the capital investment of 2002 would be needed.

Table I. Madeira-Med annual costs (in thousand euros)

Cost category	1998 Costs	1999 Costs	2000 Costs	2001 Costs	2002 Costs	2003 Costs
Operating expenses	1182	1417	1550	1546	1705	1773
Capital investment	79	226	82	38	179	90
Total	1261	1643	1632	1584	1884	1863

3.2. The need for a suppression unit and set up costs

One prerequisite for the success of SIT is that populations are reduced to very low levels prior to the release of sterile males. However, at present there is no dedicated office within Madeira-Med to carry out suppression operations. It was therefore judged necessary to estimate the potential operating costs of a suppression unit and add them to the present costs of running the programme.

Instead of carrying out all the suppression operations, this team would link up with other public authorities and farmers cooperatives to be able to perform this task in a large area at little additional cost for the programme. The team would actively seek the collaboration of farmers by implementing a scheme where farmers would receive some type of incentive in exchange for their contributions to the programme. Field suppression activities could involve ground application of a product such as spinosad[5] (a product of biological nature) and/or bait stations, mechanical control of wild primary hosts[6] and other opened areas and fruit sanitation in orchards and backyards.

- A suppression unit is necessary to ensure programme success. Such unit would consist of a team of at least three people equipped with car.

- The annual cost of this team was estimated at 42 000 euros.

3.3. Costs of expanding the programme

One possible scenario for the future of the programme would be to increase production from 50 to 100 million sterile male flies per week. This production level would, according to the estimates of the Madeira-Med leaders, be the required to expand medfly control to most fruit production areas.

For this scenario it was assumed that five more members of staff would be needed, the amount of diet would have to double (16 tonnes of diet per week) and expenses for electricity, water and gas would increase by 10%. It was assumed that the costs of running the Suppression Unit would be same for both technical scenarios since the basic work of this unit would be the coordination of activities with farmers and other institutions. The total costs of expansion are presented in Table II.

[5] When approved for use in fruit crops in Portugal.
[6] E.g. *Solanum mauritianum* known in Portugal as wild tobacco.

Table II. Estimated costs (in thousand euros) of increasing production to 100 million sterile males in 2004

Cost category	Costs in thousand euros
Operating expenses	2002
Capital investment	179
Total	2181
Construction costs (one time cost)	696
Total	2877

- If the programme was expanded to 100 million sterile males per week, the annual operating costs of the programme would increase by around 120 000 euros in 2004.

- A relatively small investment would be required to double current production levels since the present infrastructure (capital costs) and fixed costs would basically stay the same with variations only in variable costs. However, for this assumption to be valid a few bottle necks in the production process would have to be solved.

4. DIRECT BENEFITS OF SIT BASED MEDFLY CONTROL

4.1. Fruit production in Madeira

Subtropical fruits occupy 863 ha of which 641 are bananas (*Musa acuminata*). Other subtropical crops include custard apple (*Annona cherimola*), avocado (*Persea americana*), papaya (*Carica papaia*), passion fruit (*Passiflora edulia*), guava (*Psidium guajava*), mango (*Mangifera indica*), brasilian guava[7] (*Psidium cattleianum*) and pitanga (*Eugenia uniflora*). Fresh fruits[8] occupy around 537 ha. This category includes apples (*Malus domestica*), pears (*Pyrus communis*), peaches (*Prunus persica*), apricots (*Prunus armeniaca*), plums (*Prunus domestica*), loquats ((*Eriobotrya japonica),* figs (*Ficus carica*), oranges (*Citrus sinensis*), tangerines (*Citrus reticulata*) and other citrus. Production is scattered around the island[9] but areas of higher concentration can be found in the North/East and South of the island.

[7] Araçá is the common name of this fruit in Portuguese.
[8] The INE (National Institute of Statistics) classifies all temperate fruits as fresh fruits and groups subtropical fruits in a separate category.
[9] For more detail on host distribution see A.2.

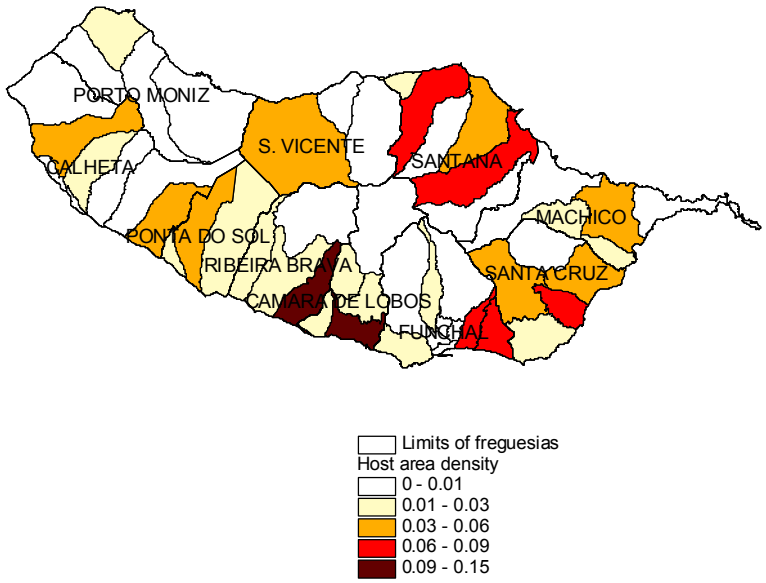

FIG. 2. Distribution map of fresh fruits and sub-tropical fruits[10] (density = area of fruit production/area of freguesia[11]).

The key medfly hosts include most of the subtropical and fresh fruits excepting bananas, avocados, lemons and cherries.

- The total annual production of the main hosts in orchards was estimated at around 8600 tonnes. Production increases to 10 864 tonnes when the production of scattered hosts is added (Table III).

- The total value of production[12] at risk from medfly was estimated at 5.3. million euros per year when scattered hosts are not considered and at 7.1 million euros per year including scattered hosts.

Table III. Annual production and value of production at risk from medfly considering average market prices

	Production (tonnes)		Value of production (euros)	
Key medfly hosts	Only orchards	Including scattered hosts	Only orchards	Including scattered hosts
Custard apple	1088	1973	943 005	1 712 890
Mango	24	24	30 874	30 874
Other subtropical fruits[13]	160	548	225 529	764 643
Apple	3230	3626	1 803 334	2 026 934
Orange and tangerines	2596	3163	1 403 116	1 707 424
Pear	1278	1278	734 080	734 080
Peach	140	168	84 700	102 850
Apricot	47	47	46 124	46 124
Loquat	36	36	68 400	68 400
Fig	1	1	3080	3080
TOTAL	8600	10 864	5 342 242	7 197 299

[10] Estimates by the Division of Fruit Production 2001. Only distribution of medfly hosts is represented on the map.
[11] Smallest administrative division.
[12] Estimated using average monthly prices in the four main markets of Madeira.
[13] Include mainly passion fruit, papaya, pitanga and guava and araçá.

4.2. Savings in fruit losses avoided

The production of these subtropical and fresh fruits is affected to a great extent by medfly which causes high production damage. Medfly was recognised by agricultural experts interviewed as the key pest of most of these fruit crops and the main obstacle to increased fruit production. Medfly is usually controlled with pesticide applications. However, the level of control achieved is low. The high population levels and the high number of generations per season (up to 8 generations in Madeira, Vieira, 19520), make it very difficult to control this pest with insecticides alone (Eng. Rui Nunes, Interview).

In custard apples, for instance, if no treatment is carried out, 90% of the production may be lost. Two to three pesticide applications are carried out every season but residual losses are estimated at around 20% on average. Furthermore, the losses are not only in terms of production losses. Serious medfly attacks occurred in custard apple in 1998 and this brought significant market problems the following after because demand fell significantly. The market thus lost was very difficult to recover. In citrus, farmers carry out an average of three treatments per season but residual losses still amount to 5 to 7%. There are other serious pests affecting citrus apart from medfly. 60% of the citrus consumed in Madeira are imported but no incentives to citrus production have been offered due to the high costs of pest control.

The economic model was used to accurately calculate the damage and losses in production caused by medfly in Madeira[14] (Table IV). The potential damage caused by medfly is immense. Even when insecticides are applied, the residual damage amounts to 2267 tonnes and the losses to 1.8 million euros per year.

