Financial cost-benefit analysis for the establishment of areas free from and areas of low pest prevalence of *Bactrocera dorsalis* (Hendel) in South Africa

by

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Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the sole author thereof (save to the extent explicitly otherwise stated), that reproduction and publication thereof by Stellenbosch University will not infringe any third party rights, and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

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Date: April 2019

Abstract

International food trade is critical for a country's economy and for facilitating food security across the globe, but there are risks associated with food trade. These risks include the spread of invasive pest species. *Bactrocera dorsalis* was introduced into Africa through food trade, after which it spread to most of sub-Saharan Africa. *Bactrocera dorsalis* was declared present in the Northern Vhembe district of Limpopo in 2013, and is currently present in some areas in six of the nine provinces of South Africa. *Bactrocera dorsalis* is considered a fruit fly of economic importance as it accounts for major economic losses such as crop damages, and also loss of export markets due to being a quarantine pest in many countries. *Bactrocera dorsalis* therefore needs to be managed, and current areas which are pest free, must be maintained as such.

Prior to a project being embarked on, it should be determined if the project will yield positive results. A financial cost-benefit analysis is used to calculate whether it will be feasible for South Africa to establish or keep certain areas free from or under low prevalence *Bactrocera dorsalis*. The *status quo* in South Africa is used as a baseline to establish if the current situation in South Africa can be feasibly maintained, and whether the spread of *Bactrocera dorsalis* to the rest of South Africa can be prevented. The financial cost-benefit analysis takes all costs and benefits related to the project in question, into account.

A financial cost-benefit analysis has been conducted, and input from stakeholders was used to determine the different categories included in the analysis. The outcome, given the assumptions of the financial cost-benefit analysis, is positive. The net present value (NPV) and the cost-benefit ratio, provided as an outcome of the financial cost-benefit analysis, were used to interpret and determine the feasibility of the project. Both the net present value and cost-benefit ratio results are positive. The positive net present value and cost benefit ratio indicate that it will be feasible to maintain the current situation concerning *Bactrocera dorsalis* in South Africa. This project serves to indicate factors which should be included when a more comprehensive analysis is needed.

Opsomming

Internasionale voedselhandel is krities vir ‘n land se ekonomie en vir die fasilitering van voedsel sekuriteit reg oor die wêreld, maar daar is risiko’s verbonde aan voedselhandel. Risko’s sluit die verspreiding van indringerspesies in. Die *Bactrocera dorsalis* (Hendel) vrugtevlieg is deur middel van handel van voedsel produkte vrygestel in Afrika, waarna dit versprei het na die grootste gedeelte van sub-Sahara Afrika. *Bactrocera dorsalis* is in 2013 verklaar as teenwoordig in die Noorde van die Vhembe distrik van Limpopo in Suid Afrika, huidiglik is *Bactrocera dorsalis* teenwoordig in ses van die nege provinsies van Suid-Afrika. *Bactrocera dorsalis* word as ‘n vrugtevlieg van ekonomiese belang beskou, omdat dit vir groot ekonomiese verliese verantwoordelik is, verliese sluit in die beskadiging van oeste en die verlies aan uitvoer markte, aangesien *Bactrocera dorsalis* ‘n kwarantyn pes in baie lande is. Om hierdie rede moet *Bactrocera dorsalis* bestuur word en die huidige areas wat as pesvry geklassifiseer is, moet so behou word.

Voordat ‘n projek begin is dit nodig om te bepaal of die projek positiewe resultate sal lewer. ‘n Finansiële koste-voordeel-analise is gebruik om te bepaal of dit vir Suid-Afrika winsgewend sal wees om sekere areas vry of areas met lae pes tellings van *Bactrocera dorsalis* sal hou. Die *status quo* situasie in Suid-Afrika word gebruik as ‘n basislyn om vas te stel of dit winsgewend is om die huidige situasie te behou en om vas te stel of die verspreiding van *Bactrocera dorsalis* na die res van Suid-Africa kan verhoed word. Die finansiële koste-voordeel-analise neem al die verwante kostes en voordele van die projek in ag.

‘n Finansiële koste-voordeel-analise is gedoen en insette van belanghebbendes is gebruik om die verskillende kategorieë vas te stel wat gebruik is in die analise. Die uitkoms van die analise, inaggenome die aannames van die finansiële koste-voordeel-analise, is positief. Die huidige netto waarde en die koste-voordeel-verhouding wat deur die gebruik van die analise as uitkoms gegee is, word gebruik om die resultaat te interpreteer en die winsgewendheid van die projek te bepaal. Beide die huidige netto waarde en die koste-voordeel-verhouding se resultate was positief. Die positiewe uitkoms van die huidige netto waarde en die koste-voordeel-verhouding dui daarop dat dit winsgewend is om die huidige situasie in Suid-Afrika, rakende *Bactrocera dorsalis* te onderhou. Hierdie projek dui ook ander faktore aan wat in ‘n meer samehangende analise gebruik en in ag geneem moet word.

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Chapter 1 : Introduction

1.1 Background

In order to increase consistent economic growth, it is critical to trade with other countries (Youm *et al*., 2011). International trade is not only important for economic growth, it is also important to facilitate food security globally (Baldos & Hertel, 2015). There are, however, risks involved in food trading when trading with other countries. In the food system, trade risks are proportionally higher than for non-food goods. These risks include the spreading of invasive pest species, and it is therefore necessary to monitor these pests to minimise the spread of the invasive pests (Mumford, 2002; Youm *et al.*, 2011). When invasive pest species are introduced into a country, additional costs are associated with the management of the pest (Youm *et al.*, 2011). According to the World Trade Organization's (WTO) Sanitary and Phytosanitary (SPS) Agreement, there are certain measures to minimise the spread of pests that countries should have in place to allow trade with other countries. International SPS standards were negotiated by the WTO, but each government can choose its own SPS standards. These SPS standards are usually lower than the international SPS standards (WTO, 2010). The International Plant Protection Convention (IPPC) was established by the Food and Agriculture Organization of the United Nations (FAO) in 1992. The IPPC was appointed by the WTO to implement the International Standards for Phytosanitary Measures (ISPM) (Ivess, 2004).

Fruit flies that originate from a foreign country and are introduced into a currently fruit fly-free country are classified as an invasive pest. Certain fruit fly species are seen as fruit flies of economic importance and these fruit flies account for considerable production losses. These fruit flies are from the fruit fly family Tephritidae, and are considered to be "true fruit flies" (De Meyer *et al*., 2014). *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae) is part of this fruit fly family (Roberto & Garcia, 2009). Since *B. dorsalis* is a quarantine pest in many countries, these countries either require fruit from areas free from *B. dorsalis*, or the monitoring of *B. dorsalis* as per phytosanitary arrangement (Manrakhan, 2016). In South Africa, *B. dorsalis* is already an established pest in some of the provinces (Hortgro, 2017). In areas where *B. dorsalis* is not established yet, it is possible to develop pest-free areas (PFA) and areas of low pest prevalence (ALPP). Such action can ensure that South Africa does not lose market access to countries that require pest-free area status or the monitoring of *B. dorsalis*. The ISPMs used for the establishment of PFA and ALPP are ISPM 26, *Establishment of pest free areas for fruit flies (Tephritidae)* and ISPM 35, Annexure 1 , *Establishment of areas of low pest prevalence for fruit flies (Tephritidae)* (IPPC, 2018b).

To establish areas free form *B. dorsalis* will require substantial initial investment and operational costs, but these actions can lead to major benefits. It is therefore important to assess whether it will be beneficial to establish these areas as being free from *B. dorsalis*. Prior to commencing with the actual project, it is important to take the feasibility of the project into account, while acknowledging that long-term benefits can arise from the initial capital investment (Mumford, 2005).

This provides the reason for conducting a financial cost-benefit analysis, as it will indicate the feasibility of the establishment of areas free from *B. dorsalis* and areas of low pest prevalence. The financial cost-benefit analysis makes use of the current situation in South Africa as an example, i.e. to indicate what the situation would be if *B. dorsalis* were to spread through the whole of South Africa. This round of the cost-benefit analysis will therefore not be a full-fledged cost-benefit analysis, but will serve as an indicator of the sufficiency of technique, and include recommendations on how to do a more comprehensive cost-benefit analysis regarding the establishment of pest-free areas and areas of low pest prevalence.

Cost-benefit analyses have been widely applied in agriculture and also in environmental and ecological studies. A few studies also completed a cost-benefit analysis on fruit flies, including the establishment of PFA and ALPP, surveillance costs, and the use of area-wide management of fruit flies (Verghese *et al*., 2004; Mumford, 2005; Harvey *et al*., 2010). A cost-benefit analysis compares the different costs and benefits of a certain project to establish whether it would be beneficial to commence with the project. Cost-benefit analyses are used to choose between challenging project alternatives, and multiple criteria should therefore be addressed. These criteria include environmental impact, costs, benefits, risks and safety (Linkov *et al*., 2004). The outcome of the cost-benefit analysis will provide a benefit-cost ratio and the net present value of the project.

When international trade takes place, a country receives foreign currency from the country it is trading with. This foreign currency is then converted to the local currency of the exporting country. Fluctuations in the exchange rate between countries can cause changes in a cost-benefit analysis since it is sensitive to such changes. It consequently is important to include a sensitivity analysis when conducting a cost-benefit analysis.

In South Africa, no cost-benefit analyses has been done regarding the establishment of pest-free areas and areas of low pest prevalence on the *B. dorsalis* fruit fly. This study will serve as an indication as to whether it will be feasible to establish pest-free areas in South Africa.

Part of the goals of this study is to identify areas where a lack of information could be addressed to strengthen a cost-benefit analysis. It is partly designed to assist technical research fields such as horticulture and entomology to identify knowledge gaps.

1.2 Problem statement and research question

B. dorsalis is a threat to many countries around the world, and in some countries it has been declared as a quarantine pest already. To establish areas that are free from *B. dorsalis* can be costly, but benefits can also be realised. Such studies have been applied with success in Australia, notably the establishment of PFAs of the Queensland fruit fly and the Mediterranean fruit fly, which indicate that a benefit significantly higher than the cost can arise. There are a number of uncertainties as to whether this could be the same for South Africa, though.

There is a lack of a full cost and benefit assessment in South Africa with regard to the establishment of pest-free areas. There are also knowledge gaps regarding the costs and benefits that should be included. The main question of this project is: what are the expected financial implications of establishing areas free from *B. dorsalis*? Issues that require attention include the selection of matters to be incorporated, such as costs and benefits, the method to use, and the availability of information.

1.3 Objective of the study

The previous paragraph highlighted that there is a need for information regarding the costs and benefits that would arise by the establishment of pest-free areas for *B. dorsalis*. The main objective of this study is to establish the expected financial costs and benefits of the establishment of pest-free areas and areas of low pest prevalence of *B. dorsalis* to indicate if it would be beneficial to establish such areas. This should indicate recommendations on how to improve the cost-benefit analysis. The application of the cost-benefit analysis is aimed at identifying information gaps.

The goals of this study are:

- To clarify the expected impact of *B. dorsalis* from a financial perspective.
- To clarify the process and benefits of the establishment of pest-free areas and areas of low pest prevalence.
- To carry out an initial financial cost-benefit analysis to establish the potential impact of pest-free areas and areas of low pest prevalence for the current situation in South Africa.
- To assess the suitability of the estimated costs and recommend what should be done to ensure that the cost-benefit analysis is comprehensive.
- To identify shortcomings that should be included for a full-fledged cost-benefit analysis.

1.4 Proposed method

For the purpose of this project, a financial cost-benefit analysis is employed to evaluate the cost-efficiency of developing areas free form *B. dorsalis* in South Africa. The *status quo* approach will be followed. A financial cost-benefit analysis differs from an economic cost-benefit analysis in that a financial cost-benefit analysis only calculates the financial feasibility of a certain project. The component analysed for the financial cost-benefit analysis is not the entire economy, but limited to the project itself. An economic cost-benefit analysis will evaluate a certain project from the point of view of the entire economy (ADB, 1992).

In order to fully understand the techniques and implications of a cost-benefit analysis, a literature overview will be conducted. This will provide the background on cost-benefit analyses and contains reviews of previous applications of cost-benefit analyses to establish pest-free areas in the agricultural sector. The limitations and constraints of conducting a cost-benefit analysis are also presented.

Using the outline of a cost-benefit analysis, a financial cost-benefit analysis will be provided to conclude whether it will be financially feasible to establish the areas in question free from *B. dorsalis* in South Africa. The information used to calculate the benefit-cost ratio will only include information that is currently available from the industry. In the absence of such information, it will be estimated by means of consultations with specialists. Information depending on estimates or still-needed information, which could not be included in this project, will be described and analysed. Recommendations regarding these costs and benefits will be provided.

The data for the financial cost-benefit analysis was collected in a quantitative way. Quantitative data was obtained from the different industry bodies, namely the Citrus Growers Association (CGA), Citrus Research International (CRI), Hortgro, South African Table Grape Industry (SATI) and the South African Subtropical Growers' Association (Subtrop). Other data that was not available or published by the different industry bodies were obtained through personal communication with industry specialists. This information is provided in quantitative format. The data required was identified by workshops held with stakeholders and from the literature that was reviewed.

1.5 Study outline

The body of the thesis commences in Chapter 2 with an overview of the industries involved, the history of the *B. dorsalis* fruit fly, the distribution of *B. dorsalis*, and its establishment in South Africa. This is followed by the definitions regarding pest-free areas, areas of low pest prevalence, and SPS measures. The cost-benefit analysis and all the limitations and benefits of this type of analysis are included in the literature review. Previous studies completed on the establishment of areas free of pests and areas of low pest prevalence regarding fruit flies are presented to illustrate the importance of pest management.

Chapter 3 will focus on the findings from the literature review and on the input from the stakeholders at the two workshops attended. The information and data that were obtained and verified through consultations with industry specialists will be explained in this Chapter. The model used for the financial cost-benefit analysis will be methodically explained and evaluated in this section. The different aspects of the cost-benefit analysis will be explained and described, including the different costs and benefits included, the cost-benefit ratio, net present value, and the internal rate of return.

Chapter 4 consists of the specific results that were obtained by applying the cost-benefit analysis, followed by an explanation of the calculations and interpretation thereof. The calculations of the different costs and benefits included in the analysis are provided. A sensitivity analysis is used to illustrate possible risks associated with the exchange rate.

Chapter 5 concludes the research project with a conclusion, summary, and recommendations. Recommendations include how a full cost-benefit analysis should be done for the establishment of pest-free areas and areas of low pest prevalence.

Chapter 2 : Literature overview: *Bactrocera dorsalis* and cost-benefit analysis

2.1 Introduction

Invasive pests and issues related to them can cause economic and biodiversity risks. In Africa, these issues are directly linked to trade. In 2011 there were no active and in-depth studies on techniques to approach and address these issues and to find solutions for them in developing countries (Youm *et al.*, 2011). International trade and invasive pests are related. Since there is an increase in international trade and the volumes of trade, strict rules and monitoring of exports and imports can contribute to the protection of trade to minimise the spread of invasive pests (Mumford, 2002; Youm *et al.*, 2011).