Table IV. Damage and losses to producers caused by medfly

Medfly Hosts	Potential damage (tonnes)	Potential losses (thousand euros)	Residual damage (tonnes)	Residual losses (thousand euros)
Custard apple	1275	1210	751	757
Mango	12	18	4	6
Subtropical fruits	358	524	257	383
Apple	1814	1014	486	272
Orange and tangerines	1473	800	379	210
Pear	831	477	319	184
Peach	109	66	52	31
Apricot	30	30	12	12
Loquat	23	41	7	13
Fig	1.0	1.7	0.1	0.4
Total	5 926	4182	2267	1868

SIT has the potential of being more effective when the populations are managed over significantly large areas and, therefore, the pressure of flies from neighbouring orchards is greatly reduced (Hendrichs, 1996). Thus, with this technology, the residual damage and losses are expected to be much smaller. Considering the experience gained in other programmes, the leaders of Madeira-Med have assumed that with SIT it would be possible to control 98% of the population.

- Under this assumption, the total savings in the quantity of subtropical and fresh fruits resulting from the SIT programme were estimated at almost 5800 tonnes per year.

[14] The quantity of each crop maturing per month was multiplied by the intensity of medfly attacks per month. The losses were calculated by multiplying monthly damage by monthly crop prices.

- The total estimated savings in production losses amounted to 4 million euros per year.

- In comparison with insecticides SIT saves more 2200 tonnes of fruit and 1.6 million euros per year in production losses (taking the average of the first 10 years of programme operation).

However, it would take time for these benefits to be realised. The assumed timeline for the full benefits to be realized is presented in A.3.

This projection was made on the assumption that:

- Until now production in the facility had not reached the maximum level. Therefore, the density of releases were not enough to control the pest effectively in the North/Eastern part of the island and Porto Santo. In 2003, the facility has reached its full capacity (Appendix 4) and should be in the position to deliver continuously 50 million pupae per week.

- A Suppression Unit needs to be set up to carry out initial suppression operations necessary to lower populations down to the levels for SIT to be effective.

- The expansion of the facility would be completed by 2004 and, in scenario 3, the programme would start yielding results in 2005.

- Control becomes more effective when the programme is expanded because there will be less pressure from neighbouring infested areas.

4.3. Savings in backyard production

SIT is an area-wide strategy that provides medfly control in all the areas attacked by the pest. Savings in backyards, not usually protected by insecticides, can be considerable. Although this production is not usually sold in the market, its loss represent an indirect cost to the household that has to resort to buying fruit from the market. In Madeira, losses in backyard production due to medfly were estimated at 170 000 euros/year. Increased fruit production in backyards is important not only due to the economic benefits but also for diet improvement. A recent study on the eating habits of local population recommended that in order to have an adequate diet, the consumption of fruits and vegetables should increase by 50% (SRASP, 1999). If medfly was controlled with SIT, an added 130 000 kg per year would be produced in backyards contributing to an increase in dietary quality of rural populations.

4.4. Savings in costs of pesticide use

In the past, pest control in Madeira was carried out by the Division of Fruit Production organised into pest control brigades. Pest control is no longer centrally organised but the Division still operates 4 to 5 brigades providing pest control services to producers. The insecticides applied for medfly are all organophosphates (OP's). The total quantity of OP's applied by the brigades is shown in A.5. Dimethoate is the main insecticide used for medfly control in the island: 1353 L of this active ingredient are applied annually by the Fruit Production Division. Other pesticides used include diazinon (4L), thrichlorfon (59 kg), fenthion (424 L) and malathion (24L). Chemical applications are carried out all over the island, in rural and also in urban areas due to the number of backyard gardens. The risk of environmental and health problems related to pesticide use are likely to be high due to this widespread application.

The financial costs of pest control operations in Madeira are extremely high due to the difficult field conditions: the terrain is very steep and, therefore mechanization is not possible; the water sources are often distant from the plots and farms often consist of several small plots distant from each other.

Consequently, many man-hours are required to carry out control operations: it takes on average three men one week to treat one hectare.

- The amount spent by the Department of Fruit Production in medfly control was estimated at more than 700 000 euros. Producers are charged a fee for pest control services however, a considerable percentage of the costs are covered by the Department of Agriculture.

- The brigades cover only around 35% of the producers. Thus, the total cost of pesticide application in Madeira is likely to be well above 2 million euros per year.

- Despite the high cost of insecticide use the losses due to medfly damage remains quite high (Table IV).

5. POTENTIAL FOR INCREASE IN FRUIT PRODUCTION AREAS

5.1. Analysis of the sector

In recent years, the political and economic importance of the production of fruit and specifically of medfly hosts has greatly increased. Banana is still the most important fruit in Madeira but its importance has been decreasing since the last Census (1989). Rural development policies (e.g. EU action 5.1) have favoured the conversion of banana orchards to the production of other fruits in order to withstand competition from other banana producing countries. Such policies financed some of the expansion of the area of production of other fruits.

In 1989 there were 1,178 ha of bananas in Madeira but 45% had been lost by 1999 (INE, 2001). Part of this production was replaced by other agricultural products. According to the Agricultural Census data (INE, 2001), around 9% of that area was replaced by sub-tropical fruit production (custard apple, avocado and other subtropical fruits including pitanga and mango). Appendix 6 shows the evolution of the areas of some of the medfly hosts from 1995 until 2001.

Technicians and politicians alike, as expressed by the agricultural development policy, believe in the potential for the further increase in these crops is very high. The reasons for this potential are varied:

- Favourable climatic conditions for subtropical fruit production. Fruits have high quality in terms of flavour.

- Stronger marketing potential. Agricultural policies are in place to favour the strengthening of producers' organisations and marketing structures which will facilitate marketing and exports.

- The strengthening of growers' organizations will decrease the need for intermediaries and increase producer returns.

- Marketing and exports are also facilitated by increased in the availability infrastructures such as cold storage units, of transport and by improved road networks.

- Subtropical fruits, such a pitanga (*Eugenia uniflora*), may benefit from being the first to enter the international marketplace (Figure 3).

FIG. 3. Pitanga (Eugenia uniflora).

- Favourable agricultural policies. These include a number of measures to increase competitiveness of regional production in the national and international market place; to promote quality and innovation in terms of agricultural production; to strengthen organization capacity, farmers associations and producer initiative. Further measures include the support for the maintenance of human activity in rural areas, the improvement of the revenues of producers and families living off agriculture and support measures for small property farms deemed essential for environmental balance and landscape conservation. A budget of around 155 million euros for rural development was announced in 2001 by the Regional Secretary of the Environment and Natural resources (Baptista, 2001).

- Public interest. The media has promoted subtropical fruits of Madeira as exotic and high quality (Diário de Notícias, 13/05/99). Public interest was demonstrated by the number of tourists and locals that attended the "II Mostra de Gastronomia Regional", an event organised to promote regional sub-tropical fruits. The media also reported (Pereira, 2002) that there growing share of regional agricultural produce in the diet of the population.

However, there are constraints to this potential development of fruit production in Madeira. The key constraints have been identified as:

- Decrease in labour availability
- High production costs
- Profitability problems due to difficult terrain conditions and small plot size
- Marketing problems: transport costs are higher than in continent
- Low private and public investment
- Medfly attacks.

It was recognized by several experts during interviews and in publications (Carvalho, 1999) that medfly is one key limiting factor to the expansion of fruit crops in Madeira. According to the Division of Fruit Production, the trend towards the increase in area of some medfly hosts can only be sustained if medfly is controlled. Furthermore, the potential increase would be higher if the medfly problem was resolved.

5.2. Gains from increased fruit production area

The fruit crops that have the highest potential for increase are those with comparative advantages. Such is the case of custard apple. Madeira has favourable climatic conditions for the development of this fruit being able to place good quality fruits in the international market at a time when competitors do not have good quality fruits. Furthermore, custard apple has been awarded a "certificate of origin" certifying the quality of the fruits that confers it a market advantage. A key element for the economic success of custard apple production is that most producers are members of the cooperative Agripérola which has been instrumental in modernizing and organizing production and marketing. Agripérola export to mainland Portugal and France: exports have reached 109 tonnes in 2002. Innovation in husbandry practices and improved varieties will allow a sharp increase in the productivity in five years time. However, it was recognised by the one of Agripérola leaders that medfly is the only key pest and one key constraint to the expansion of this crop. Husbandry practices required for this crop would be minimal if medfly was under control. A conservative estimate is that an annual 7% area increase could be expected during the next 10 years, if this constraint was removed[15]. If other problems such as marketing are solved, increases in area could potentially be much higher possibly reaching 14%.

The area of pitanga has increased exponentially in the past two years. There are few commercial orchards in the world, so there is a window of opportunity to enter the international market. The recent increase in local demand is associated with the growth of the tourist industry and the new demands of agro-industries, which are looking to produce pitanga paste for ice cream, concentrated pitanga juice and liquors (Pereira, 2000). The commercial interest of this crop is dependent upon effective control of medfly, the key pest of this crop (Pereira, 2000). The potential annual increase was estimated to be between 15% to 50% per year during a 10 years period.

Other subtropical crops, without economic importance nowadays but with potential for increase include English tomato (*Cyphomandra betacea*), carambola (*Averrhoa carambola*) and guava. These fruits are also medfly hosts in Madeira. Their potential annual increase was also estimated between 15% to 50% per year.

The area of some fresh fruits, such as apples and pear is also expected to increase. It was estimated that a 1 to 2% annual increase in apples and pears could be reached if medfly was controlled. There is also some potential for increase in orange production for local consumption. Oranges are present in most backyards and have a social importance. During the Christmas period there is high demand for oranges and demand is nowadays difficult to satisfy due to the high damage caused by medfly. However, a number of other pests also attack oranges and so any increase in area would not be very significant (between 2 to 4%). As far as oranges are concerned most gains from medfly control would come from increased production. Within the temperate fruits, persimmons (Diopiros *kaki*), figs and loquats also have some potential in the regional market for use in marmalades, deserts, ice-creams, etc.

Considering these estimates, the annual area increase was calculated at 15 ha/year in the conservative scenario and at 33 ha/years in the more optimistic scenario. An increase between 155 to 355 000 euros per year would occur as a result of the expansion of production area (Table V). If such an increase were sustained for 10 years, this would represent an increase in production between 2.4 to 5.3 million kg.

[15] The projection for increased production area assuming medfly was controlled was based in the analysis of experts from the Division of Fruit Production (Rui Nunes, Interview).

Table V. Estimated annual increase in the value of hosts production (in euros) for a 10 year period if medfly is controlled

HOSTS	Potential production increase (Thousand euros/year)	
	Conservative scenario	Optimistic scenario
Custard apple	66.0	131.8
Subtropical fruits	33.8	36.1
Orange and Tangerine	28.1	0.3
Apple	18.0	111.2
Pear	7.3	56.0
Mango	0.9	2.2
Fig	0.1	2.4
Loquat	1.4	14.7
TOTAL	155.6	354.7

6. ENVIRONMENTAL AND HEALTH BENEFITS

The insecticides of concern for this study are the organophospates (OPs), the group of insecticides used for medfly control. Due to the wide use of organophosphates, there are many opportunities for exposure. OPs are generally much more toxic to vertebrates than other classes of insecticides. As a result, the threat they pose to humans is serious.

As for their impacts on the environment, although they are generally non-persistent in the environment, organophosphates may cause contamination of water and injury to plants or animals that were not the targets of the pesticide application (USEPA, 1999). Pesticide application may cause, for instance, the death of bees and natural enemies. Animals living near an area where pesticides are used can also be affected.

6.1. Savings in human health costs of organophosphates

Organophosphates may induce a variety of symptoms from acute symptoms that may be life threatening but preventable by an antidote, to intermediate symptoms that may arise a couple of days after poisoning and chronic symptoms. Although chronic effects are more difficult to establish there is a vast number of testimonies reporting long term illness which they believed to be caused by OP exposure. There are serious gaps in knowledge and experts agree that further research is needed on the subject (working group on organophosphates).

Acute effects on farmers health

It is difficult to assess how many farmers are affected by pesticides because there is no monitoring system in place to register occupational accidents. The fruit producers survey has been carried out to overcome information gaps that exists.

According to several experts consulted, the risk in those applying pesticides in Madeira is increased as a result of the deregulation of the sales of pesticides and their application. Very often doses used are higher than recommended (50% of the farmers surveyed believe that the recommended doses are not enough to control the pest). Technical assistance is insufficient and most of it is provided by pesticide salesmen.

Furthermore, the survey found that farmers do not take the required protective measures when handling pesticides. Studies in workers involved in the formulation or spraying of OPs have indicated that dermal absorption represents the main route of exposure (WGO, 1999). Only 14% of the respondents claimed they wear gloves when applying pesticides therefore the level of risk exposure is quite high.

- In the light of the findings of the survey, the total costs of insecticides on farmers' health were estimated at around 11 500 euros per year.

Those involved in the sale of OPs may also be exposed, especially if appropriate workplace practices are not adopted. This seems to be the case in Madeira, where many expert accounts report the inadequate storage conditions of many points of sale of pesticides. Although no data is available on occupational poisoning of pesticide salesmen, the risk is considered to be high and the human costs are potentially very high (Figure 4).

FIG 4. Child with sprayer (Madeira).

Household and secondary exposure to occupational uses

Although infrequent in Portugal, accidents with pesticides are amongst the most serious[16]. Intoxication often requires hospitalisation and follow-up treatment. In Portugal, some fatal accidents have occurred due to accidental pesticide intoxication although none has been registered in Madeira. However, the EHLASS reports some cases of accidents involving adults.

- The cost of pesticide effects on household and farming families was estimated at 7500 euros per year.

[16] Information from the european Home Leisure Accidents Surveillance Systems (EHLASS).

Impacts on consumers' health

According to the Department of Residue Analyses[17], the levels of pesticide residues in fruits are not worrying but the situation could deteriorate. Nevertheless, the EHLASS reports that during a five year period, two serious accidents with children leading to hospitalization due to ingestion of contaminated peaches. Although there is no information on the insecticides involved, it is very likely that one directed at medfly control would have been used, as this is the most devastating insect pest in this crop.

- The cost of child intoxications by pesticides was estimated at 3300 euros per year.

A further matter that must be taken into account is the existing concern about the short and long terms effects of consumer exposure to dimethoate. According to the United Kingdom Pesticide Safety Directorate (PSD), there is a risk that the combined exposure from all approved uses and imports could potentially exceed acceptable levels. The problem is considered especially serious for toddlers and infants. These concerns have lead to the suspension of approvals of dimethoate in the UK (PSD, 2001). If the concerns expressed by the PSD are substantiated, the impacts of OP's in consumer's health may prove to be considerably higher than estimated here.

Monitoring and prevention costs for residues in fruits

These costs are incurred by the Residue Analysis Department for monitoring of pesticide residues. The total costs of monitoring the substances used for medfly control were estimated at around 4800 euros per year.

This value is likely to be an underestimation as additional costs with pesticide monitoring are incurred by private and public institutions for pesticide residue monitoring. Furthermore, the costs with pesticide monitoring are likely to increase in the near future. The number of active ingredients being used in agriculture is increasing and, furthermore, the new active ingredients are more difficult to analyse as each of them has a separate methodology of analysis[18].

Prevention costs include the costs of supporting policy measures aiming at reducing pesticide use. Within the framework of the common agriculture policy, the rural support scheme[19] has one measure directed towards the reduction of the risks in the distribution and application of pesticides. The costs that could be attributed to the prevention of pesticide use for medfly control were estimated at around 20 600 euros per year. Although these have not been included, the costs of providing advice to farmers concerning pesticide incurred by the Division of Fruit Production, could also be considered as prevention costs.

6.2. Savings in environmental costs of organophosphates

Madeira's environment remains relatively unspoiled compared to the rest of Europe. However, the development the island has undergone since the 1970s has subjected the island's environmental system to many of pressures (Sziemer, 2000). Clearly recognising that environmental conservation is a fundamental part of any development plans for the island, Madeira's Regional Government has proved to be seriously committed to the implementation of a sound environmental policy via the support it provides to several environmental protection agencies.

As far as agriculture is concerned, the main negative impacts identified in the Regional Plan for Environmental Policy[20] include erosion, soil, water and air contamination, residues production and excessive water consumption for irrigation. Pesticides are one of the inputs that contribute both to contamination and to residue production.

[17] Secção de Análises de Resíduos, Directorate General of Agriculture.
[18] Such is the case of spinosad (e.g. Success) and chloronicotinyls (e.g. Confidor).
[19] PAR- *Plano de Apoio Rural*.
[20] Plano Regional da Política do Ambiente.

Monitoring and administration costs

Water pollution: Exposure to OPs *via* drinking water is limited. However, several United Kingdom Environment Agency studies found that in that country the presence of diazinon in river water was widespread and that, in some cases, levels were above the maximum allowable concentration in the Environmental Quality Standard. In Madeira, there are no reports of water contamination by pesticides. However, there are risks that contamination may occur. For this reason, some pesticides are monitored in water. A percentage of the costs of monitoring pesticides in water are included as a proxy for costs of pesticide contamination of drinking water (Table VI).