In Chapter 1 the main research question was stated as "what are the expected financial implications of establishing areas free from *Bactrocera dorsalis*?". In order to establish pest-free areas and areas of low pest prevalence for *B. dorsalis*, it is advised to conduct a cost-benefit analysis to ensure that by establishing such areas, benefits will arise that outweigh the costs of doing so. An understanding of the concept of establishing pest-free areas and areas of low pest prevalence will be provided in this chapter by presenting an overview of the industries which will be affected by the spreading of *B. dorsalis*. This will be followed by an overview of the history of *B. dorsalis*, the spreading thereof, and the phytosanitary regulations regarding the establishment of pest-free areas and areas of low pest prevalence. Lastly, the cost-benefit analysis, previous studies pertaining to cost-benefit analyses, and the establishment of areas which are pest-free and areas of low pest prevalence, will be discussed.

2.2 Industries affected

South Africa's agricultural production was valued at R273 344 million in 2016/2017. It contributed R80 247 million to the GDP in 2016 (DAFF, 2016a). The fresh fruit industry contributes 33% of South Africa's agricultural exports, with 2,7 million tons of fresh fruit exported to more than 90 trading countries. The value of South Africa's fresh fruit exports in

2017 amounts to R26 billion (FPEF, 2017). In Figure 2.1 the proportional contributions of the deciduous, citrus and subtropical fruit are illustrated. The figure clearly indicates that the fresh fruit industry is of significant economic importance for South Africa, since the proportion of agricultural land contributing to the value of the fresh fruit industry is quite small in terms of the value generated by the industry.

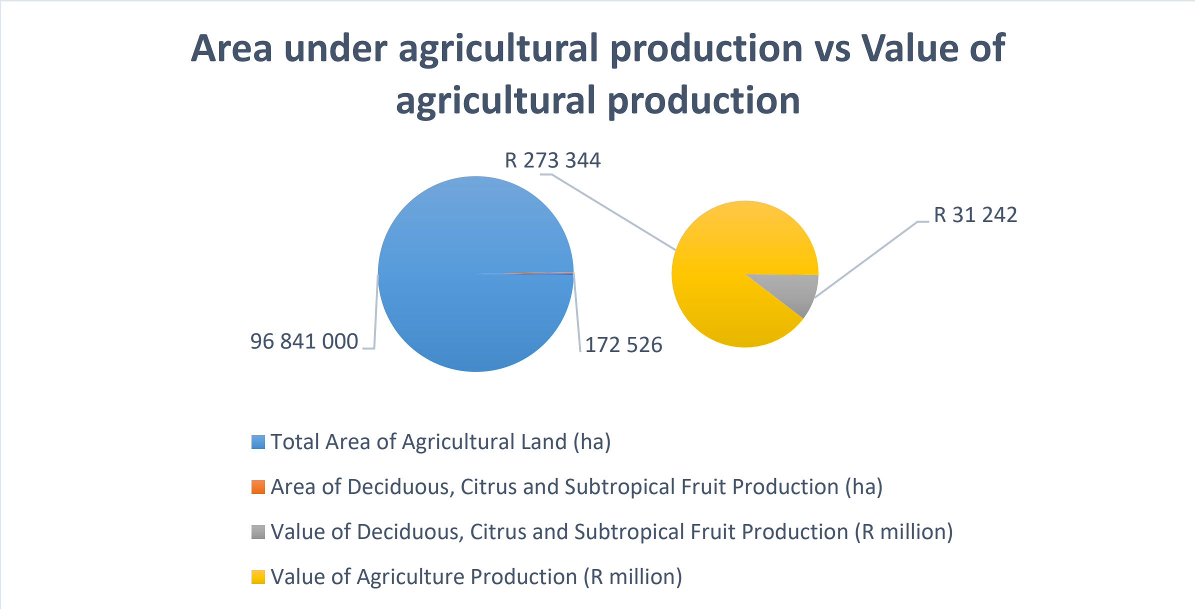

Figure 2.1: Area of land under agricultural production and fruit production and the value of agricultural production and fruit production.

According to the Department of Agriculture, Forestry and Fisheries (DAFF), there are several types of commercial fruit that are impacted by *B. dorsalis*. These fruit include mango, guava, citrus, papaya, apple, pear, apricot, peach, pear, cherry, grapes, passion fruit, pepper, tomato and cucurbits (DAFF, 2018a). The following horticultural industries will be included for this financial cost-benefit analysis study:

- deciduous fruit;
- table grapes;
- citrus; and
- subtropical fruit.

Each of these industries will be explained in terms of its economic importance, illustrated by tables. This information was provided by the respective representative bodies of the different industries. Said bodies are SATI (Southern African Table Grape Industry), Hortgro (deciduous fruit industry), CRI (Citrus Research International), CGA (Citrus Growers Association) and Subtrop (South African Subtropical Growers' Association). These four industries combined generate a total value of R31 242 million on 172 526 hectares, and they employ 248 482 employees, indicating the economic importance of these industries in South Africa's economy. The main export destinations for each fruit group exporting from South Africa are illustrated in Tables 2.1-2.4 below.

Table 2.1: Top 10 importing destinations of South African table grapes 2017

Ranking	**Destination**	**Volume of exports (ton)**
1	European Union	143 116,72
2	United Kingdom	69 251,54
3	Far East	21 617,33
4	Middle East	17 331,66
5	South East Asia	14 299,67
6	Canada	9 900,35
7	Russian Federation	7 278,63
8	Africa	5 932,66
9	United States of America	606,97
10	Indian Oceans	148,08

Source: (SATI, 2017)

Table 2.2: Main export destinations of subtropical fruit exported by South Africa 2015

Fruit type	**Mangos**		**Litchis**		**Avocados**	
No.	**Destination**	**Volume of exports (ton)**	**Destination**	**Volume of exports (ton)**	**Destination**	**Volume of exports (ton)**
1	Africa	2 041	Europe	3 688	Europe	63 829
2	Asia	670	Africa	296	Asia	1 160
3	Europe	541	Asia	128	Africa	856
4	America	10	Americas	43		

Source: (DAFF, 2015a,b,c)

Table 2.3: Top 10 export destinations for citrus fruit exported from South Africa 2018

No.	**Destination**	**Volume of exports (ton)**
1	Netherlands	406 510
2	United Kingdom	171 481
3	United Arab Emirates	152 235
4	Hong Kong, China	115 066
5	Russian Federation	149 162
6	China	100 940
7	Saudi Arabia	117 001
8	Portugal	83 974
9	Canada	59 118
10	United States of America	55 311

Source: (ITC, 2018)

Table 2.4: Main export destinations for deciduous fruit from South Africa 2016

Fruit type	**Apples**		**Pears**		**Apricots**	
No.	**Destination**	**Volume of exports (ton)**	**Destination**	**Volume of exports (ton)**	**Destination**	**Volume of exports (ton)**
1	Far East & Asia	123 344	Europe	95 543	Middle East	1 596
2	Africa	123 344	Middle East	44 438	Europe	864
3	United Kingdom	76 559	Far East & Asia	39 995	United Kingdom	831
4	Middle East	42 533	United Kingdom	11 110	Africa	33
5	Europe	29 773	Russia	11 110	Far East & Asia	33
6	Russia	17 013	Africa	8 888	Indian Ocean Islands	33
7	Indian Ocean Islands	8 507	USA & Canada	6 666		
8	USA & Canada	4 253	Indian Ocean Islands	4 444		
Fruit type	**Peaches**		**Nectarines**		**Plums**	
No.	**Destination**	**Volume of exports (ton)**	**Destination**	**Volume of exports (ton)**	**Destination**	**Volume of exports (ton)**
1	Middle East	2 267	United Kingdom	5 120	Europe	26 163
2	United Kingdom	2 211	Europe	2 610	United Kingdom	15 116
3	Europe	719	Middle East	1 807	Middle East	11 046
4	Far East & Asia	111	Indian Ocean Islands	201	Far East & Asia	2 907
5	Indian Ocean Islands	111	Far East & Asia	100	Russia	1 163
6	Africa	111	Africa	100	Africa	581
7	USA & Canada	55	USA & Canada	100	Indian Ocean Islands	581
8					USA & Canada	581

Source: (Hortgro, 2016)

The deciduous fruit industry is summarised in Table 2.5 below. The equivalent of permanent labourers include the seasonal workers converted to permanent workers. The deciduous fruit sector of South Africa has a total turnover worth R13.63 billion per year, and provides 1.34 permanent jobs per hectare on a total 53 891 hectares (Hortgro, 2016).

Table 2.5: South African deciduous fruit statistics 2016

Fruit	**Hectares**	**Permanent labourers**	**Dependants**	**Industry value (R million)**
Apples	24 212	27 526	110 106	R7 827,10
Pears	12 279	13 283	53 133	R4 210,40
Peaches	7 338	8 024	32 097	R234,60
Plums	5 093	6 529	26 116	R1 859,70
Apricots	2 838	3 404	13616	R144,30
Nectarines	2 131	2 473	9 894	R478,90
TOTAL	**53 891**	**61 239**	**244962**	**R14 755,00**

Source: (Hortgro, 2016)

South Africa is one of the world's top table grape exporting countries, with a 5,5% share in world exports. The exports of South African grapes are valued at USD 435 975 000 (SATI, 2017). Table 2.6 contains information regarding the South African table grape industry.

Table 2.6: South African table grape industry 2017

Fruit	**Hectares**	**Permanent labourers**	**Seasonal labourers**	**Industry value (R million)**
Table grapes	19 674	8 339	43 254	R4 900

Source: (DAFF, 2016b; SATI, 2017)

South Africa is ranked as the second biggest exporter of citrus with 1 702 000 tons of citrus exported from South Africa (CGA, 2017a). The citrus industry provides jobs for 125 000 people, worth R1.6 billion in wages (CGA, 2017b). The citrus industry is the third-largest horticultural industry in the country, contributing R11 billion to the horticultural industry in the 2014/2015 season (DAFF, 2016c). Table 2.7 reflects information regarding the citrus industry.

Table 2.7: South African citrus industry 2017

Fruit	**Hectares**	**Labourers**	**Industry value (R million)**
Citrus	72 731	125 000	R9 297

Source: (CGA, 2017a,b)

The subtropical fruit industry provides jobs for 10 650 people in South Africa, and the industry is worth R2.29 billion, with 26 230 hectares under cultivation (Donkin, 2018 *pers comm*). Table 2.8 contains information regarding the subtropical fruit industry of South Africa.

Table 2.8: South African subtropical fruit industry 2018

Fruit	**Hectares**	**Seasonal and permanent labourers**	**Industry value (R million)**
Avocado	17 500	5 250	R1 850
Litchi	1 730	2 400	R120
Mango	7 000	3 000	R320
Total	**26 230**	**10 650**	**R2 290**

Source: (Donkin, 2018 *pers comm*)

Certain areas are completely dependent on the agricultural sector within the area. If the Cederberg municipality is used as an example, it can be clearly seen that the agricultural sector of this municipality contributes most to job creation, 39.9% or 9 495 people being employed directly in the agricultural industry of the Cederberg municipality (Western Cape Government, 2017). In the Cederberg municipal district, the agricultural sector consists mostly of citrus and deciduous fruits. The same accounts for the Witzenberg municipality, where deciduous fruit such as apples and pears are the main farming commodity, 34.9% of employment in the municipality being allocated to the agricultural industry. The remaining employment is divided among the following sectors: manufacturing, electricity, gas and water, construction, wholesale and retail trade, finances, community and general government. The agricultural industry contributed R1.2 million to the GDP of this municipality in 2015 (Witzenberg Municipality, 2017).

If a fruit fly such as *B. dorsalis* leads to the damage of fruit and the loss of export markets, these municipalities will suffer from a significant economic impact, and it will also contribute to job losses. This is just an example of two municipalities in South Africa, there being many more municipalities where the agricultural sector is of significant economic importance to the municipal area.

2.3 Pest management and eradication

The yield potential of plants is determined by so-called crop yield defining factors. These factors include CO_2 availability, radiation, temperature and the intrinsic features of the crop itself. There are certain limiting factors which cause the potential yield to be unattainable. These factors are mostly due to water and nutrient availability. Another factor that impacts on yield is related to crop yield reducing factors that include competition from weeds, pollutants and damage due to pest and diseases. These factors are demonstrated in Figure 2.2 below.

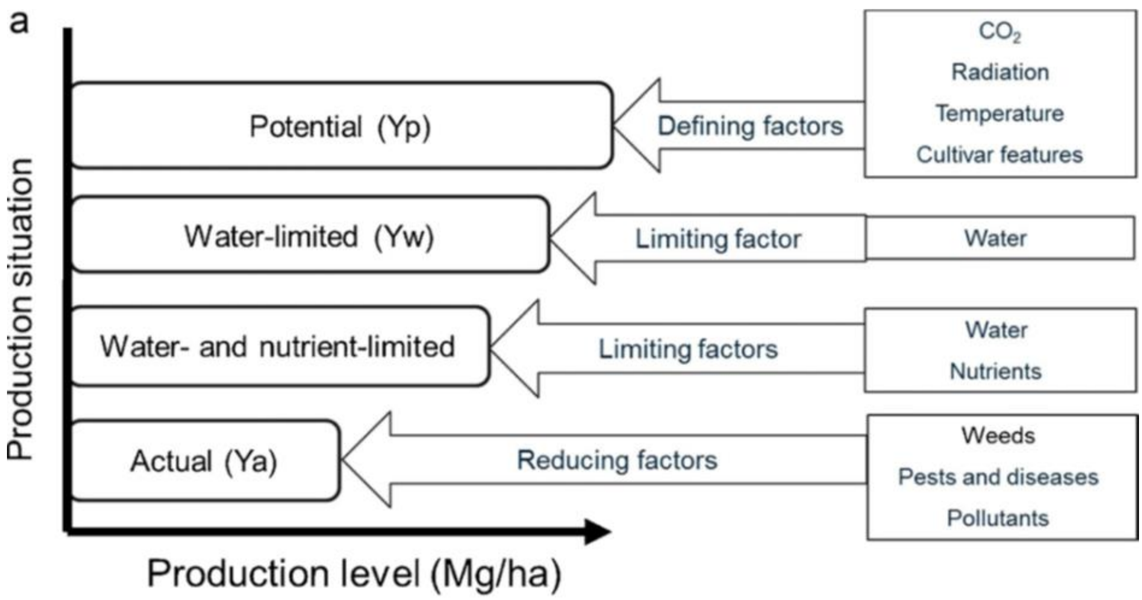

Figure 2.2: Different production levels of plant production systems as determined by crop yield by defining, limiting and reducing factors.

Source: (Van Ittersum et al., 2013)

The total value of income from the South African agrochemical industry amounted to R30.983 billion in 2014 (Hassen, 2017). This demonstrates the importance of weed, pest and disease management. The scope of this research project is not on pest management in general terms, however. The focus of this research project is rather on the impact of a specific pest species on trade and access to markets. The cost of management of fruit flies are included in this thesis. The level whereat the costs of general management of fruit flies in an orchard need to be balanced with potential income, is much lower for species where the pest is already established, however. In this case, costs are aimed at eradication rather than management.

2.4 Fruit flies

Fruit flies account for major economic losses in agriculture. Worldwide, there are 70 different fruit fly species which are considered to be of economic importance in agriculture (Mankad *et al*., 2017). Fruit flies are a pest, the female fruit fly laying eggs within the fruit, causing the fruit to rot from the inside out when the larvae eat their way out of the fruit (Abdalla *et al*., 2012; Harvey *et al.*, 2010). Fruit flies account for significant crop losses and obstruct market access. If a fruit fly specimen is found within fruit which is ready to be exported, the whole container or shipment can be refused for export.

All fruit flies are not endemic or widely spread in all countries, but are dispersed to different countries *via* the trade of fresh produce. It is therefore a paramount requirement that fruit which are exported, are fruit fly free. Fruit flies can be managed on farms by applying integrated pest management (IPM) systems, which include the use of pesticides and orchard sanitation. Apart from IPM, certain sanitary and phytosanitary measures need to be followed to ensure continued access to different export markets.

2.4.1 Background of *Bactrocera dorsalis*

Within the order Diptera there are two main groups of fruit flies, namely Tephritidae and Drosophilidae. These fruit flies are known as “true fruit flies” and “common fruit flies” respectively. The family of Tephritidae fruit flies are considered as fruit flies that have greater economic significance.

These fruit flies attack different types of fruit and vegetables, both commercial and non-commercial crops, resulting in agricultural crops getting damaged (De Meyer *et al*., 2014; Vargas *et al*., 2015). Within the subfamily of Tephritidae is Dacinae, which consists of 41 genera, one of which is *Bactrocera* (Roberto & Garcia, 2009). The *B. dorsalis* (Hendel) complex of fruit flies are endemic to Southeast Asia (Clarke *et al*., 2005). This fruit fly was described as *Musca ferruginea* by Fabricius in 1794 (Dohino *et al*., 2016), but was first recognized as a complex by Hardy in 1969 (Hardy, 1969). The *B. dorsalis* species complex of Dacinae was expanded in 1994 by Drew and Handcock (Drew *et al*., 2005). Previously considered to be separate species within the complex, *B. dorsalis, B. philippinensis, B. papayae* and *B. invadens* have now been formally synonymised and recognised as biologically the same species, with *B. dorsalis* as the senior synonym (Dohino *et al*., 2016; Schutze *et al*., 2015).

Bactrocera dorsalis is a major pest of economic importance in South East Asia and also in some of the Pacific Islands. If the climate conditions are maintained, *B. dorsalis* may spread to tropical and subtropical regions (Stephens *et al*., 2007; Wei *et al*., 2017). It is possible that *B. dorsalis* originates from Sri Lanka (Goergen *et al*., 2011). However, the first recording of *B. dorsalis* dates back to 1912, where it is recorded in Taiwan (Wan *et al*., 2011; Wan *et al*., 2012; Wei *et al*., 2017). It was also discovered in Hawaii on 10 May 1949 (Hardy, 1969). After the first presence of *B. dorsalis* was established, the fruit fly quickly spread throughout the mainland of China, India, Hawaii, Pakistan, Nepal, Vietnam, Laos, Burma, Thailand and further (Wan *et al*., 2011).

Commonly known as the oriental fruit fly (*B. dorsalis*) is considered to be the worst fruit fly species. This fruit fly species accounts for problems in the field and also regarding market access (Dohino *et al*., 2016). *Bactrocera dorsalis* attacks commercial fruit and vegetables and is feared because of the economic losses caused by this fruit fly species (Kamala *et al*., 2017). Due to the importance of *B. dorsalis*, the taxonomic work to describe the species is quite advanced (Clarke *et al*., 2005).

Bactrocera dorsalis, along with other fruit flies also from the complex of *B. dorsalis*, are of international and economic significance. This fruit fly is seen as part of the most important pest species in agriculture in the world (Clarke *et al*., 2005; De Meyer *et al*., 2014). The presence of this fruit fly in a country can result in the loss of market access (Clarke *et al.*, 2005). In 2015, Vargas *et al*. published that this highly polyphagous species, has more than 270 host species.

More than fifty of the near thousand described species in Africa are of economic importance, four of which belong to the genus *Bactrocera* which originated from Asia (De Meyer *et al.*, 2014). *Bactrocera dorsalis* was first found in Africa in Kenya in 2003, and thence spread to most of sub-Saharan Africa. It is reported that *B. dorsalis* is now present in more than 28 African countries (Ekesi *et al*., 2010; Dohino *et al.*, 2016). This fruit fly species causes great economic losses in Africa (Dohino *et al.*, 2016). Climate change is seen as the main reason for the dispersion and establishment of *B. dorsalis* into new areas. *Bactrocera dorsalis* is a serious threat to many countries in the world. Due to climate change, this threat will continue to increase. This is expected to lead to damaged fruit and vegetables and to affect the costs of market access (Stephens *et al*., 2007). Since *B. dorsalis* was found in Africa, it quickly spread to the sub-Sharan part of Africa, resulting in trade barriers and economic and nutritional losses in many African countries (Dohino *et al*., 2016).

According to Clarke *et al*. (2005), economic losses which are caused by *B. dorsalis* should be quantified, since *B. dorsalis* accounts for quantitative and qualitative losses (Vargas *et al.*, 2015), in order to highlight that research is needed for the management and quarantine of the pest (Clarke *et al.*, 2005).

Verghese *et al*. (2006) found that even *B. dorsalis*, which is a major pest, can be effectively managed with the use of pre- and post-harvest treatment. Pre-harvest control is used to prevent crop losses and infestation, whereas post-harvest control is used to comply with international market requirements (Verghese *et al*., 2006). Blanquart (2009) found that the implementation of pest management practices affects various criteria, economic considerations, socio-economic factors, technological factors, ecological factors and the quality of information (Blanquart, 2009). Fundamental problems in the establishment of area wide management (AWM) programs are those of “free riding”, where benefits accrue to those who did not pay the necessary costs to enjoy those benefits (Mankad *et al*., 2017).

2.4.2 Distribution of *Bactrocera dorsalis* in South Africa

Bactrocera dorsalis is seen as a quarantine pest in many countries, including the European Union (ICIPE, 2013). Quarantine species are potentially invasive organisms and pest species which can affect the health of humans and animals, crops and the environment and are prevented, detected and eradicated before it becomes established in an area or country (Mumford, 2002). To prevent *B. dorsalis* to infest fruit or become established in an area, producers apply chemical cover sprays. The application of the cover spray results in an increase in the residue of pesticides found on the fruit. The European Union, for example, has maximum residue requirements that are very strict. If the fruit exceed those maximum limits, the fruit may not be imported to the European Union (ICIPE, 2013). The interception of fruit exported to the European Union from Africa is increasing because of *B. dorsalis* (Dohino *et al.*, 2016). This can lead to major losses of export markets and additional costs if the fruit must be redirected or repacked for a new market.

The direct negative impact of *B. dorsalis* on fruit increases when an area's climatic suitability for the establishment of *B. dorsalis* improves. This will have a direct effect on market access costs (Stephens *et al.*, 2007). The invasion of *B. dorsalis* highlights that new phytosanitary treatments for gaining market access should be developed, approved and implemented (Dohino *et al.*, 2016). If *B. dorsalis* becomes established in South Africa, the export market destinations for fruit will most likely require assurance that the fruit are not containing any live fruit flies in the fruit that are exported (Grout *et al*., 2011). When first detected in South Africa in 2010 in the northern Limpopo border region, eradication measures were implemented. Since 2010 and especially during early 2013, there where multiple invasions of *B. dorsalis*, but all of these invasions were considered to have been eradicated successfully (Manrakhan *et al*., 2015).

Bactrocera dorsalis was declared present in South Africa in March 2013, in the Vhembe district, Limpopo. The areas affected with *B. dorsalis* were placed under quarantine. Eradication and monitoring continue in other areas. The focus of the national control strategy is to prevent further incursions and to monitor the rest of South Africa to prevent the pest's distribution (Manrakhan *et al.*, 2015). The current distribution of *B. dorsalis* in Africa is shown in Figure 2.3. As indicated on the map in Figure 2.3 and in Table 2.9 *B. dorsalis* was present in 2017, in five of the nine provinces in South Africa, being Limpopo, Mpumalanga, North West, Gauteng and KwaZulu-Natal. Provinces in which *B. dorsalis* is absent are the Northern

Cape, Free State, Eastern Cape and the Western Cape (Hortgro, 2017). The first occurrence of *B. dorsalis* in the Western Cape was recorded on 31 January 2018, followed by another one on 6 February 2018. This area was placed under quarantine and eradication measures were implemented. Another fruit fly specimen was found on 14 February 2018 (DAFF, 2018a). Since then, eradication from the Western Cape has been confirmed and reported to the IPPC (IPPC, 2018c).

Table 2.9: Current distribution of *Bactrocera dorsalis* in South Africa, adapted from Hortgro (2017)

Status of *Bactrocera dorsalis*	**District**	**Province**
Present, subject to official control	Vhembe Mopani	**Limpopo**
	Ehlanzeni Nkangala	**Mpumalamga**
	City of Tshwane	**Gauteng**
	King Cetshwayo Ugu uMkhanyakude eThekwini	**KwaZulu Natal**
	Ngaka Modiri Molema	**North West**
Only present in areas where host crops are grown, subject to official control	Capricorn Sekhukhune Waterberg	**Limpopo**
Low prevalence and seasonal, subject to official control	Bojanala Platinum	**North West**
Temporary under surveillance	Z.F. Mgawu	**Northern Cape**
Absent	Gert Sibande	**Mpumalanga**
	DR Kenneth Kaunda Dr Ruth S. Mompati	**North West**
	Amajuba uMgungundlovu uMzinyathi uThukela Zululand	**KwaZulu Natal**
	Namakwa Pixley ka Seme John Taolo Gaetsewe Frances Baard	**Northern Cape**
	All	**Free State**
	All	**Eastern Cape**
	All	**Western Cape**

Source: (Hortgro, 2017)

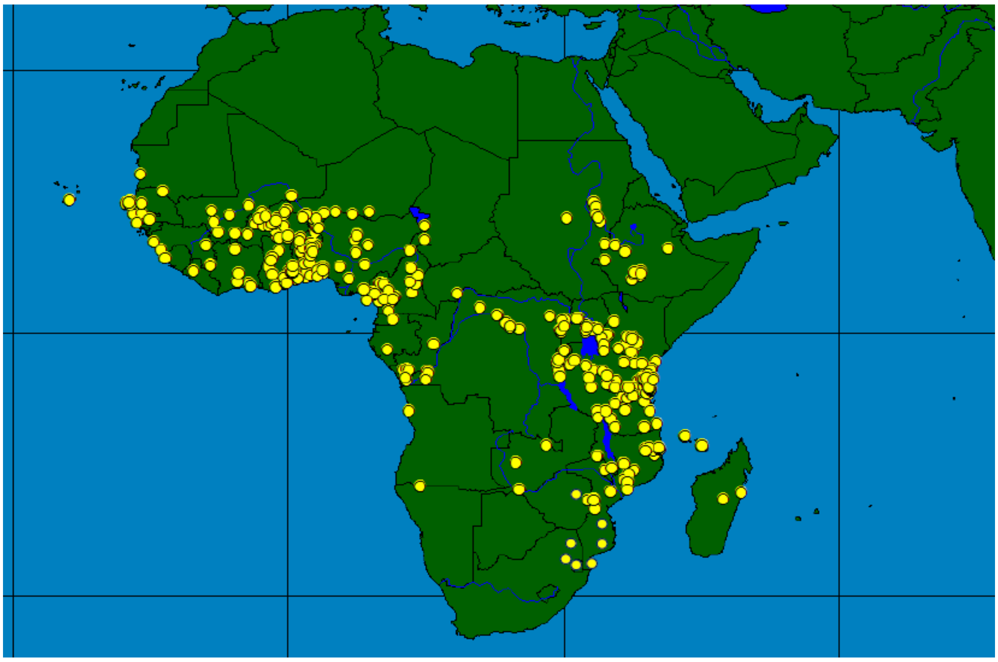

Figure 2.3: Current distribution of Bactrocera dorsalis in Africa

Source: (De Meyer, 2017)

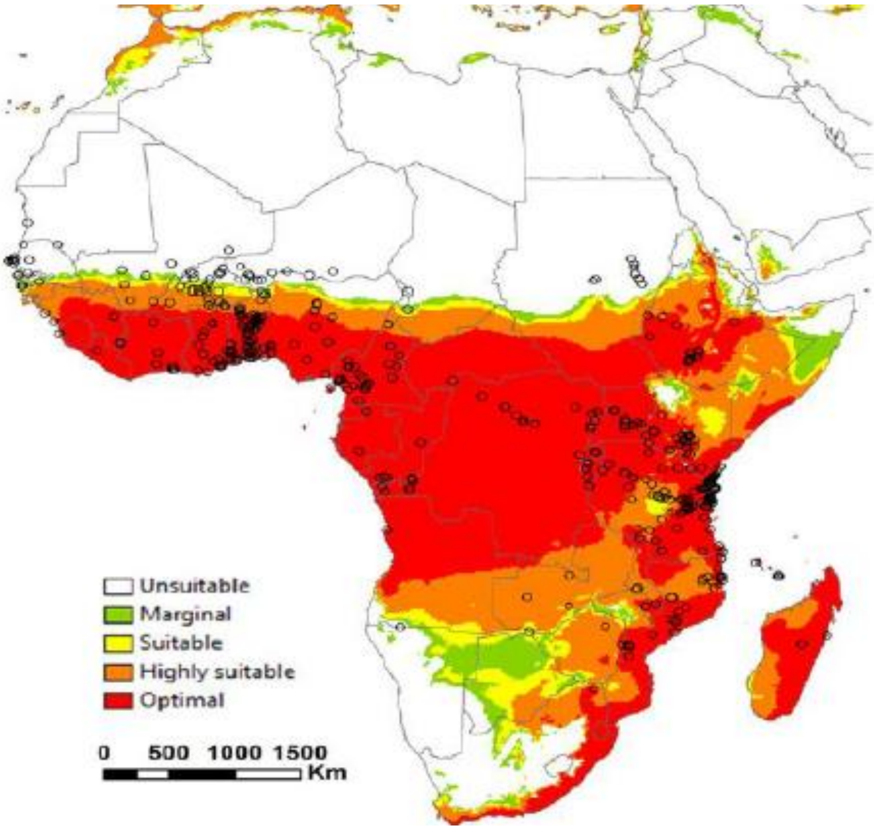

Figure 2.4: Projected distribution of Bactrocera dorsalis in Africa

Source: (De Villiers *et al*., 2016)

As illustrated in Figure 2.4, *B. dorsalis* can become more widely spread throughout Africa and also South Africa. *Bactrocera dorsalis* adapts to a wide range of climates (De Villiers *et al.*, 2016). The Western Cape, which is the main production area of table grapes and deciduous fruits and second-largest production area of citrus fruit (Limpopo is the leading producer), is highly suitable for *B. dorsalis*. This means that *B. dorsalis* can easily establish in this province if it is not monitored, and eradicated. Establishment in the Western Cape will result in more quarantine restrictions from international market destinations. The preferred climates of *B. dorsalis* are tropical wet and dry savanna climate; warm temperate climate; wet all year; or warm moderate climate with dry winters. However, *B. dorsalis* also tolerates tropical rainforest climates and tropical monsoon climates (CABI, 2018).