Table VI. Summary of annual indirect benefits of Madeira-Med

EXTERNALITIES	Value (euros)
HEALTH EFFECTS	
In those applying insecticides	19 003
Consumers of food treated with insecticides	3283
Monitoring costs in fruits	4 821
Monitoring costs in honey	48
Treatment or prevention costs	
organic agriculture	2968
Subtotal	20 578
ENVIRONMENTAL EFFECTS	
Water and soil pollution	
Decrease of biodiversity and resilience of the ecosystem	
natural enemies	7840
loss of bees	4 684
animals injured	5167
Monitoring of drinking water	687
Waste	7101
Abandonment of fruit production land	
rat control	732
prevention	11 759
Social benefits capacity building	16 250
WTP for organic fruits	585 953
Total	690 874

Monitoring of dangerous substances: Within the framework of the EU Environmental Policy, a monitoring project for dangerous substances will be implemented by the Regional Directorate of the Environment in Madeira. Although agricultural substances are not the main concern they may become so in the future. A percentage of the costs incurred in monitoring the pesticides under this programme was included as an additional cost of pesticide use.

Decrease of biodiversity and resilience of the ecosystem

Killing of natural enemies: Pesticides are one of the factors responsible for the destruction of natural enemies and, as a consequence, for the increase in damage by pests that otherwise would be secondary pests. In Madeira, this phenomenon is particularly visible in citrus where pesticides are considered to be responsible, for instance, for the increase in damage caused by *Panonychus citri*. Taking citrus as an example, cost estimates were made assuming a certain probability that natural enemies are killed by pesticides and that this will give rise to an outbreak of *Panonychus citri.* The costs were estimated at around 7800 euros per year.

Effects on bees: Most of the pesticides used for medfly control are toxic to bees. Experts estimated that, in Madeira, 15 to 20% of honeybees are killed by pesticides. Additionally, when the pesticide dose is not enough to kill the bee, it will affect behaviour and decrease pollination. Pollination losses are believed to be around 45% higher that the losses due to killed honeybees (Karalliedde & Meredith, 2000). Based on these values, the total costs of the impacts of insecticides on honeybees were estimated at around 4700 euros per year.

Other animals: Pimentel *et al.* (1993) report that 20% of the total value of animal production is lost to illnesses and that 0.04% of the deaths reported to veterinarians were caused by pesticides. Pimentel *et al.* calculated that costs of poisoning treatment were 45% higher than loss by death. If these values were to be reported to animal production in Madeira, it would mean that almost 2500 euros per year in farm animals are lost to pesticide poisoning.

Although no specific information was found on the subject in Madeira, the survey of fruit producers found that 10% of the farmers reported accidents with domestic animals they believed were caused by pesticides. Assuming that all the poisoned animals were taken to the veterinary, the costs of animal intoxication would be around 2600 euros.

Costs of waste management

Waste is a serious problem, especially on small islands like Madeira. The accumulation of containers of hazardous substances was identified as one of the negative impacts of agriculture in Madeira (Nunes Correia & Melim Mendes, 2000). The number of containers of pesticide used for medfly control was estimated at more than 5000. Many of these containers are not properly disposed of and constitute a source of pollution. The survey of farmers indicates that 26% of containers are thrown onto unused land. A further 50% of the containers are either buried or burnt, which is not considered good environmental practice. As new waste management legislation is being implemented[21], a system of collection of pesticide containers will have to be set up. The cost of such service was estimated at approximately 7000 euros per year.

Costs of abandoning fruit production

Despite some of the negative environmental impacts of agriculture, its abandonment has even more serious consequences (Nunes & Melim, 2000). The abandonment of agricultural terraces, for example, causes the collapse of the stone walls and the subsequent increase of erosion. It also leads to the establishment of weeds and to the increase in the risk of fires. According to the Department of Civil Protection, most of the fires occur in agricultural areas dedicated to the production of sub-topical fruits and that have been abandoned.

One way of quantifying the costs of abandoning fruit production is by using as a proxy the treatment costs incurred by the government to recover agricultural areas. Although the causes for abandoning of fruit production in Madeira are multiple and complex, medfly problem is view by many experts as one of the key reasons to this. Thus, by controlling medfly, Madeira-Med is contributing to the maintenance of agriculture. A percentage of the prevention costs can be therefore included as benefits of Madeira-Med. The savings in prevention costs that could be obtained with Madeira-Med were estimated at around 12000 euros[22].

One of the problems associated with the abandonment of agricultural areas is the increase in the quantity of rats. Rats are controlled with centrally organised programmes and, in the last years, although the quantity of pesticide applied increased it is not enough to effectively control the population. The costs of rat control due to the abandonment of fruit production areas were estimated at

[21] *Sistema de Gestão de Embalagens e Resíduos de Embalagens.*

[22] Within one of the measures of PAR (Action 2.1.7) there is one sub-action directly aimed at the conservation of rural landscape. This estimate took into account total PAR budget, the percentage that could be used for these measures, the area of fruit production as a percentage of total agricultural area and the percentage of pesticide use for medfly control.

around 730 euros. A similar estimate could be made to estimate the increase in the number of fires due to the abandonment of fruit production.

Benefits of organic farming

In the past years in Madeira, there has been increasing interest for organic farming: The Regional Government has created a department dedicated to support organic production and the number of certified producers is increasing. The value added that can be derived from the adoption of organic farming in Madeira is very significant. For instance, in a study commissioned by the Society for the Development of Madeira[23], to identify the potential industry of interest to be located in the tax-free area of Madeira[24], indicated the production of natural products as the one with most market potential. The production of raw materials, chemically free, is a prerequisite for such enterprises to go ahead. Furthermore, the production of high quality organic products can give to Madeira's agricultural products a market advantage in international markets.

Mainly due to the natural conditions on the island, the agricultural systems remain in many ways traditional. Therefore the transition to organic farming is not a very difficult one. As far as fruit production is concerned, it was agreed by several experts that medfly is one of the main obstacles to organic fruit production. The control of the pest could dramatically increase the area for organic production. Based on the potential increase in organic fruit production, the benefits of SIT for organic production were estimated at around 3000 euros.

7. WILLINGNESS TO PAY FOR ORGANIC AND LOCAL PRODUCTS

Consumers willingness to pay (WTP) more for locally produced fruit was clearly positive: 78% of the respondents indicated that they would pay more for local products. In fact, 40% of the respondents consider that imported fruit has less quality than the locally produced and only 8% believed imported fruit was better. The average additional WTP was situated at 15% for oranges and 16% for mangoes. The total additional WTP for local products was estimated at around two million euros.

The survey showed an even higher willingness to pay more for organically produced products with 84% of the respondent being prepared to pay more. In average, the respondents were willing to pay 38% more for organic oranges and 25% more for organic mangoes. The total additional WTP for organic fruit was estimated at around 2.9 million euros. Considering that, as has been discussed previously, one of the key objectives of organic farming is to decrease pesticide use and that, in the case of fruit production, medfly is the constraint to its development, a percentage of the value of the contingent valuation was considered as a benefit of SIT.

8. SOCIAL BENEFITS: CAPACITY BUILDING

Social benefits include the value added for Madeira of being the pioneer in the implementation of a large scale and area-wide, technologically advanced pest suppression programme using an environmentally friendly pest control method. The existence of such a project has already strengthened the position of Madeira in the international scientific arena. Madeira-Med technicians have participated in several international conferences and have written more than twenty papers (Carvalho, 1999). The importance of these events for the promotion of Madeira as a place of innovation and an environmentally conscious place cannot be dismissed.

[23] Sociedade de Desenvolvimento da Madeira.
[24] This is an industrial area created as part of a bid to diversify the economic activity on the island.

Furthermore, the know-how acquired by the technicians of the Madeira-Med is extremely valuable for the implementation of any other integrated pest management programme. Additionally, the intense monitoring programme enables Madeira to be ready to tackle more effectively any invasion of a new pest. For instance, early detection of the peach fruit fly (*Bactrocera zonata*), now present in the SE Mediterranean, would save farmers about 16 000 euros/year.

9. BENEFITS FOR THE TOURIST INDUSTRY

The benefits that Madeira-Med may bring to the tourist industry are two-fold: Firstly, it allows the production of regional fruit production and second it contributes to the conservation of natural and cultural heritage.

The fruit consumption in hotels represents more than 26% the overall fruit consumption in Madeira. According to interviews carries out, hotels spend a daily average of 1.4 euros per client. The total hotel fruit consumption was thus estimated at more than 6 000 tonnes and 8 million euros. It is therefore important that the industry uses a product that is of good quality and satisfies their clients.

In a survey conducted with tourists in Madeira to assess their views of fruit quality and the environment, the respondents showed a clear concern for quality ranked as the most important factor affecting the decision to buy fruit. Almost 50% of the tourists prefer to consume fruit produced locally. 35% believe that the quality of imported fruit is worse and only 5% believe imported fruit has higher quality. Tourists are prepared to pay 20% more for local fruits. Furthermore, there is also a concern about the environmental impact of the production method. In 71% of the interviews there was a positive extra WTP for both organic products. Tourist average additional WTP for organic product is at 22%.

- Based on the WTP, the total added value that organic fruit production has to the tourist industry in Madeira was estimated at 1.8 million euros. A percentage of that may be considered as a benefit of Madeira-Med to the tourist industry.

Tourism in Madeira is based on the value of the landscape and cultural heritage. The Tourism Development Plan[25] recognises that tourism uses this "Environmental capital" and that it depends upon its conservation if it is to succeed. Furthermore, the maintenance of this capital depends upon the maintenance of the social and cultural heritage of the population in different parts of the island. Interviews with stakeholders in this sector have confirmed that it is widely accepted by the sector that the maintenance of agriculture brings important benefits to the tourist industry. Data collected during the interviews allowed the identification and quantification of the benefits presented below (Table VII).

[25] Plano de Ordenamento Turístico da Região Autónoma da Madeira (2000).

Table VII. Summary of annual benefits of Madeira-Med to the tourist industry

	Value (euros)
Savings in costs of conserving agricultural areas used by tourists	33 759
Maintaining levadas Madeira's irrigation channels used as hiking paths for tourists	
Maintaining terraces and walls	
Prevention of fires	
Maintenance of rural heritage	
Increase tourist spending	
Opportunities for the development of new tourist activities in the rural milieu	8265
Increase tourist spending by offering high quality products	353 879
Increased number of tourists by increasing attractiveness	
Environmental certification of hotels and tour operators[26]	99 133
Increases viability of rural tourism	43 967
TOTAL	539 003

10. ECONOMIC ANALYSIS

The aim of this analysis was to evaluate the attractiveness of the three different strategies: Scenario 1: the *status quo* scenario; Scenario 2, where production is maintained but control efforts are directed at selected areas in the Eastern parts of the island and Scenario 3, the expansion scenario. Two types of analysis were performed: a financial one where only the gains to farmers from increased production are considered and a more comprehensive economic one where the indirect benefits calculated in the previous sections were incorporated.

The analysis without inclusion of the indirect benefits of the programme indicates that there would be no financial benefits from the *status quo* scenario. Although all the indicators are negative this option, nevertheless, yields important benefits to fruit producers by saving on average 650 000 euros per year more than insecticide based control in the first 12 years of the programme.

Scenario 2 (the East Madeira scenario) is more favourable than the *status quo* scenario. Although the NPV is negative, the IRR becomes positive after 15 years. This difference is due to the higher

[26] Based on WTP for a hotel with environmental certification.

concentration of the production targeted with this strategy which explains that the average annual production savings are higher than for the *status quo* scenario amounting to 780 000 euros.

The expansion scenario gives a negative NPV in the short term but both economic indicators, the NPV and the IRR, are positive in the long term. The average yearly benefits to farmers in terms of saved production amount to 1.6 million euros more than if insecticides were used (Table VIII).

Table VIII. Economic indicators for the three technical scenarios

Strategy	Time horizon	NPV (mn euros)	IRR
Scenario 1 STATUS QUO	6 years	-6.3	NA
	12 years	-7.0	NA
	15 years	-7.3	NA
Scenario 2 EAST MADEIRA	6 years	-4.5	NA
	12 years	-2.0	-2%
	15 years	-1.3	2%
Scenario 3 EXPANSION	6 years	-0.1	4%
	12 years	12.6	25%
	15 years	14.6	27%

The benefit of the East Madeira scenario is more visible when the net benefits are analysed: whilst they are always negative in the *staus quo* scenario, in the East Madeira scenario they become positive after five years. The analysis shows positive net benefits soon after the expansion of the facility[27]. However, it would take four years for the project to break even.

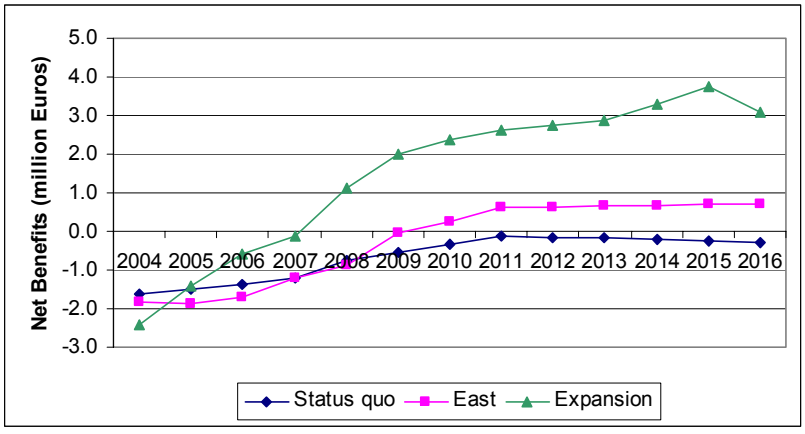

FIG.5. Net benefits for the three technical scenarios (in million euros).

The situation changes dramatically when indirect benefits are included in the calculations demonstrating the societal benefits of the programme (Table IX). The NPV's for the *status quo* scenario are still negative but the IRR becomes positive in the 12 year projection. If the longer time horizon (15 years) is considered, the IRR increases to 8% and the NPV becomes positive (1.3 million euros). The results for the East Madeira scenario show that both the NPV and IRR become positive in

[27] It was assumed that enlargement would only happen in 2004.

12 years. The IRR increases from –2% to 21%. Unsurprisingly, all the indicators are positive in the expansion scenario both in the short and long terms. In the long term, the NPV is approximately 21.8 million euros with a very favourable IRR (33%).

Table IX. Economic indicators for the three technical scenarios (including indirect benefits)

Strategy	Time horizon	NPV (mn euros)	IRR
Scenario 1 STATUS QUO	6 years	-3.9	NA
	12 years	-0.001	5%
	15 years	1.3	8%
Scenario 2 EAST MADEIRA	6 years	-1.3	NA
	12 years	7.5	21%
	15 years	10.6	23%
Scenario 3 EXPANSION	6 years	1.1	11%
	12 years	16.2	31%
	15 years	21.8	33%

Even though some of the economic indices are negative, the average yearly benefits in the first 12 years of the *status quo* scenario amount to 2.5 million euros (including direct and indirect benefits). In five years, the net benefits of the project become positive and, as the figure shows, the project breaks even after 10 years. The East Madeira scenario, due to a more efficient control strategy, breaks even after seven years.

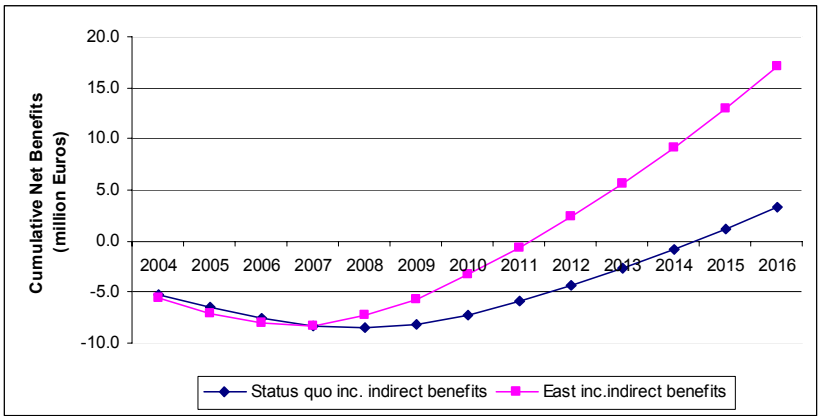

FIG. 6. Cumulative net benefits for status quo and East Madeira scenarios including indirect benefits.

For the expansion scenario, the average yearly indirect benefits from using SIT in the whole of Madeira island amount to 4.3 million euros. In this option, the programme breaks even six years after the expansion and shows significant benefits thereafter (Figure 7).