The following markets require either the monitoring of *B. dorsalis* as a prerequisite for phytosanitary registration for exports from South Africa or fruit from pest-free areas in South Africa: the USA, Mexico, China, Israel, South Korea, Taiwan, Mauritius, Japan and the European Union (Manrakhan, 2016; Venter, 2017; Johnson, 2018 *pers comm*). Markets such as the USA, Israel, South Korea, China and Japan require cold sterilisation against fruit fly species for all fruit that are exported from South Africa (DAFF, 2018b; Dohino *et al.*, 2016). It is important to develop effective management strategies for areas free from *B. dorsalis* in South Africa, since this fruit fly has serious implications on the South African fruit industry (Kleynhans *et al*., 2014).

2.5 The function of the International Sanitary and Phytosanitary Measures (ISPM) and the International Plant Protection Convention (IPPC)

The International Plant Protection Convention (IPPC), appointed by the Food and Agriculture Organization of the United Nations (FAO), was established in 1951. The Commission on Phytosanitary Measures (CPM) administers the implementation of the IPPC. Since March 2017, 183 parties have joined this convention (IPPC, 2018a). On international, national and regional level, the function of the IPPC is to oversee and coordinate world-wide phytosanitary activities. The National Plant Protection Organisation (NPPO) in a country specifically implements the IPPC regulations. The goal is to prevent the introduction of new pests and to eradicate pests at the earliest stage possible, and if this is not possible, to implement control measures to control the pests (Schrader & Unger, 2003). The IPPC was recognised by the SPS Agreement of the World Trade Organisation to provide the International Standards for Phytosanitary Measures (ISPM) (Ivess, 2004).

2.5.1 Sanitary and phytosanitary measures

The Agreement on the Application of Sanitary and Phytosanitary Measures (SPS) of the World Trade Organisation (WTO) was put into effect on 1 January 1995 (WTO, 2010). These measures may result in trade barriers and boundaries to assure food safety and protection of health. It is recognised by the WTO that each country has the right to protect itself from exotic pests and from the risk that is concomitant with these pests by applying sanitary and phytosanitary measures (Florec *et al.*, 2010; WTO, 2010). The developing perception of sanitary and phytosanitary measures is seen as to protect international trade and prevent the spread of invasive pest species. SPS measures lead to increasing phytosanitary import standards. Regulations, rules, new trade agreements and international trade will continue to tighten. African countries should involve themselves in addressing pests and pest introduction issues in order to benefit from trade without suffering from losses and restrictions in international trade. To minimise the negative impact from the SPS measures and trade rules, the quality measures require that products should not be infected with pests when the products are exported (Youm *et al.*, 2011).

One major challenge for plant protection organisations is to oversee phytosanitary factors and measures. This is necessary due to foreign trade patterns requiring oversight of these measures to ensure that they are consistently and reliably applied (Youm *et al.*, 2011).

It is advised that African countries should involve more specialists to identify ways to benefit from trade by meeting SPS requirements and measures. These countries should aim to improve awareness of local pests and to protect food supplies from new invasive pests. Irradiation, which is a phytosanitary treatment, is used to eradicate pests that are regarded as quarantine pests for the different commodities. This can be a very expensive process for developing countries (Youm *et al.*, 2011). Irradiation can also be used as a post-harvest disinfestation method and has the potential to be used on deciduous fruit, since it appears that irradiation contains chemicals which kill the insects without damaging the fruit (Pryke & Pringle, 2008).

Hot water treatment and cold treatment are also used as post-harvest phytosanitary treatments to export fruit to areas that require fruit to be free from *B. dorsalis* (Dohino *et al.*, 2016).

2.5.2 Pest-free areas and areas of low pest prevalence

Due to the potential damage to fruit that can be caused by fruit flies, the risk of restricted access to export markets exists. Fruit flies consequently is a pest of high economic importance. Importing countries restrict imports from areas in countries where this pest is established. This is the reason for the establishment of ISPM 26, *Establishment of pest free areas for fruit flies (Tephritidae)* and ISPM 35 Annexure 1, *Establishment of areas of low pest prevalence for fruit flies (Tephritidae),* which provide guidance for establishing and maintaining areas that are pest-free and areas of low pest prevalence (IPPC, 2018b).

Pest-free areas (PFA) are defined as "an area in which a specific pest is absent as demonstrated by scientific evidence and in which, where appropriate, this condition is being officially maintained" (IPPC, 2016). An area of low pest prevalence (ALPP) is defined as "an area, whether all of a country, part of a country, or all or parts of several countries, as identified by the competent authorities, in which a specific pest is present at low levels and which is subject to effective surveillance or control measures" (IPPC, 2016). The difference between PFA and ALPP is that in a PFA the pest is absent, whereas in an ALPP it is accepted that the prevalence of the pest is lower than the specified population level (IPPC, 2005).

Buffer zones are needed between pest-free areas and infested areas to ensure that no pests are found in the areas which are considered pest free. A buffer zone is defined as "an area surrounding or adjacent to an area officially delimited for phytosanitary purposes in order to minimise the probability of spread of the target pest into or out of the delimited area, and subject to phytosanitary or other control measures, if appropriate" (IPPC, 2016).

If an area is regarded as an ALPP, extra phytosanitary protocols and treatments may be required for maintaining the ALPP. The maintenance of an ALPP should be done through the continuous use of the measures which were used for the establishment of the area. The necessary documentation and verification procedures are also important for the maintenance of an ALPP (IPPC, 2005).

It is costly to be certified as a PFA, since there is a need for continuing surveillance and measures that exclude imports from countries where the specific pests are present. When certified as a PFA, a country can export its products without experiencing the additional costs resulting from treatments and quarantine measures. The certification to become a PFA is more essential for countries that face higher costs for treatments that are required if the country or region is not established as a PFA. If there is an increase in the revenue gains from exports, pest damages and the continuing cost of control are lower, which surpasses the cost of eradication and continued monitoring of areas for which PFA certification is necessary (Lichtenberg & Lynch, 2006). Everyone in a region does not benefit from the PFA certification, however. Local consumers can be the ones not benefiting, due to the increase in the export price, which leads to an increase in domestic prices (Lichtenberg & Lynch, 2006). The implementation of some activities are required to maintain a PFA. These required activities include eradication and maintenance of quarantine areas when outbreaks occur; border control; surveillance and management costs; research and development; and communication costs (Florec *et al.*, 2010).

The eradication of pests are not necessarily more efficient and effective as on-going control efforts. The benefits of the process are usually measured as the sum of all the losses that are prevented by the process. Losses include losses to growers, producers and markets (Myers *et al*., 1998). Benefits from a PFA that was established in Mexico include the significant growth of the horticultural industry. This growth generated more foreign currency as a result of increased exports, more jobs were created in rural areas, and there was an improvement in human nutrition since the supply of fruit and vegetables was increased. The annual investment by the Mexican government for the area-wide management (AWM) of the Mediterranean fruit fly has been recouped due to the absence of the fruit fly in Mexico (Enkerlin *et al*., 2015). Government support will be needed to secure PFA certification. This will be easier in developed countries, whereas in developing countries it will be more difficult to obtain (Lichtenberg & Lynch, 2006).

Where countries have natural boundaries such as rivers or mountains, it is often easier for such regions or countries to achieve PFA status. SPS standards can sometimes be used as barriers to export to certain markets (Lichtenberg & Lynch, 2006).

2.6 Cost-benefit analysis

Prior to commencing a project, the technical and economic feasibility of the project should be assessed. Such projects usually involve a major amount of initial capital investment. The initial investment provides long-term benefits (Mumford, 2005). The traditional cost-benefit analysis criteria estimate the project's net benefits and effects over time in an economy (Anandarup, 1990). The cost-benefit analysis embeds the concept of economic efficiency, meaning that the benefits must exceed the costs (Pearce, 1998). A cost-benefit analysis can be used to determine whether it would be cost-effective to establish a PFA, and to combine the economic aspects of pest management, the biological characteristics and the environment of the targeted pest (Florec *et al.*, 2010). Problems that involve multiple criteria that need to be addressed, like the establishment of pest-free areas, cannot be successfully addressed without access to all the necessary information that are related to the problem (Brans & Mareschal, 2005). The benefits from the use of an economic analysis include economic efficiency, which is seen as the primary benefit of an economic analysis. Other benefits include objectivity; inclusiveness; transparency and accountability; and the appreciation of uncertainties and risks (Henson & Masakure, 2009). It is possible for uncertainties to arise in a cost-benefit analysis, as the benefits and costs are estimated at future values (Mumford, 2005).

In order to make well-informed decisions, data needs to be collected and analysed to evaluate the impact on all the different factors involved. The co-operation and input of all stakeholders are required to successfully implement controls and projects (Aceng, 2014). Decision makers spend time and effort to define the context of the problem and the constraints of the decision. The decision makers also have the responsibility to select the final decision and to implement this decision (Kiker *et al*., 2005). The flow of a decision-making process will be determined by the stakeholders involved, the decision-making context, and the implementation of the process used (Dooley *et al*., 2009). When finalising a decision, decision makers should motivate the weights that are awarded to the criteria and sensitivity analysis (Brans & Mareschal, 2005).

2.6.1 Origin and use of the cost-benefit analysis

The cost-benefit analysis was developed in 1844 by Jules Dupuit, who was a French engineer and economist (Hause, 1975; Pearce, 1998). Jules Dupuit established the "marginal analysis", which is defined as the method to measure costs and benefits in order to make investment decisions whose benefits will outweigh the costs (Pearce, 1998). Ekelund (1968) found that Jules Dupuit's work was relatively unexplored and apart from the fact that Dupuit has the entitlement of being the first cost-benefit economist, the concept of the short-run marginal cost theory cannot be attributed to Dupuit (Ekelund, 1968). In honour of the 100-year anniversary of Dupuit's development of the cost-benefit analysis, Maneschi (1996) published a paper, reflecting on the foundations of the cost-benefit analysis. This paper gives Dupuit the credit of having established the foundations of the cost-benefit analysis.

In 1936, the United States Flood Control Act utilised the cost-benefit analysis to analyse whether the USA should proceed with water projects. This was the first time the actual technique of cost-benefit analysis was formulated (Bizoza & De Graaff, 2012; Nas, 2016; Pearce, 1998). Not only gainers and losers, but also the public and political motivations were considered (Pearce, 1998).

The Federal Interagency River Basin Committee considered costs and benefits from 1946 to 1950, and produced a "Green Book" on the evaluation of costs and benefits in water projects. Further guidance on the cost-benefit analysis was provided by the Bureau of Budget in 1952. These efforts on the cost-benefit analysis were lacking theoretical foundations, however (Pearce, 1998). Research and studies about the cost-benefit analysis have been actively done since the early 1960's (Anandarup, 1990), and the economic basis of the cost-benefit analysis was nearly in place, lacking only two components: environmental and socio-economic costs and benefits (Pearce, 1998). Pearce *et al.* (2006) published a book in collaboration with the OECD regarding the development and inclusion of environmental costs and benefits. The cost-benefit analysis has been widely applied throughout the world as a decision making tool since the 20th century.

In the cost-benefit analysis, the benefits and costs are fundamentally defined as the increase and decrease in human wellbeing respectively (Pearce *et al.*, 2006). It is important to justify the outcome of a cost-benefit analysis. Even if the benefits exceed the costs, it must be determined who would carry the costs and who would receive the benefits. If the "losers" in the situation do not benefit from the project, the project should not be implemented (Pearce, 1998).

The cost-benefit analysis is defined as the economic way, in a methodical and logical process, to choose between numbers of alternatives (Mishan & Quah, 2007). The benefits and costs for a certain project are compared with each other, and the project whose benefits are greater than the costs, is recommended (Argyrous, 2017; Hansjürgens, 2004; Pearce, 1998). The cost-benefit analysis is established as a formal technique to make well-informed decisions regarding the use of scarce resources (Mishan & Quah, 2007). The cost-benefit analysis is not a substitute for the decision-making process - it only assists the decision makers to make well-informed decisions (Pearce, 1998).

The cost-benefit analysis attempts to demonstrate if the proposed project is meaningful and worthwhile (Mishan & Quah, 2007). When the benefits of a project are greater than the costs, it means that the project is possibly worthwhile. If there is more than one option to choose from, the different projects should be ranked according to the cost-benefit ratio, and the project with the highest ratio should be recommended (Pearce, 1998). The costs and benefits of the projects are indicated in monetary terms (Hansjürgens, 2004). The monetary value of the costs and benefits should all be objectively estimated for the period of the project's duration (Mumford, 2005). Many economists view a cost-benefit analysis as an instrument that reduces inefficiencies and illogical decision making. This analysis can be used to overcome misconceptions, for example the insufficient control of measures and inaccurate priorities (Hansjürgens, 2004). Cost-benefit analyses and risk assessments can include more qualitative data, while other models' results may include more quantitative data (Kiker *et al.*, 2005).

Costs and benefits that influence producer welfare are:

- The compliance effect, which includes the quarantine, surveillance and monitoring costs;
- The quality effect, i.e. the benefits that will arise from the reduction of post-harvest treatments;
- The post-harvest cost effect;
- Crop damage effect, being the producer's loss caused by the exotic pest, based on the reduction of farm yield; and
- The input-use effect, which includes the avoided pest control costs (Florec et al., 2010).

A full cost-benefit analysis should take into consideration both producer and consumer welfare (Florec *et al.*, 2010).

The cost-benefit analysis is not only a method that evaluates the costs and benefits of certain programmes, but it also is a framework that identifies the effects of certain measures. The cost-benefit analysis is also a guideline for the collection of the data, in a methodical way, that is needed for the analysis (Hansjürgens, 2004). The traditional framework provided to do a cost-benefit analysis assesses and compares the flow of the costs and benefits of the project over time (Mumford, 2005). There are two main types of cost-benefit analyses: the *ex-ante* cost-benefit analysis and the *ex-post* cost-benefit analysis. The *ex-ante* cost-benefit analysis is the cost-benefit analysis that is generally mostly used, and is done while the project is still being considered. The *ex-ante* cost-benefit analysis contributes to the decision-making process by allocating resources (Boardman *et al*., 2017). An *ex-ante* cost-benefit analysis will provide information on whether the project will be feasible (Pearce *et al.*, 2006). The *ex-post* cost-benefit analysis is only engaged when the project has been completed. A less immediate value is given by the *ex-post* analysis, but it is considered to be broader than the *ex-ante* analysis. The *ex-post* cost-benefit analysis contributes to the understanding of the meaningfulness of the project (Boardman *et al.*, 2017). The main steps for conducting a cost-benefit analysis are depicted in Figure 2.5 below.

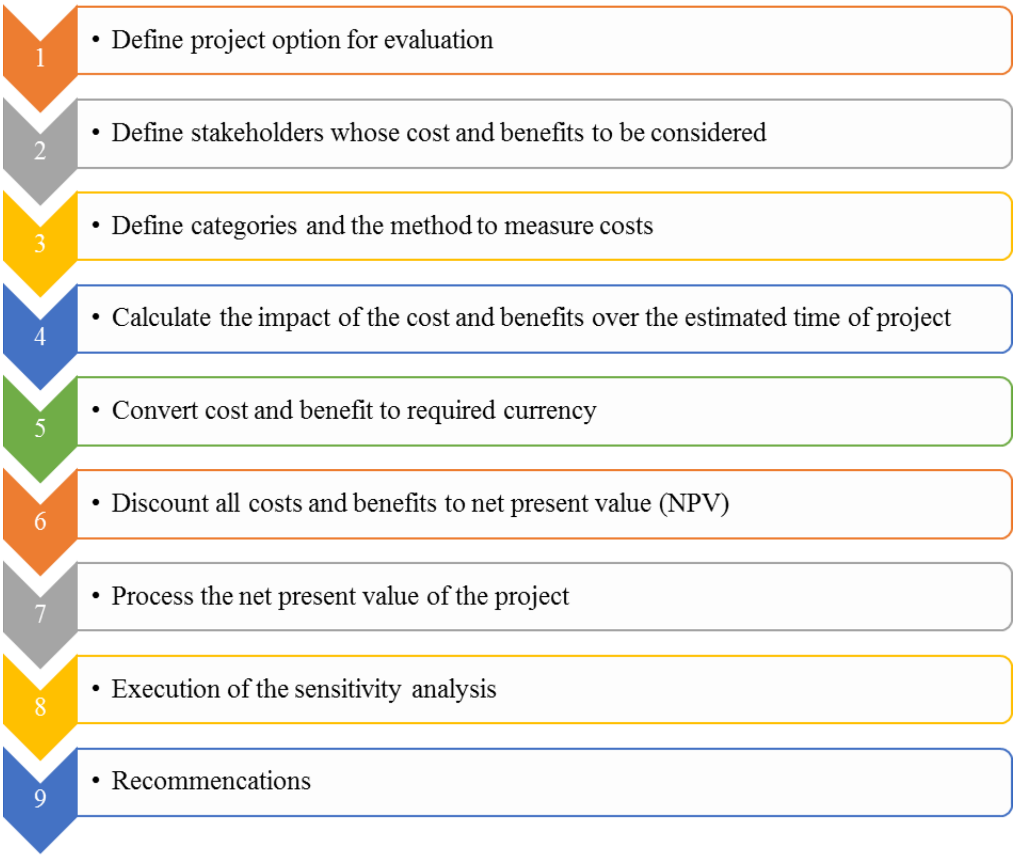

Figure 2.5: Main steps for a cost-benefit analysis

Adapted from: (Boardman *et al*., 2017; Saarikoski *et al*., 2016).

The cost-benefit analysis falls within the neoclassical welfare economic view (Pearce, 1998). Operational guidance for public policy is provided in the neoclassical economy (Argyrous, 2017). The neoclassical economic approach relies on the assumption that both the costs and benefits involved in the analysis are weighed up against one another. Therefore, the benefits of improvements made and the cost of the different measures are weighed up. During the process, when an option is selected as the preferred one, the alternative one is regarded as unnecessary (Hansjürgens, 2004). In a neoclassical economy a price is assigned to everything (Argyrous, 2017).

Neoclassical economics judges the capability of the benefits to be substituted and the reversibility of the benefits more optimistically than ecological economics' representatives. Neoclassical thinking does not take the problem of irreversibility fully into account, but it recognises the problem. The cost-benefit analysis is important in welfare economies, since cost-benefit analyses provide a basis for decision making before carrying out any actions.

Ecological economists would insist that other criteria be used before a final decision can be made (Argyrous, 2017; Hansjürgens, 2004).

Assumptions of the cost-benefit analysis are (Fischhoff, 1977; Florec *et al.*, 2010; Myers *et al.*, 1998):

- all the important consequences can be numbered in advance;
- judgements concerning the cost-benefit analysis are meaningful;
- different costs and benefits can be compared;
- the valuation of different consequences in the present and future is known; and
- the maximisation of the differences for the expected benefits and costs.

In the cost-benefit analysis of pest eradication, programmes tend to overvalue benefits and undervalue costs (Florec *et al.*, 2010; Myers *et al.*, 1998). The costs and benefits of such a programme does not affect all individuals equally.

Reasons for the overvaluation of benefits include:

- lack of scientific data, since the distribution of species is not documented, which makes the evaluation more difficult;
- a potentially biased decision process, as the industry that is affected by the pest concludes the evaluation; and
- a potentially biased evaluation, due to the effect of producers being the primary concern of the economic evaluation (Myers *et al.*, 1998).

Reasons for the undervaluation of costs are *inter alia*:

- the costs for killing the last individual pest are nearly as high as killing the first 90-99% of the pest;
- costs of the impact on other aspects;
- costs of monitoring and the initial reduction of the pest;
- costs related to the potential re-introduction of the pest; and
- costs of public relations, risks for human health, and human error (Myers *et al.*, 1998).

The application of the cost-benefit analysis can be used according to simple accounting principles. It can be based on very complex econometric models, and can then be described as an analysis that can express costs and benefits in monetary values by calculating and comparing the flow of the costs and benefits over time. Discounting is used to express the real rates of present and future costs (STDF, 2009). The cost-benefit analysis tool can be used for assessing the priorities for research and development projects. This tool can guide decisions makers regarding the investment required to allocate funding to these projects to address biosecurity issues, which are built around the expected welfare gains of producers and consumers (Florec *et al.*, 2010). The future benefits and costs need to be discounted to arrive at a current value, and a suitable discount factor should be used. The cost-benefit analysis concludes with a net effect that reflects the extent to which the benefits exceed the costs. This net effect fails to take into account the effects of circulation that is taking place (Hansjürgens, 2004). When a cost-benefit analysis is conducted and not all information is available, the question that arises is whether it is better to have an imperfect analysis that contains the available information, or to have no analysis at all. An inaccurate cost-benefit analysis can lead to an error in the decision-making process (Henson & Masakure, 2009).

The benefits of undertaking a cost-benefit analysis can easily exceed the costs (Fischhoff, 1977). The cost-benefit analysis is used to estimate the net benefits of management strategies and allows for the assessment of costs and benefits for different alternatives (Harvey *et al.*, 2010). It is necessary and important to conduct a sensitivity analysis as part of the cost-benefit analysis to account for uncertainties and risks (Mumford, 2005). However, a sensitivity analysis does not indicate the combined effect of changes in variables, and neither does it indicate that more than one change can occur together (Anandarup, 1990).

The quantitative function of the cost-benefit analysis makes it possible to adjust it for different uses and takes into account the calculations of parameters which are changeable (Stošić *et al*., 2017).

2.6.2 Financial cost-benefit analysis

For the purpose of this study, the cost-benefit analysis will be limited to a financial cost-benefit analysis, as indicated in Chapter 1. The financial cost-benefit analysis is used to determine the social and economic conditions in which a certain project will be beneficial (Bizoza & De Graaff, 2012). Accordingly, no shadow prices will be used and the costs and benefits used will be limited to the project itself and not the entire economy. Shadow prices are used in an economic cost-benefit analysis to calculate the market price of a specific input when the market price is not available (De Rus, 2010).

The financial cost-benefit analysis is a logical and rational tool which can contribute to the decision-making process. This instrument is widely accepted (Stošić *et al.*, 2017). When a financial cost-benefit analysis is completed for a project, the goal of the analysis is to assess whether the project is financially feasible and profitable (Bizoza & De Graaff, 2012). The following outcomes are usually presented by the cost-benefit analysis: total benefits and costs of the project; net present value (NPV) of the project; the internal rate of return; and the benefit-cost ratio (Keefe, *et al*., 2012; Stošić *et al.*, 2017). The study by Keefe *et al*. (2012) found that the NPV receives the most attention when analysing and interpreting the cost-benefit analysis, and that the cost-benefit ratio provides the same indicator as the NPV. When two or more projects are weighed up against each other, the project with the highest cost-benefit ratio should be chosen.

A constraint of completing a financial cost-benefit analysis and using just the market value, is that other values, which can have an impact on the society, could be omitted (Keefe *et al.*, 2012). Much attention has been given to distributional issues of the cost-benefit analysis, and it is noted that, in developed countries, the shadow prices are higher than real values (Maneschi, 1996). However, as mentioned earlier, shadow prices will not be used in this financial cost-benefit analysis.

2.6.3 Cost-benefit analyses previously applied in agriculture

Various cost-benefit analysis studies have been completed with the aim to control pests and diseases, including fruit flies. The major reason for this type of analysis is to gain entry to export markets where access is not possible due to quarantine restrictions. Numerous studies make use of the *ex-post* analysis and focus on the impact of direct control measures, while taking into consideration that broader economic benefits may be important. Observations have been made that *ex-post* analyses of benefits are variable and *ex-ante* analyses of variables are unpredictable. The modelling of supply and demand behaviour is a time-consuming, resource-intensive and challenging process (Henson & Masakure, 2009). If both the net impact and cost-benefit ratio of a project are positive, it indicates that the resources were used acceptably from the viewpoint of the project objectives (Anandarup, 1990).

The economic impact of the spreading of the fruit fly is expected to return the expected value of all the costs that will prevent the spreading to happen (Cook, *et al*., 2010). In 1997, Molloy *et al*. found that the benefit-cost ratio for preventing the spread of fruit flies in Australia before they are established, is 17.7:1. In that study the benefits are seen to be significantly more than the costs. Costs in this analysis include monitoring of traps, roadblocks, and the inspection of fruit on local markets. The costs associated with outbreaks are calculated as an average of the eradication costs and an average number of outbreaks that may occur (Molloy, *et al.*, 1997).

Bactrocera dorsalis was successfully eradicated from the Okinawa Islands over a period of five years. According to Myers *et al.* (1998), this programme was feasible. The feasibility of the programme was based on the effective lure, which attracted the male flies, and the isolation that reduced the immigration of the flies (Myers *et al.*, 1998).

A cost-benefit analysis has been conducted on the use of the sterile insect technique (SIT) as an area-wide integrated pest management (AWIPM) programme for the establishment of pest-free areas of Mediterranean fruit fly (*Ceratitis capitata*) in Western Australia. The process to conduct a cost-benefit analysis and to compare the future costs and benefits in terms of present value, is provided. A checklist of input of the cost-benefit, as well as examples of the cost-benefit outputs are also presented in this study (Mumford, 2005).

In a study by Kim *et al*. (2006), it was found that it is more economically efficient when more resources are spent on management activities to prevent invasive pests from entering a country, rather than waiting until the pest is discovered in the country. Every situation with invasive pests differs, and is case-specific (Kim, *et al*., 2006).

Costs to prevent a fruit fly species from spreading include monitoring and surveillance costs, quarantine borders (roadblocks are used for this aspect), response and eradication, and continuous control (Abdalla *et al*., 2012). A study of the Queensland fruit fly (*Bactrocera tryoni*) found that the area-wide management of fruit fly is cost-effective. These schemes are dependent on government funding, however (Florec, *et al*., 2013). Results obtained from the study indicated that roadblock protection is more effective than increasing surveillance (Florec, *et al.*, 2013). The costs of implementing the programme for the establishment of pest-free areas need to be paid first before any benefits can be generated. The costs to establish the programme are fixed (Ha, *et al*., 2010). In the cost-benefit analysis of the management of the Queensland fruit fly in Victoria by Ha *et al.* (2010), the maintenance costs include all the fixed and variable costs. The monitoring and surveillance costs of the traps are fixed, whereas the eradication cost is a variable cost, since this cost only occurs when there is an outbreak. The eradication costs are calculated by taking the probability of an outbreak, the cost of eradication, size and period of outbreaks into consideration (Ha *et al.*, 2010). An *ex-ante* cost-benefit analysis was undertaken on the management of the Queensland fruit fly in Australia. The aim of the study was to discuss the cost-benefit analyses of three different management strategies regarding the Queensland fruit fly, as opposed to a "do nothing" counterfactual, and to provide insights to other agencies. A number of issues were encountered in this study, e.g. the estimation of welfare effects, the way in which the social and environmental costs and benefits should be considered, and the incorporation of the risks of managing a pest. The three different management strategies provided three different benefit-cost ratios, namely 2.02:1, 2.15:1 and 2.35:1 respectively. Management strategy three was the preferred option, given its cost-benefit ratio of 2.35:1. This management strategy option was based on: establishing pest-free areas in areas where high production takes place; there are areas of low pest prevalence outside the pest-free areas; verification and certification costs are required for all fruits entering pest-free areas; and the risk of an outbreak is lower (Harvey *et al.*, 2010).

The benefits included in the study by Harvey *et al*. (2010) were: premium prices achieved in export markets; avoidance of pre- and post-harvest treatment costs; and the costs being those of the management of the Queensland fruit fly. All of these costs were quantified, whereas other costs were not quantified but also considered. These costs and benefits include environmental and human health costs and benefits, external benefits, costs from backyard growers, and IPM benefits when chemicals are not used (Harvey *et al.*, 2010).

Florec *et al*. (2010) conducted a literature review to compare the choice between being registered as a PFA and the use of pre-and post-harvest treatment on fruit in Australia. According to Florec *et al.* (2010), the sum of the change in producer and consumer welfare is used to measure welfare in a full cost-benefit analysis. This takes into account the affected population over the time period that the project is established and valid. It also takes into account the costs related to establishing and maintaining the PFA. When not assessing a full cost-benefit analysis, producer surplus is taken into account, but it is assumed that consumer surplus does not change. In a full cost-benefit analysis, it is important to take both producer and consumer welfare into account (Florec *et al.*, 2010). An analysis has not yet been done on the change in production and consumption. This problem of the invasive species may be formulated as a risk-benefit analysis rather than a cost-benefit analysis (Florec *et al.*, 2013).