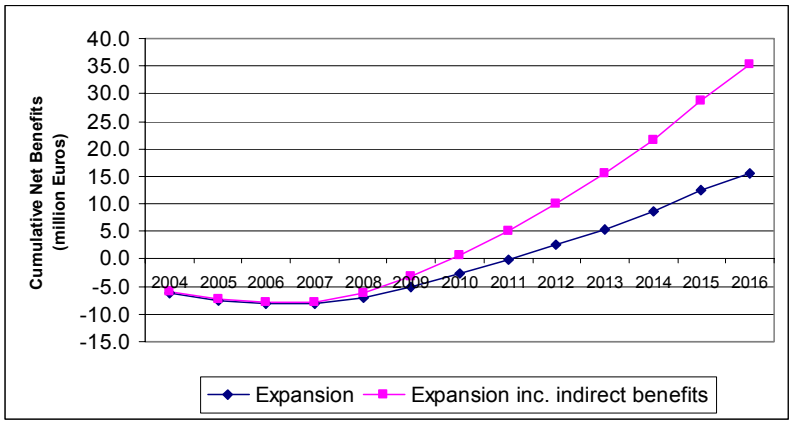

FIG. 7. Cumulative net benefits for the expansion scenario (with and without indirect benefits).

The above results were based on our best estimates of a number of key variables. However, some of the variables included in the calculation were considered to have some associated uncertainty. Several variables were tested for their impact on the NPV. The most sensitive variables identified are presented here ranked in terms of their sensitivity[28]:

- The rate of growth of fruit prices
- The rate of increase in the programme costs (for both technical scenarios)
- The discount rate
- The potential savings in crop losses (including farm and backyards) gained with SIT
- The costs of expanding the programme to produce 100 million sterile males.
- The value of indirect benefits
- The potential for area increase.

A sensitivity analysis was performed by attributing maximum and minimum values for each of the uncertain variables. The table below shows the original point value and the tested values (Table X).

Table X. Value attributed to tested variables

Variable	Original point value	Minimum value	Maximum value
Discount rate	5%	3%	10%
Changes in fruit prices	5.5%	0%	7%
SIT expansion costs	2.8 million euros	2.8 million euros	50%
Evolution of SIT costs	6%	5%	7%
Medfly control	98%	60%	98%
Indirect costs	100%	100%	200%
Potential for area increase	155.6	77.5	354.6

[28] % of variation of the NPV caused by a 5% change in the variable.

The evolution of fruit prices is a key determinant factor in the analysis. Firstly, there is a high uncertainty associated with it. Although agriculture output prices are expected to decrease overall, the opposite tendency is expected for some commodities such as fruits. An analysis of the evolution of the prices of fruit in Madeira for the last seven years has revealed than the prices increase at an average rate of 5.5% per year, the rate chosen for the base scenario. However, the fluctuation in market prices of fruits is very high making it difficult to predict. Secondly, the sensitivity tests revealed that this is one of the most sensitive variables in the model. For instance, for the expansion scenario, a 1% variation of this variable leads to an increase of 3 million euros in the NPV.

According to the information available, it seemed reasonable to test this variable for two values: 0% and 7%. The 7% increase would, in effect, be realistic in case farmers would produce value added commodities such as organic products. Indeed, by effectively controlling medfly without insecticides, SIT could contribute to an expansion of the organic farming area. The analysis shows that, in the absence of any increase in fruit prices, the *status quo* scenario ceases to be viable as all economic indicators become negative. The East Madeira scenario without indirect costs is also unviable, however, if indirect benefits are included the IRR is positive in the long term. Expansion still carries a positive IRR in the long term. On the contrary, if there is an increase in price of 7% a year, the results for scenarios 1 and 2 become more favourable.

The rate of yearly increase in programme costs used in the original scenario was based in the analysis of the evolution of costs of Madeira-Med from 1998 to 2002. However, it is also possible that this rate is being over-estimated. The analysis shows that, even a small decrease in this rate would render the NPV for the *status quo* option including indirect costs positive (from –0.001 to 1.7 million euros). It would also benefit the East Madeira scenario. By contrast, if the costs of the programme increase at 7% a year, the East Madeira scenario without indirect benefits ceases to be viable even in the longer-term scenario.

There are a wide range of approaches to determine the discount rate. In the case of this project, it seemed reasonable to assume that the lower level should be set at 3% and the higher at 10%[29]. The analysis of the impact of this variable showed that a lower discount would be more favourable for the expansion option which would give positive results for all indicators. On the other hand, even if the discount rate increases to 10%, the results become less favourable for the status quo scenario which would have all the NPV's negative even when indirect benefits are included.

For the potential savings obtained with SIT, the worst case scenario would be that no benefits at all would be gained (if the technology failed to work). Given the number of successful cases of application of this technology and the amount of investment in research and development, the probability that the problems encountered in Madeira cannot be solved is low. However, a more likely possibility is that results are lower that expected. It was found that if only 60% of the predicted savings are obtained, the IRR still remains positive for the expansion scenario including indirect benefits. Below this threshold, all economic indices become negative.

In the case that the expansion costs had been underestimated, the results were tested for successive higher programme costs. It was concluded that even if the costs increased by 60%, the expansion option (excluding indirect benefits) would still remain viable in the long term.

Finally, the value of the environmental and health benefits is uncertain. The financial estimates already portray the situation where there are no indirect benefits. However, it seems more likely that the estimates carried out are an underestimation. For instance, in the calculation of health benefits, the costs of one day of lost work were valued at around 25 euros based on the average monthly revenue from agriculture. However, other studies[30] valued one day of lost work at 100 euros. The sensitivity analysis shows that if the benefits were set at double the initial value, all the indicators would be

[29] Rate adopted recently by the World Bank, for instance (Massimo *et al.,* 2002).
[30] Pimentel *et al.*(1993) and Pretty *et al.*(2000)

positive for the East Madeira option (the NPV for 6 years was negative) and the indicators for the *status quo* scenario in the 12 year projection also become positive.

The previous analysis gives an idea of what may happen in extreme cases. Subsequently, the results were tested using a risk analysis software Crystal Ball™[31] In this instance, the variables were made to vary between values considered reasonable (Table XI).

Table XI. Values attributed to the variables for the risk analysis

Variable	Original point value	Type of distribution	Minimum value	Maximum value	New distribution mean value
Discount rate	5%	Triangular	3%	7%	5%
Changes in fruit prices	5.5%	Triangular	3%	7%	5.2%
SIT expansion costs	2.8 million euros	Triangular	2.8 million euros	+30%	+10%
Evolution of SIT costs	6%	Triangular	5%	7%	6%
Medfly control	98%	Triangular	40%	98%	80%
Environmental costs	100%	Normal	70%	130%	100%
Potential for area increase	155.6	Triangular	75	354.6	191

Substituting the original point values with the distributions, the original value of the indicator changes. The results show that the economic indicators for the *status quo* scenario become negative in all scenarios. The East Madeira scenario without indirect benefits becomes unfavourable, however the indicators remain positive including indirect benefits in the long term projections. The only change registered in the expansion scenario is that the short-term projections become negative (Table XII).

[31] Crystal Ball™ software is an Excel add-in that allows probability distributions to be assigned to some of the model parameters. The user selects a probability distribution from a distribution gallery and the software then conducts Monte Carlo simulations where the model is run thousands of times using both fixed parameter estimates and those sampled randomly from the selected probability distributions. This software produces outputs such as the probability distribution of parameters such as the NPV or the likelihood of breaking-even or better

Table XII. Economic indicators after substitution of original point values by distributions

INCLUDING DIRECT BENEFITS			
Strategy	Time horizon	NPV (million euros)	IRR
Scenario 1 STATUS QUO	6 years	-7.9	NA
	12 years	-11.3	NA
	15 years	-12.6	NA
Scenario 2 EAST MADEIRA	6 years	-6.5	NA
	12 years	-7.4	NA
	15 years	-7.8	NA
Scenario 3 EXPANSION	6 years	-4.5	NA
	12 years	0.4	4%
	15 years	1.3	7%

INCLUDING INDIRECT BENEFITS			
Strategy	Time horizon	NPV (million euros)	IRR
Scenario 1 STATUS QUO	6 years	-5.8	NA
	12 years	-4.7	NA
	15 years	-4.2	NA
Scenario 2 EAST MADEIRA	6 years	-3.7	NA
	12 years	1.6	9%
	15 years	3.6	12%
Scenario 3 EXPANSION	6 years	-1.0	-0.1%
	12 years	11.8	24%
	15 years	16.8	26%

Figure 8 shows the distribution of the NPVs for the expansion scenario (12 year projection), based of the data randomly sampled for the 1000 simulation iterations. The most important conclusion is that, considering the assumptions for the distribution of the variables, there is more that 90% probability that this scenario is viable in the long term confirming the robustness of this scenario. The East Madeira scenario also withstands this test with almost 80% probability that the NPV is positive.