Australia developed a national action plan against fruit flies and used a cost-benefit analysis to assess whether the plan would be economically feasible. Assumptions regarding key parameters were made after consultations with stakeholders and experts. These key parameters included international access to markets, emergency response capability, and management and production losses. The results of this study indicated a benefit-cost ratio of 12.1:1 in the low-case scenario and 15.6:1 in the high-case scenario. The low-case scenario represented a reduction of 30% from the key parameters in the cost-benefit analysis that was used in 2009 in Australia's National Fruit Fly Strategy .The sensitivity analysis done for this report illustrated that even if the original assumptions overestimated the benefits that would be gained, the benefit-cost ratio would still be 10.6:1 and 13.6:1 for the low-case and high-case scenarios respectively (Abdalla *et al.*, 2012).

In Florida, USA, the *B. dorsalis* was detected in 2015. The main costs for the farmers in Florida's quarantine areas were:

- to strip the host materials, which would result in production losses;
- areas neighbouring the affected areas could only harvest the fruit if post-harvest treatments were done;
- pre-harvest treatment would require additional bait sprays; and
- farmers could decide to no longer plant fruit crops in that specific year.

The study concluded with results for both a pessimistic scenario, where *B. dorsalis* are still discovered, and a mid-range scenario, where no further outbreak of fruit flies occurred. If no further outbreak occurred but pre-harvest treatment was still necessary, the total economic impact was estimated at USD27 million. The total economic impact in a pessimistic scenario was estimated at USD58.5 million (Alvarez *et al*., 2016).

Other industries in Australia also benefited from the country's National Fruit Fly strategy, for instance the ability to access new markets. The benefits for the horticultural industry in the study by Abdalla *et al* (2012) are: increased market access (exports to premium markets will result in greater sales revenues); the reduction of pre- and post-harvest treatments; and the decrease in production losses due to fruit fly damage to fruit (Abdalla *et al.*, 2012). Cook & Fraser (2015) used a cost-benefit analysis to determine whether the benefits will exceed the costs when an eradication programme is implemented in Western Australia to annihilate the

Mediterranean fruit fly, or if more benefits would be gained when only controlling the fruit fly with pre- and post-harvest treatment. The outcome of this study was that, if the costs were shared between government and industry, it would be beneficial in the long run to implement the eradication programme (Cook & Fraser, 2015).

IPM is a system that manages pesticides. The IPM system manages the pests with the intent of minimising the damage to the environment and increasing productivity (Blanquart, 2009). A study entitled *Economic evaluation of integrated management of fruit fly in mango production in Embu Country in Kenya* by Kibira *et al*. (2015), found that the use of a integrated pest management (IPM) package had a positive impact on mango production in Kenya. The programme consisted of the use of male annihilation technique (MAT); protein bait spray; releases of exotic parasitoid *Fopius arisanus*; and the use of augmentoria. It was found that the use of the IPM package resulted in a 54.5% decrease in the amount of mangos that were rejected, 46.3% less expenditure on pesticides per acre, and a 22.4% increase in net income, compared to the growers that did not participate in the programme. The data collected for this programme was collected from farmers before and after the package of IPM were used. It was suggested that further research should be done to integrate IPM training with agricultural practices. It is recommended that a thorough cost-benefit analysis be conducted to provide further information and evidence for the increased utilisation of IPM packages (Kibira, *et al*., 2015). IPM is considered to be a sustainable practise, since it entails less expensive methods and IPM attempts to avoid the negative effects of pesticides on human health and biodiversity (Blanquart, 2009).

A cost-benefit analysis was adopted in Mexico for the establishment of areas free from the Mediterranean fruit fly by preventing the fruit fly from establishing itself in that country. This was done with the use of integrated area-wide SIT programmes. With a benefit-cost ratio of 112:1, it is clear that the Mexican government made the right choice to establish those pest-free areas (Enkerlin *et al.*, 2015).

All of the cost-benefit analyses cited above indicate that both the establishment of PFA in a country or in certain parts of a country and the maintenance of the status quo regarding distribution of fruit flies within a country, have a positive benefit-cost ratio. When using the cost-benefit analysis in the decision-making process, the limitations and constraints of the analysis must be taken into account. Limitations and constraints that were highlighted in previous studies will be provided in the following section.

2.6.4 Limitations and constraints of cost-benefit analyses

It is important to take the limitations and constraints of the cost-benefit analysis into account (Henson & Masakure, 2009), as it will ensure that the decision making will be based on a correct interpretation.

Six constraints of the cost-benefit analysis were highlighted by Pearce (1998). The constraints include:

- to distance policy from the cost-benefit analysis;
- irrational monetarisation;
- transparency and flexibility of the analysis;
- the goal, which is economic efficiency, is not always the main objective; and
- the estimation of benefits and costs can change easily (Pearce, 1998).

The cost-benefit analysis does not only monetarise costs and benefits, it is also a model that explains the process of valuation. The cost-benefit analysis is a guideline for collecting required data in a methodical way. Limitations of the cost-benefit analysis come to the fore when goods are not substitutable, the process or project is irreversible, and it has long-term effects (Hansjürgens, 2004). The quality of data available in developing countries is a major constraint to constructing a cost-benefit analysis. Costs and benefits of past investments can be inaccurate guides for the impact of future investments (Henson & Masakure, 2009).

The cost-benefit analysis received criticism as being a method that compares diverse components, e.g. human health is weighed up against economic efficiency. These two components are viewed as non-comparable (Hansjürgens, 2004). Other objections are the concern about decisions that are based on productivity considerations only, and the fear that economic assessments do not account for nature (Hansjürgens, 2004), as nature has an essential value (Pearce, 1998). Attaching a monetarised value to the environment degrades the environment since it appears that the environment can be "sold" (Pearce, 1998). The collection of data and the ranking of alternatives are also questioned. Data collection and the nature of the costs that are taken into account are seen as uncertain, as the data and costs are usually extracted from company surveys. The person who collects the data can decide to only consider certain aspects and neglect others (Hansjürgens, 2004).

By quantifying data such as regulations, the accuracy of data can sometimes be questionable. This criticism can be overcome and defended by the performance of a sensitivity analysis and examining the robustness of the results. Undue weight could be attached to quantitative facts, since "hard" numbers have a greater effect than the "soft" numbers that are gathered from qualitative data (Hansjürgens, 2004). A further complaint about the cost-benefit analysis is that the analysis gives too much credence to shadow prices when adjusting and transforming financial in- and outflows to economic terms (Anandarup, 1990). The sensitivity analysis is necessary to test whether the model is realistic and includes all uncertainties and risks (Mumford, 2005). When assessing the costs and benefits, a problem that arises is the uncertainties that result from restricted knowledge about future scarcity. Data collection is time-consuming, expensive and complicated, and there consequently should be a trade-off between improved information and the resources and time required. Non-economists consider the cost-benefit analysis as an instrument that has no additional benefits. In their view, the conversion of costs and benefits to monetary values is a myth, and the methodology's shortcomings make it impossible to arrive at a quantitative cost-benefit analysis (Hansjürgens, 2004).

In this project data collection, the choice of variables and the structure of the model itself will be transparent. It is important for this model to be transparent, since this study may serve as indicative of the necessity for a more comprehensive cost-benefit analysis.

2.7 Costs and benefits involved in the establishment of pest-free areas and areas of low pest prevalence

There are several criteria that need to be considered when decisions are made regarding the use of management practices to regulate pesticides in agriculture (Blanquart, 2009). The criteria include: economic factors; environmental factors; technical factors; social factors; and informational criteria (Blanquart, 2009; Dantsis, *et al*., 2010; Linkov *et al.*, 2004). Food safety and food security have various impacts on other factors such as trade, socio-economic, health and economic factors. All the criteria need to be considered by decision makers (Aceng, 2014).

Costs and on-going funding were cited as the most dominant barriers with regard to the application of AWM, according to the participants of a study pertaining to the eradication and management of the Queensland fruit fly in South East Australia. Other barriers include insufficient knowledge; indifference to the control of the Queensland fruit fly; the absence of social collaboration between growers; and the incompatibility of AWM and SIT programmes with current practices (Florec *et al.*, 2010).

An issue of high importance in agricultural policy is the valuation of policy information's impact on agricultural production. There is a strong relationship between agricultural and environmental policies, as the quality of the environment is a big concern due to it being affected by the application of pesticides and fertilisers (Gómez-Limón *et al*., 2004). Useful decision-aiding data should be provided to decision makers, e.g. information on decision makers' preferences (Brans & Mareschal, 2005).

Benefits resulting from the successful eradication and management of the Queensland fruit fly in Australia would be numerous. These benefits include: increased market access; increase awareness of fruit flies; leaders that would facilitate the programme and the supply chain in certain regions; and the credibility of adapting the AWM programme (Mankad *et al.*, 2017). The method of carrying out a cost-benefit study is well established. All costs and benefits should be considered, even those not captured by previous analyses. Benefits stated by Harvey *et al.* (2010) also include avoided chemical costs and market access. The costs included in this study are those related to the establishment of PFAs, monitoring costs, surveillance costs and eradication costs. The costs and benefits of maintaining the IPM measures have not been priced. There are also other indirect costs and benefits that were not considered by Harvey *et al.* (2010). Numerous benefits can arise from the establishment of PFAs in a country, since an increased number of export markets can be secured when PFAs are established and maintained. To become certified as a PFA is expensive, however (Florec *et al.*, 2010).

If investments are made to establish PFAs, the options to develop these areas may be present in either or both the public and private sectors. If the increase of exports is the key focus, choices should be made between SPS capacities that are related to exports. In a world where resources are limited, a methodical framework should be addressed to establish logical SPS improvements that are beneficial. The methodical framework needs to identify weaknesses and gaps in the SPS capacity (Henson & Masakure, 2009). When economic gains arise from increased exports, reduced pest control, the decrease of surveillance costs and the reduction in monitoring and eradication protocols that are required to maintain areas free from pests, it represent an increase in welfare (Florec *et al.*, 2010).

2.8 Conclusion

This chapter provides an overview of the *B. dorsalis* fruit fly and the use of the cost-benefit analysis which is used to establish whether a specific project will be feasible.

The horticultural industry of South Africa contributes substantially to the country's GDP, confirming that this industry is quite important for the South African economy. Municipalities in many areas are dependent on agriculture as the agricultural industry is the main employer in those areas. The agricultural industry should therefore be protected and supported to ensure continuous economic growth and job creation.

Bactrocera dorsalis is a widely feared and highly invasive pest, and is of major economic importance as it accounts for losses in the horticultural industry. *Bactrocera dorsalis* is consequently treated as a quarantine pest in many countries. International trade is important for a country's economy. Countries should therefore acknowledge the importance of SPS measures to avoid trade restrictions that can negatively affect the country's export potential. *Bactrocera dorsalis* is already established in some of the provinces in South Africa. It is possible to establish and maintain certain areas pest free and areas of low pest prevalence from *B. dorsalis* where the pest is not yet established, thereby ensuring continued trade with countries where *B. dorsalis* is a quarantine pest.

A cost-benefit analysis could make a positive contribution towards ascertaining whether it will be feasible to establish pest-free areas and areas of low pest prevalence. The cost-benefit analysis is a widely accepted method used to assist with the decision-making process. The model's ability to take multiple criteria into account and to rank different alternatives, makes the method attractive and widely used. This analysis makes use of a cost-benefit ratio, and its net present value and internal rate of return assist the decision-making process. The cost-benefit analysis has been widely used in agriculture, and also for the establishment of pest-free areas and areas of low pest prevalence regarding fruit flies. All the previous studies mentioned in this chapter indicate that the establishment and maintenance of pest-free areas and areas of low pest prevalence were beneficial for the countries in which the programmes were applied. In the following chapter, the application of the cost-benefit analysis and all the benefit and costs used within the analysis will be explained.

Chapter 3 : Application of the cost-benefit analysis

3.1. Introduction

As discussed in Chapter 2, the cost-benefit analyses have been applied in relation to the establishment of pest-free areas in some countries, and the outcomes of those analyses were positive.

This chapter provides information regarding the method that will be used to do the financial cost-benefit analysis of the current situation in South Africa. The cost-benefit analysis provides the possibility to take diverse criteria and uncertainties into account, and it makes use of a sensitivity analysis. Each benefit and cost used in the analysis is explained. Detail is provided on how the information used, was obtained. The different costs and benefits were either provided by the stakeholders at the workshop held at Devonvale, or by analysing literature.

The different aspects of the cost-benefit analysis and the calculation methods used in respect of each aspect, will be explained. The criteria that assist the decision-making process will also be explained. This chapter also reflects the costs and benefits that are not included in this project's financial cost-benefit analysis, but which should be included in a more comprehensive cost-benefit analysis.

3.2. Description of workshop for the establishment of PFA and ALPP

A workshop was held at Devonvale Golf Estate, Stellenbosch on 27-29 November 2017. Attendees were stakeholders involved in the project proposal, i.e. a Standard and Trade Development Facility (STDF) for the establishment of areas free from fruit flies and areas of low pest prevalence with special reference to *B. dorsalis*, *Bactrocera curcurbitae*, *Ceratitis rosa*, *Ceratitis quilicii* and *Ceratitis capitata* in South Africa and Mozambique. It was decided at the workshop that the financial cost-benefit analysis for this project proposal should only address the establishment of pest-free areas and areas of low pest prevalence for *B. dorsalis* in South Africa. The stakeholders provided input regarding the costs and benefits that should be included in the cost-benefit analysis.

Another workshop was held on 6 June 2018 at the Orange Hotel, Nelspruit, at which the project for the STDF was finalised and the cost-benefit analysis was presented. Participants at this workshop again provided input regarding the criteria used, following which the cost-benefit analysis was adapted. Annexure A provides detail regarding the attendance at the workshops and the participants of the two separate workshops.

Some of the salient costs have been provided by the industry in order to complete this financial cost-benefit analysis. Most of the information was obtained from the representative bodies of the different industries. These bodies include: SATI (Southern African Table Grape Industry); Hortgro; CRI (Citrus Research International); CGA (Citrus Growers Association); and Subtrop (South African Subtropical Growers' Association).

The relevant costs and benefits were identified by the stakeholders at the different workshops. The pre- and post-harvest treatment costs were identified, cold-sterilisation having been determined as a post-harvest treatment for purposes of this financial cost-benefit analysis. Direct and indirect costs were also decided upon, which include certification costs and the different levies paid. Prices paid by growers to enable them to export to special markets, the statutory levies paid by growers, and the levies paid to the Perishable Produce Export Certification Board (PPECB) for all cartons passed for exports, are included in this analysis. The eradication and surveillance costs and the premium prices lost are also included in this analysis.

3.3. Structure of the cost-benefit analysis

A cost-benefit analysis reflects the financial impact of the indicated management options, and is important for the assessment of economic returns created by the chosen option or project (FAO, 2001). For this financial cost-benefit analysis a *status quo* approach was followed, which means keeping the situation as it is, merely maintaining the situation, or doing nothing (Kim & Kankanhalli, 2009; Samuelson & Zeckhauser, 1988). *Bactrocera dorsalis* has spread throughout Africa and threatens agriculture since it accounts for market losses and crop damages (De Villiers *et al.*, 2016). The short-term strategy for the management of *B. dorsalis* is to continue with surveillance for the early detection of the presence of *B. dorsalis* in new areas, and also to prevent *B. dorsalis* from spreading further. Suppressing *B. dorsalis* in areas where it is already present will reduce the numbers and spreading of the pest within South Africa. As regards the long-term strategy, *B. dorsalis* needs to be managed as with the other fruit flies in South Africa, using techniques on an area-wide basis (Manrakhan *et al.*, 2015). Since *B. dorsalis* spreads so rapidly, it is considered a major pest because of its status, its ability to be invasive, and the impact it has on market access (CABI, 2018). The national action plan is in place in the event of the *B. dorsalis* fruit fly being found in an orchard. This action plan was compiled by Manrakhan *et al.* (2012), and developed by the South African *B. invadens* Steering Committee.

All economic and social changes that are important for the project should be included in the cost-benefit analysis (Maneschi, 1996). There are no definite differences between costs and benefits - costs are the benefits which will be lost if the resources are used for something other than the project. If costs and benefits are used in the same standard, the net impact of the chosen objective will be indicated (Anandarup, 1990). Prior to commencing with a project, the benefits and costs must be identified and boundaries regarding the benefits and costs must be clearly defined (Maneschi, 1996).

Microsoft Office's spreadsheet program, Excel, was used for this financial cost-benefit analysis to determine the benefit-cost ratio and the net present value, to break down the costs and benefits, and to structure it in a logical way. Benefits and costs are separated and all values are reflected as monetary values. The cost-benefit ratio and the net present value (NPV) are determined within the Excel spreadsheet. In order to determine the cost-benefit ratio, the total rand value of benefits is divided by the total rand value of costs. Net present value is determined by subtracting the total rand value of costs from the total rand value of the benefits. A project can be accepted when the benefit-cost ratio of the project is higher than one, the NPV is larger than zero, and the internal rate of return (IRR) is larger than the discount rate and market value (Nas, 2016). No internal rate of return will be used in this analysis since there is no initial investment made, and the net present value and benefit cost ratio are therefore used.

The current markets that can be accessed are seen as the benefit, because there are areas in South Africa where *B. dorsalis* is not present, there are countries where *B. dorsalis* has never been introduced, and there are countries where *B. dorsalis* is high on the countries' quarantine list (e.g. the European Union). The costs to maintain these markets at present are used as costs in the calculations. These costs include costs pertaining to eradication, surveillance, pre- and post-harvest treatment, certification for exports to special markets, statutory requirements, PPECB levies paid for all cartons exported, and the premium prices lost.

It is important to acknowledge the assumptions on which the cost-benefit analysis is based:

- calculations of the different costs and benefits;
- some data is based on estimates and averages;
- the data used is considered to be fixed and unchangeable. Prices used are based on 2016-2017 figures; and
- data that was collected is trustworthy.

3.3.1 Benefit component

The benefits used in a cost-benefit analysis are defined as gains that arise from a certain project (Pearce, 1998). With the benefit function, Mumford (2005) takes account of the costs that would replace the current costs and losses in the area that is controlled, the additional markets that can be accessed, and the cost-saving of not having to spray pesticides (Mumford, 2005). In this instance, the current market access to markets where either the monitoring of *B. dorsalis* or pest-free status is required, is used as the benefit.

3.3.1.1 Market access

In Australia, major benefits arose from controlling the Queensland fruit fly, one primary benefit being access to international export markets. Japan, New Zealand and the United States are important markets for Australia's fruit exports. These countries require that fruit must originate from pest-free areas (Ha *et al.*, 2010). The different elements of costs and benefits, which are in a foreign currency, as is the case with the trade in products, need to be identified. The foreign values need to be described and then multiplied by the shadow exchange rate. Many shadow exchange rates should be included (Anandarup, 1990).

Market requirements differ, as some markets are more sensitive than others (Florec *et al.*, 2013). The following markets require the monitoring of *B. dorsalis* as a prerequisite for phytosanitary registration for exports from South Africa: the USA; Mexico; China; Israel; South Korea; Taiwan; Mauritius; Japan; and the European Union (Manrakhan, 2016; Venter, 2017; Johnson, 2018). *Bactrocera dorsalis* has been declared as a quarantine pest by these countries (Dohino *et al.*, 2016; Venter, 2017). Monitoring is conducted with methyl eugenol bait traps in all commercial orchards, regardless of whether the pest is considered to be absent in the area. These traps should be observed weekly (Manrakhan, 2016).

Since the *status quo* approach was adopted for the financial cost-benefit analysis, the value of the current markets which require the monitoring of *B. dorsalis* and fruit which originate from pest-free areas as phytosanitary registration, were used. Trade Map data was used to determine the value of traded products for the identified horticultural industries in South Africa to the countries of destination.

3.3.2 Cost components

Costs are defined by Pearce (1998) as any losses experienced in a certain project. In a study by Mumford (2005), the cost function takes into account the variable costs per area that will be treated, including all the costs related to pest management activities and the fixed costs related to the functioning of the project. For this project, the costs include all costs currently used to maintain the current situation in South Africa regarding *B. dorsalis*.

3.3.2.1 Eradication

The challenge to eradicating pests in developing countries is to meet the requirements of the export markets and the costs involved. The requirements of the export markets will be met if all gaps in the phytosanitary oversight are fulfilled. Trade is critical to increase economic growth (Youm *et al.*, 2011). Eradication is necessary since the introduction of new species can lead to increased marketing and production costs. It can also cause damage to the environment by the increased use of chemicals and other controls, which can lead to yet more trade restrictions and quarantine markets. Declaring the eradication of pests as the end goal may create optimistic expectations. Providing area-wide management as a goal may be more realistic (Myers *et al.*, 1998). To achieve and maintain PFAs, it is necessary to implement a minimum surveillance and monitoring level. If an outbreak occurs, eradication should be implemented immediately. The success of the eradication programme should be investigated and evaluated to confirm the areas as being free of the pest (Florec *et al.*, 2010).

Eradication has high associated control costs, and in South Africa the eradication of *B. dorsalis* is not a sustainable option. South Africa has large areas, and it is possible that in the larger areas the benefits of eradication will be reduced (Manrakhan *et al.*, 2015). As soon as one *B. dorsalis* fruit fly is captured in an area, one should immediately implement a delimiting survey (Manrakhan *et al*., 2012). Delimiting surveys are defined by the International Standard for Phytosanitary Measures (ISPM) as "a survey conducted to establish the boundaries of an area considered to be infested by or free from a pest." (McMaugh, 2005). The method usually used for eradication is on-going control measures and intensive monitoring for a certain period since the last fruit fly was captured. If there are no further captures, the eradication is declared successful (Barclay & Hargrove, 2005).

The delimiting survey commences with the area immediately surrounding the area where the fly was found, declared as the core area. The core area comprises a 1 km x 1 km grid area. Bait traps of methyl eugenol (ME) and BioLure (BioLure is only placed in the core area) should be placed in the core area at a density of 10 traps per km^2. There are three zones that surround the core area, the sizes of the three zones being 8 km^2, 16 km^2 and 24 km^2 respectively. The trapping density in these zones should be two methyl eugenol bait traps per km^2 (Manrakhan *et al.*, 2012).

Insects may radiate 100 km from the third surrounding zone, usually following the main roads. The placement of the methyl eugenol bait traps in this 100 km area is as follows: for the first 10 km traps, it should be placed every 2 km; for the next 40 km, every 5 km; and for the next 50 km, every 10 km. Methyl eugenol traps will be placed on farms within 50 km of the core area that have orchards and fields containing host material (Manrakhan *et al.*, 2012). The core and three surrounding areas are visually illustrated in Figure 3.1, indicating the number of traps required in the different zones.

Trap density is determined by farm size, the extent of planting, and crops. For approximately 12 weeks the traps that have been placed will be maintained and monitored weekly. Within the core area, traps will be monitored daily for the first week (Manrakhan *et al.*, 2012). The probability of an outbreak is the key element that determines the cost of eradication. If an outbreak occurs, the process of eradication needs to be followed for 12 weeks (Ha *et al.*, 2010). If another fruit fly specimen is found in an additional trap, a new (or another) core area must be established, following the same rate, weeks and costs as mentioned above. In other words, the whole proses will start from the beginning until the fruit flies are successfully eradicated (Baard, 2018; Manrakhan *et al.*, 2012). In delimiting surveys, record-keeping is essential (Manrakhan *et al.*, 2012). The NPPO should keep records of the trap numbers, the places where the traps are located, dates and outcome of the servicing of traps, status and replacement of traps, if necessary, as well as the replacement of the lures. Other information considered necessary may be added (IPPC, 2015; Manrakhan *et al.*, 2012).

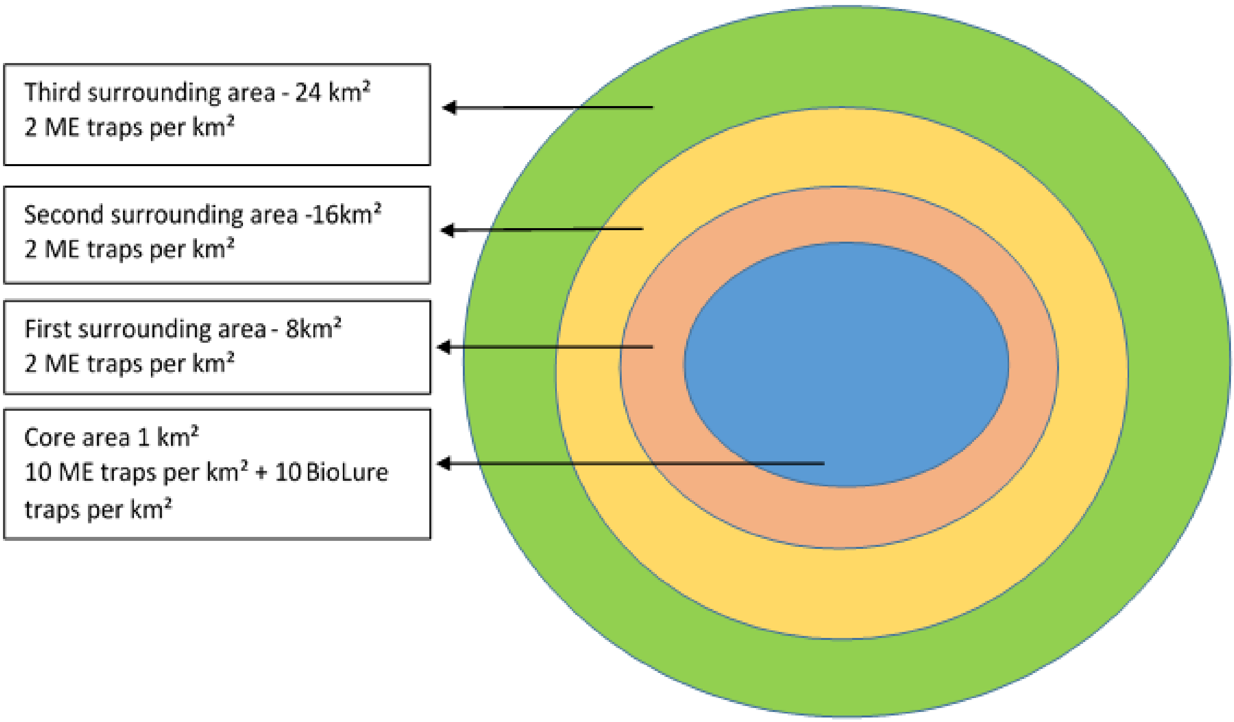

Figure 3.1: Delimiting survey and trap density of core area and three surrounding areas adapted from Manrakhan et al. (2012).

The eradication costs were provided by the manager of FruitFly Africa (FFA), and include all the equipment used, bait sprays, labour and aerial spray of the pesticides. These costs were verified by the national coordinator of the exotic fruit fly surveillance programme (the Manager: Plant Health and Early Warning Systems, Directorate Plant Health, Department of Agriculture, Forestry and Fisheries, South Africa). Eradication is seen as a fixed cost in this cost-benefit analysis and does not change due to different situations.

3.3.2.2 Surveillance costs

Surveillance is needed to determine the presence and prevalence of *B. dorsalis* throughout South Africa (Kleynhans *et al.*, 2014). An ongoing surveillance programme should be in place to detect the presence of *B. dorsalis.* This should include all entry points to the country, as in border posts, airports and sea ports, as well as production areas where *B. dorsalis* is present or areas that are close to entry points (Manrakhan *et al.*, 2012). When there are high levels of surveillance in a country, it is easier to detect the presence of a pest at an early stage and to implement eradication. When surveillance is in place, it may also lead to a reduction in eradication costs (Harvey *et al.*, 2010). To prevent *B. dorsalis* from spreading and invading new areas, fruit that are transported from infested to un-infested areas must be subjected to strict quarantine protocols (Wei *et al.*, 2017). Monitoring is also important for the identification of species in orchards and to identify potential problems within orchards, as it provides an indication of the quantity and severity of the pests that are present. Monitoring can also be used to determine the efficacy and time spent on control measures and actions (Kleynhans *et al.*, 2014). Surveillance costs in a study by Florec *et al.* (2010) include the number of traps used in an area, inspectors needed, and spacing between traps to calculate travel time and labour costs for AWM.

The surveillance costs for South Africa were provided by DAFF. These surveillance costs include costs related to the equipment used in areas where *B. dorsalis* are not present, labour, transport, toll fees, accommodation, food and beverages, and other equipment and consumables used for surveillance (Venter, 2018 *pers comm*).

3.3.2.3 Pre- and post-harvest treatment costs

The use of pre- and post-harvest treatments will decrease, if pest-free areas are established. It will also lead to a decrease in costs for producers, including the costs of chemicals used and labour costs for applying it. The reduction of pre- and post-harvest treatment costs can also lead to ecological and health benefits (Ha *et al.*, 2010). Post-harvest costs are sensitive to per-unit costs of post-harvest treatments. Complete and accurate information on production per hectare per year, land usage, probability of outbreaks per hectare, effectiveness of surveillance, market access and post-harvest treatment costs can increase the effectiveness of the area-wide management programme (Florec *et al.*, 2013). In areas where fruit flies are present, pre-harvest treatments are essential. In areas where fruit flies are not present, crops that might be vulnerable to fruit fly damage also require pre-harvest treatment. The calculation of pre-harvest treatments is done as follows: multiply the cost of treatment per hectare with the total amount of hectares that require the treatment (Abdalla *et al.*, 2012).