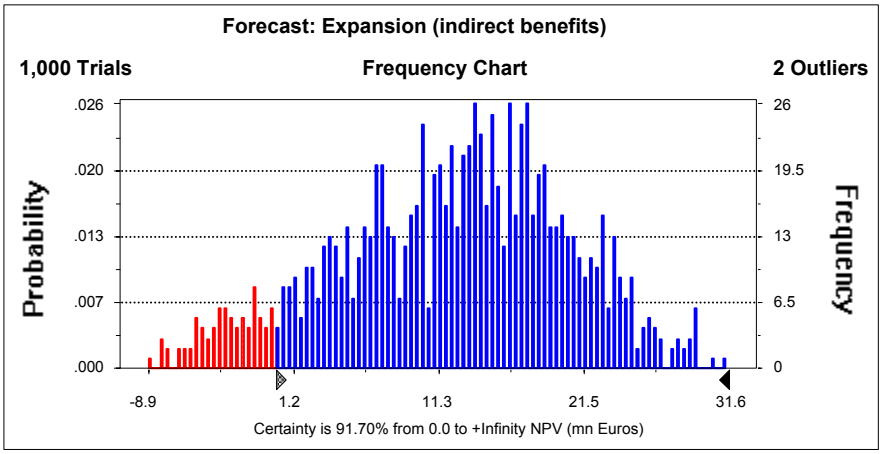

FIG. 8. Forecast for the distribution of NPV's for the expansion scenario (12 years).

11. CONCLUSIONS

The analysis conducted evaluated the costs and benefits of the SIT programme in Madeira in comparison with conventional pesticide use. It had a broad scope as it attempted to evaluate not only direct and indirect financial gains for producers but also other aspects of the investment such as environment and social effects.

The main conclusions are the following:

- The main financial gains of Madeira-Med lay in the increase in revenue for producers from a decrease in production losses. Medfly has proved very difficult to control with conventional pesticide applications. Although high quantities of insecticides are applied, the residual losses remain at around 1.8 million euros. The effective use of SIT would reduce damage to less than 3% leading to the production of an extra 2.2. million kg of fruits per year and to an annual increase in 1.6 million euros of revenues to producers.

- Further to that producers and home-owners would benefit from increased production in backyards. These gains were estimated at an average of 170 000 euros per year in the first 10 years.

- Indirect benefits for producers also include the gains from increased planted area. There are a number of fruit crops with high potential for increase in Madeira if medfly is controlled. These include mainly subtropical fruit crops such as custard apple, pitanga and passion fruit. Areas of citrus, figs, loquats and apples also have some potential for increase. The conservative estimate indicated that an increase of 155 000 euros per year could occur as a result of the expansion of production area. If other problems were solved, the average benefits from increase area could reach 355 000 million euros/year.

- The key societal benefits included benefits in terms of improved health and environment and social benefits in terms of capacity building. An effort was made to quantify only those indirect costs that could be directly attributed to pesticide application for medfly control in fruit crops. Of these benefits that could be quantified, the most significant ones came from:

  — Savings in health costs for those applying insecticides

  — Savings in costs incurred by the state in preventing adverse impact from pesticide use

  — Savings in costs of control of related pests

  — Social benefits in terms of capacity to deal with other pest outbreaks.

  These societal benefits were estimated at more than 690 000 euros annually.

- Important benefits are also to be gained in the key sector of the economy: tourism. The benefits of Madeira-Med for the tourist industry included the contribution to the production of high quality fruit. The production of local quality fruit and/or without pesticide residues is a value added to the tourist industry, which currently imports most of the fruit that is consumed in hotels.

  Another important indirect benefit for tourism comes from the programme's contribution to the maintenance of agriculture by removing one obstacle to the profitability of fruit production: medfly. The abandonment of agriculture causes landscape degradation in a number of ways: destruction of the characteristic terraces and the consequent soil erosion, increase in invasive plant species and deterioration of the landscape amongst others. It also causes social problems due to the human migration to the coast and hinders the development of rural tourism.

  The benefits for the tourist industry resulting from this programme were estimated conservatively at 500 000 euros/year.

- Very often, the valuation of some of these effects was difficult to quantify fully in monetary terms so there is a need to appreciate them also qualitatively.

  These include the value of the increase in organic farming. Medfly was identified as one of the main constraints to the conversion of fruit production to organic agriculture as there is no other alternative to insecticides for medfly control. It is important to refer again that the conversion to organic agriculture may be one of the keys for Madeira fruit production to become competitive in the European market place. Further opportunities arise from the production of organic produce for use as raw materials in transformation industries to be set up in the industrial tax heaven established in the North of Madeira.

  Additionally, the increased attractiveness of Madeira as an "organic" destination and the importance of the maintenance of rural landscape were difficult to quantify fully.

Under the scope and assumptions of the analysis, the main conclusions of the cost benefit analysis are the following:

- The most favourable option is the expansion of the programme to the production of 100 million sterile males per week, which would allow an expansion of the medfly control. In the long term this strategy gives positive returns whether indirect benefits are considered or not. The IRR in the 12 year projection is very favourable in both cases: 25% including only direct benefits and 31% including indirect benefits.

- Inclusion of the indirect benefits makes the expansion option viable in the short term indicating the high benefits for the environment and the society to be gained from the project.

- Furthermore, the sensitivity analysis shows the robustness of this strategy. The economic indicators remain positive for all the scenarios tested (except when control levels fall below 60% of the expected). Furthermore, the risk analysis carried out using Crystal Ball, indicated that, considering the assumptions for the distribution of the variables, there was more that 90% probability that this scenario is viable in the long term.

- The East Madeira scenario also presents itself as a viable option, without the need for greater investment. Although in the first years the NPV's are low this strategy gives positive returns after five years without indirect benefits and after four years including indirect benefits. This scenario would call for a change in the present control strategy and would require an effective cultural control programme to be put in place in the targeted areas in order to be effective.

- If the programme is dimensioned to produce 50 million sterile males and indirect benefits are not included (*status quo*), the economic indicators are negative. However, when the indirect benefits are added, the IRR becomes positive in the long-term scenario. The robustness of this result is however, low and, after the risk analysis, the IRR becomes negative.

- To finish it may be noted that a comprehensive project evaluation should include many aspects of the project. Such an evaluation should include, for instance, a technical evaluation and a safety evaluation. The economic analysis is a tool that assists in coming to a project decision but, the results of such an analysis should be considered in conjunction with the other aspects.

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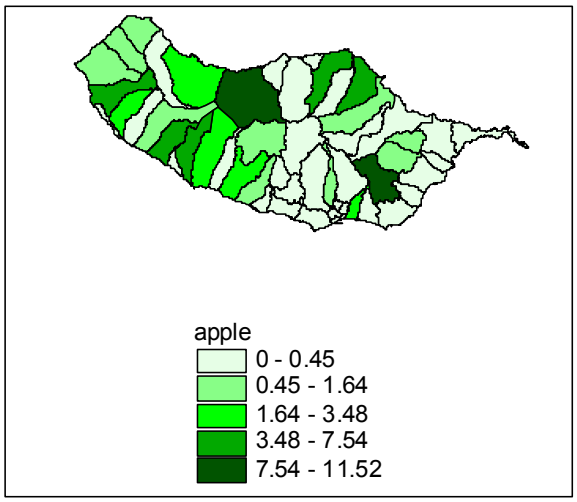
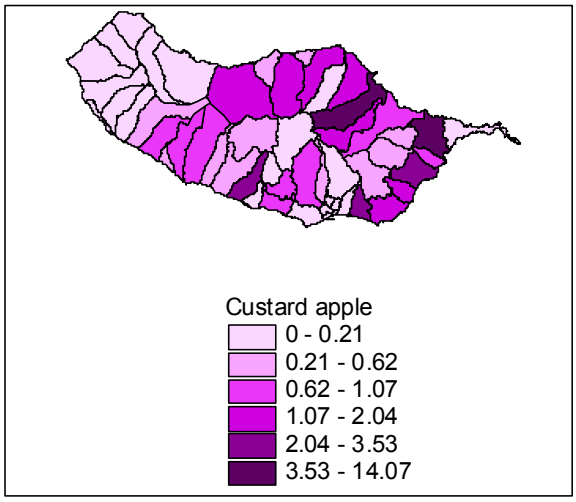
Appendix 1:
KEY STAKEHOLDERS INTERVIEWED

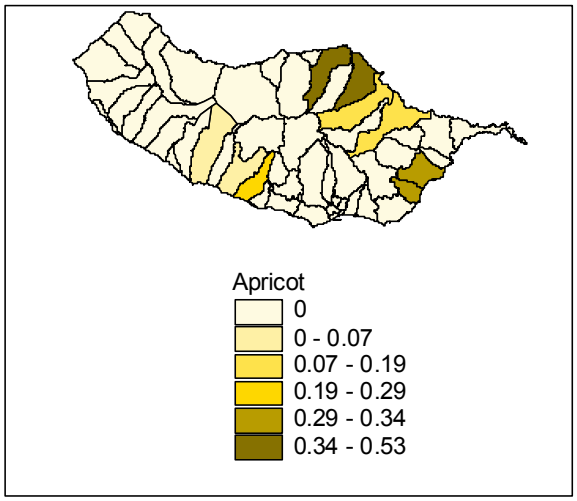
1	Regional Environmental Department		
1.1	Agriculture Directorate	Direcção Regional de Agricultura- Regional Director	Manuel Pita
		Divisão de Serviços de Producao Agricola (DSPA)	Rui Nunes
		Divisão de Protecção Integrada da DSPA Secção de Entomologia Divisão de Análises Agrícolas	Ana Paula Félix Miguel Franquinho Paulo Jorge Fernandes
		Divisão de Serviços de Investigação Agricola- - Head	Angela Brazão
		Divisão de Serviços de Investigação Agricola – Director Madeira-Med Programme	Luis Dantas
			Rui Pereira Alexandre Rodrigues
1.2	Veterinary Deparment	Laboratório de Veterinária	Margarida Neves da Costa
1.3	Environment Directorate	Direcção Regional do Ambiente Conservação da Natureza	Adelaide Valente Bernardo Faria
1.4	Water Management Institute	Instituto de Gestão da Água – President	Pimenta de França Alexandra Reynolds
1.5	Organic Agriculture Division	Missão Biológica	José Carlos Marques Alcino Silva
1.6	Madeira Nature Reserve Authority	Parque Natural da Madeira	Paulo Silva
			Graça Mateus
2	Tourism and culture Directorate	Direção Regional do Turismo e Cultura- - Regional Director	Bruno Pereiro
3	Health authority	Coordinator of Health Services from Funchal to Porto Moniz	Maurício Melim
4	Tourist industry association	Associação Industria hoteleira	Lars Hansen
5	Growers association	Agripérola	Nely Rodrigues
6	FRUIT INDUSTRY		
6.1	Supermarket chain- SuperSá	Operational Director	Nelson
6.2	Qualifrutas		Carlos Pimenta
7	HOTELS & RESTAURANTS		
7.1	Hotel Choupana Hills		Antonio Silva
7.2	Restaurant Casa Madeirense		Filipe Gouveia
7.3	Hotel Madeira Palácio		Luis Lume
7.4	Restaurant Eat Well		Yves Gautier
7.5	Quinta do Furão		Miguel Freitas
7.6	Hotel Jardim Atlântico		Luís Calaça
7.7	Reids Hotel	Food and beverage manager	Marcelino Rodrigues

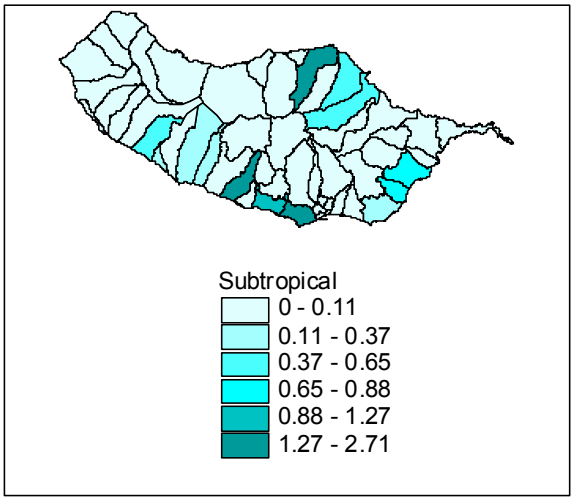
8	Tourist Agency	
8.1	Abreu Viagens	Guida Gomes
8.2	TUI	Ana Barbosa
8.3	Terras de Aventura	Pinto Machado
9	Quercus Madeira	Helder Spinola
10	Regional Agency for Energy and Environment of Madeira AREAM	Filipe Oliveira
11		Rui Vieira

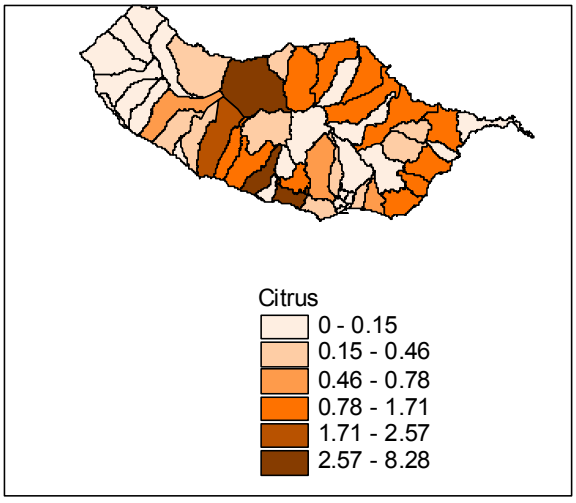
Appendix 2:
DISTRIBUTION OF KEY HOSTS AREA
(IN HECTARES) PER FREGUESIA

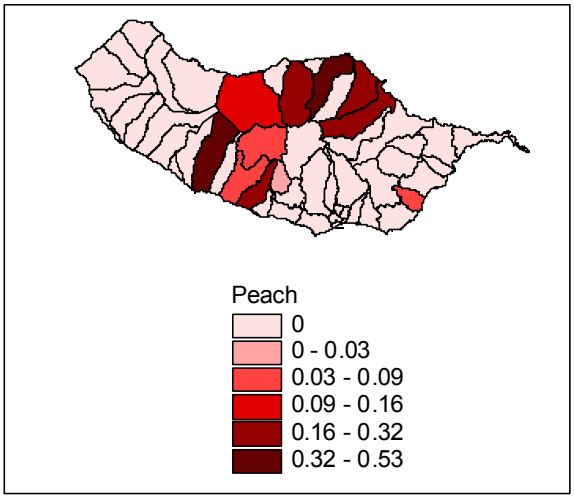












Appendix 3:
ASSUMPTIONS ON THE PERCENTAGE OF CONTROL ACHIEVED WITH MADEIRA-MED

	2004	2005	2006	2007	2008	2009	2010	2011
Scenario 1: status quo	20%	30%	40%	50%	70%	80%	90%	97%
Scenario 2: East Madeira	6%	15%	36%	50%	78%	86%	97%	97%
Scenario 3: Expansion	20%	20%	40%	50%	75%	90%	95%	97%

Appendix 4:
EVOLUTION OF NUMBER OF PUPAE REARED IN THE FACILITY

Pupae production	1998	1999	2000	2001	2002	2003
Total production (million of pupae/year)	889	1315	1876	1421	2257	2600
Average weekly production (million of pupae/week)	17	25	36	27	43	50

Appendix 5:
ANNUAL COSTS INCURRED BY THE FRUIT PRODUCTION DIVISION FOR MEDFLY CONTROL

Insecticides	Quantity	Value (euros)
Diazinon	4 L	129
Dimethoate	1353 L	13 232
Trichlorfon	59 kg	1580
Fenthion	424 L	13 746
Malathion	24L	264
Total pesticide use		28 951

Appendix 6:
EVOLUTION OF THE AREAS (IN HECTARES) OF SOME KEY MEDFLY HOSTS FROM 1995 TO 2001

	Hosts area (hectare) Estimates by the Division of Fruit Production							
Medfly hosts	1995	1996	1997	1998	1999	2000	2001	Average yearly area variation
Custard apple	85	87	88	89	93	96	100	2.50
Apple	183	183	190	190	190	190	190	1.17
Subtropical fruit	8	9	9	9	11	13	13	0.83
Orange and tangerines	117	118	120	122	130	130	130	2.17
Mango	10	10	10	12	12	12	12	0.33
Pear	67	68	70	70	70	71	71	0.67
Peach	10	10	10	9	10	10	10	0.00
TOTAL HOST AREA	480	485	497	501	516	522	526	7.67