3.3.2.3.1 Pre-harvest treatment costs

Pre-harvest costs can be defined as the cost of applying chemicals before the fruit become exposed to the invasive pest, which happens while the fruit start to ripen. Pre-harvest treatment prevents the invasive pest from contaminating fruit (Ha *et al.*, 2010). To control *B. dorsalis* the following methods are used: cover and bait sprays; male annihilation technique (MAT) blocks; sterile insect techniques (SIT) programmes; and control within the orchard (Vargas *et al.*, 2015). The use of SIT on *B. dorsalis* in South Africa has not been done yet. Hawaii's area-wide pest management programme for fruit flies include the following components for their IPM package: sanitation of fields and orchards; bait-sprays; male and female annihilation; SIT; and the release of other parasitoids that are beneficial (Vargas *et al.,* 2008). In China the following methods are used to manage *B. dorsalis*: putting areas which are infested under quarantine; monitoring and trapping in orchards; biological control by applying pesticides; and SIT (Wei *et al.*, 2017). A study by Harvey *et al.* (2010) stated the examples of costs to include when assessing a cost-benefit analysis. These include the environmental costs related to the invasive species and the impact that this pest will have on the IPM systems in place, e.g. the increase in pesticides used against the invasive pest.

India recorded a reduction of 77-100% on *B. dorsalis* infestation in mangos after having applied an IPM package for 45 days prior to harvest time. The IPM package consisted of weekly removal of fruit that have fallen from the trees, inter-tree ploughing every three weeks, and spraying cover sprays every two weeks. The returns on the cost-benefit were reliant on the level of pest pressure. When the pressure of the pest is low, the IPM package may not recuperate the costs. A threshold approach would therefore be necessary. This IPM package may be further developed in future by incorporating MAT and to replace pesticides with ingredients that have economic and environmental advantages (Verghese *et al.,* 2004). The problem with the use of chemicals as bait spray is that the pest can build up resistance to the chemicals. Such resistance needs to be delayed before a bigger problem arises while efforts are made to develop new pesticides (Wei *et al.*, 2017).

In South Africa, *B. dorsalis* is controlled by using bait sprays and bait stations to trap the fruit fly, since *B. dorsalis* is attracted to methyl eugenol (Dohino *et al.*, 2016). GF-120 is a protein bait that contains spinosad as the toxic component. This is a bait-insecticide mixture used in numerous fruit fly eradication and suppression programmes (Ekesi *et al*., 2011). In Kenya, the use of MAT blocks caused a significant drop in the *B. dorsalis* population in two seasons. In both seasons, measured at 49 days after deployment, a 99.5% reduction in fruit flies was recorded. The sole usage of MAT is not encouraged, as MAT should be used with an IPM (Ndlela *et al*., 2016). IPM programmes include the use of bait sprays, MAT blocks that attract and kill the lures, and other cultural and biological components (Ekesi *et al.*, 2010; Vargas *et al.*, 2015).

The costs used to calculate the total pre-harvest pesticide cost were provided by the various industry bodies. The deciduous fruit pre-harvest pesticide costs are published by Hortgro in the Key Industry Statistics booklet (Hortgro, 2016), and table grape pesticide costs are published in the SATI Statistical booklet (SATI, 2017). Pesticide costs for the citrus industry are not published, but a grower (Van Zyl, 2018), an agrochemical consultant (Baard, 2018) and Frudata (Page, 2018) were contacted to calculate and verify this cost. The subtropical fruit's pre-harvest treatment costs were provided by the South African Avocado Growers Association, a subsidiary of Subtrop (Bester, 2018).

The pre-harvest treatment costs provided account for the treatment of all pesticides and not only costs related to fruit flies, except where it explicitly states that the costs are only applicable to fruit flies. These costs were provided as cost per hectare (R/ha), and were multiplied with the number of hectares planted with the specific crop in question.

3.3.2.3.2 Post-harvest treatment costs

Post-harvest treatment is necessary when produce are transported to areas that are known as fruit fly-free areas from areas where the fruit fly is present (Abdalla *et al.*, 2012). Post-harvest costs pertain to the chemicals that are applied after the harvest to prevent the invasive pest from spreading to other markets. Post-harvest costs are only implemented if an outbreak took place in the area from where the fruit are sourced (Ha *et al.*, 2010). Post-harvest treatment is required when fruit are exported to special markets. The special markets are the USA, South Korea, Japan, China, Taiwan and Israel (DAFF, 2018b; PPECB, 2017). These markets require that a minimum of 72 hours of cold sterilisation is applied before the fruit are exported (PPECB, 2017).

This cost was provided by two South African exporting companies as a cost per ton (R/ton) (Groenewald, 2018 *pers comm*; Engelbrecht, 2018 *pers comm*). To calculate the post-harvest treatment costs, the percentages, provided by different industry bodies and DAFF, are used to calculate the estimated amount of tons which were exported to these markets. For this initial financial cost-benefit analysis, cold sterilisation appears to be the only post-harvest treatment option for exports to special markets.

3.3.2.4 Other direct and indirect costs

3.3.2.4.1 Certification costs for export to special markets

Exporting fresh fruit from South Africa to special markets entail additional costs, such as certification costs that must be paid to DAFF. Annual certification costs for exports from South Africa to special markets amount to R106 per market per Food Business Operator (FBO) (Johnson, 2018). An FBO needs to be registered by DAFF. These FBO's used to calculate the costs by including the Production Unit Codes (PUCs) and Pack House Codes (PHCs) which are registered by DAFF for exports to special markets (DAFF, 2018b).

The different markets and the compulsory sanitary and phytosanitary (SPS) measures that comply with the markets are stipulated in the *Export manual for the South African fruit industry*, which is accessible from the Department of Agriculture, Forestry and Fisheries' website. The special markets which one needs to pay certification costs for include China, South Korea, the USA, Israel, Mexico and Taiwan (DAFF, 2010).

Each FBO registered with DAFF on the Producer Database for Special Markets, was multiplied by R106 to determine the total value of the certification costs.

3.3.2.4.2 Levies paid

In order to export fruit, levies or statutory measures must be paid to the different industry bodies and to the Perishable Products Export Control Board (PPECB). The statutory measures apply to the volumes which are inspected and passed for exports. These levies are published by the relevant industry bodies in annual statistical information booklets (CGA, 2017a; Hortgro, 2016; SATI, 2017). The subtropical fruit industry members pay levies to Subtrop, but these levies are not statutory and are therefore not included in the calculation (Donkin, 2018). These statutory levies are also published in the Government Gazette (DAFF, 2016d,e). The PPECB must inspect all loads before it can be exported from South Africa and for this reason levies must be paid by producers to the PPECB. These levies are paid per carton inspected. PPECB levies are published by the PPECB, and where these levies are not published for a certain fruit type, the costs published by Hortgro were used (Hortgro, 2016).

The levies are published in rand per box exported. This cost is then multiplied with the total amount of boxes exported to establish the total cost paid for levies.

3.3.3 Benefit-cost ratio

The benefit-cost ratio is determined by dividing the total value of benefits by the total value of costs. The ratio of benefits to costs is determined by the benefit-cost ratio, and provides a relative measure of the benefits and the feasibility of the project (Ha *et al.*, 2010; Nas, 2016). When there are different options which can be implemented, the option with the highest benefit-cost ratio should be selected, since this ratio reflects how efficiently the resources are used (Ha *et al.*, 2010). A project can be accepted if the benefit-cost ratio is larger than one (Nas, 2016). If the benefit-cost ratio is greater than one, it can indicate that the net present value and internal rate of return from the project are also positive.

3.3.4 Net present value (NPV)

The net present value is provided when benefits and costs, in their discounted forms, are subtracted from each other. When the NPV is positive, it means that net benefits are positive (Bizoza & De Graaff, 2012). The NPV provides the actual monetary value of the net benefits and is used to rank the different options in a cost-benefit analysis (Ha *et al.*, 2010). The net present value is calculated by subtracting the value of the costs from the value of benefits.

3.3.5 Internal rate of return (IRR)

When the internal rate of return of a project is higher than the discount rate, the NPV will be positive. It is not always possible to determine the internal rate of return if no investments are made at the initial stages of a project (Bizoza & De Graaff, 2012). No internal rate of return is calculated for this analysis since there is no initial investment made for maintaining the current situation regarding *B. dorsalis* in South Africa.

3.4. Costs and benefits not included

The costs and benefits reflected below have not been included in the financial cost-benefit analysis due to constraints and limited access to information. It is recommended that these costs should be included in the full cost-benefit analysis since these costs and benefits could prove quite important. It is not always possible to monetarise all costs and benefits. In such an instance use should be made of a multiple-criteria decision analysis (MCDA) process. The MCDA enables decision makers to include costs and benefits in the decision-making process without the need to include these specific costs and benefits with a monetary value.

3.4.1 Social impact

The social procedures that underpin the combined approaches for pest management are potentially important for the control of the pest as the biological control. Therefore, if area-wide management of the fruit fly is to be applied successfully, social factors must be taken into account (Mankad *et al.*, 2017). If it is desired that decisions regarding social values need to be made by decision makers which are involved in the process, the economic analysis will organise and provide information regarding the social values for the decision makers so that they can relate the issues to the costs and benefits (Anandarup, 1990). Social impact includes the costs of potential job losses and the impact of potential job losses on a community, measured in welfare terms.

3.4.2 Direct and indirect costs

Indirect costs such as human health and backyard growers can lead to additional costs since these backyard growers can cause outbreaks of fruit fly, in which event the cost will then be borne by commercial producers (Ha *et al.*, 2010). Management costs can be calculated by multiplying the affected area with the cost of the control that is locally used (Cook *et al.*, 2010). To calculate the removal (eradication) costs, the affected area(s) can be multiplied by the cost of eradication (Cook *et al.*, 2010). The probability of an outbreak determines the eradication costs. If the pests are detected early, the eradication can be more cost effective. The success of eradication is also determined by the methods that are used (Florec *et al.*, 2010).

Valuation techniques such as depending valuation, travel cost methods and hedonic pricing must be used to assess non-market costs when market costs and benefits do not support the biosecurity strategy and non-market impacts may be significant (Harvey *et al.*, 2010).

3.4.3 Research costs

Research is required for the establishment of pest-free areas. This cost, which is directly related to the establishment of PFAs, can be limited to the costs of projects that clearly benefit from the establishment and maintenance of PFAs, or costs that are assumed by the authorities (Florec *et al.*, 2010).

3.4.4 Crop/production losses

The costs of production losses are dependent on the probability of an outbreak (Florec *et al.*, 2010). In Indonesia, crop losses due to fruit fly range from 40% to 100%, these major crop losses being mostly present in fruit and vegetables. Quarantine restrictions, if the fruit fly is present, are quite strict for trade. It has costly implications for market access technologies, i.e. to meet marketing restrictions and the continuing quarantine surveys to assure the importing country that fruit fly is not present in the area from where the import originates (Vijaysegaran, 2008). In the 2012 study by Abdalla *et.al,* it was recorded that the implementation of the plan to maintain pest-free areas in Australia can reduce production losses in low-case and high-case scenarios by 28% and 36% respectively (Abdalla *et al.*, 2012).

In Kenya, the fruit infestation from *B. dorsalis* while using GF-120 as pre-harvest treatment only was, after six weeks, 28-30% (Ekesi *et al*., 2011). Where GF-120 and *Metarhizium anisopliae* were used in combination, the infestation rate decreased to between 11% and 16%. In situations where there were no control in the orchards, the infestation rate was 60%. When the infestation rate is 11-16%, the level of control is insufficient, and in the absence of post-harvest treatment, the fruit that will be exported can be limited by quarantine restrictions (Ekesi *et al.*, 2011). The damage levels for fruit that are not protected from *B. dorsalis* can range up to 100%. *Bactrocera dorsalis* is a threat to many countries and requires costly quarantine restrictions (CABI, 2018).

3.4.5 Long term benefits

Other benefits that can arise from the suppression of *B. dorsalis* are the reduced application costs of MAT and bait sprays, the elimination of residues from insecticides of fruit, and the reduction of infestation (Ndlela *et al.*, 2016).

3.5. Conclusion

In this chapter the application of the financial cost-benefit analysis and the benefit and costs associated with the analysis were explained. Data used has been provided by the industry bodies and where data was not available, producers and exporting companies were consulted. The different costs and benefit criteria which are included, were identified by the stakeholders at the workshop. Literature, where the cost-benefit analysis was previously used to establish pest-free areas, was then analysed, providing information regarding the inclusion of these costs and benefits.

The methods used on the calculation of the benefit-cost ratio, net present value and internal rate of return were explained. The internal rate of return will not be used as a decision criterion, since no initial investments have been made in this financial cost-benefit analysis. It is important to interpret the different indicators correctly and to acknowledge the values provided by the indicators. Due attention should be accorded to the benefit-cost ratio and the net present value in the decision making context when interpreting the cost-benefit analysis.

As this is not a full cost-benefit analysis, some costs and benefits cannot be included due to the limited data available. These costs are included in this chapter to provide information regarding the assembly of the data which is required for future reference when a more comprehensive cost-benefit analysis is undertaken.

Chapter 4 : Results and discussion

4.1 Introduction

A description of the data that was collected and used in the cost-benefit analysis was included in the previous chapter. In Chapter 3, the application of the cost-benefit analysis, information regarding the calculation of each cost and benefit, and the economic indicators were explained, as well as the description of some costs that could not be included.

In the first part of Chapter 4 the monetary values associated with each benefit and cost, as explained in Chapter 3, will be provided. After conducting the cost-benefit analysis, the benefit-cost ratio and the net present value will be indicated to provide the necessary information to interpret the cost-benefit analysis. In the second part of Chapter 4, a sensitivity analysis is conducted to indicate how sensitive this model is to changes in the USD-ZAR exchange rate, since Trade Map's data is provided in USD values. These values are converted to South African rand prior to using it in the financial cost-benefit analysis.

In conclusion, the interpretation of the cost-benefit analysis provides the industry with the necessary information to indicate whether it will be feasible to do further research regarding the establishment of pest-free areas and areas of low pest prevalence and whether to conduct a more comprehensive cost-benefit analysis. The interpretation includes the benefit-cost ratio and the net present value of the current situation in South Africa to facilitate the decision-making process.

4.2 Costs and benefits involved

This section will follow on Chapter 3, explaining and indicating how each benefit and cost was calculated. The sources of the cited costs and the monetary value of each benefit and cost will be provided.

4.2.1 Benefits

Since the *status quo* approach is followed to determine whether it will be beneficial to establish areas free from and areas of low pest prevalence of *B. dorsalis*, the markets which South Africa can currently export to as a result of this pest not having being established in the whole of South Africa, are viewed as a benefit.

4.2.1.1 Market access

Table 4.1 displays the value of exports from South Africa to the current markets for citrus, deciduous and subtropical fruits, amounting to R19 305 076 890,00 (ITC, 2018). Trade Map provides the values in United States dollar, which were converted to South African rand by using 2017's exchange rate, which was ZAR13.31: USD1.

Table 4.1: Value of exports to markets that require monitoring of *Bactrocera dorsalis* as phytosanitary registration from South Africa

Importers	**Exported value in 2017**
United States of America	R662 119 260
South Korea	R151 933 650
Israel	R54 863 820
Mexico	R1 291 070
Japan	R360 235 150
China	R1 268 935 470
Thailand	R22 866 580
European Union (28)	R16 365 896 140
Taiwan	R230 302 930
Mauritius	R186 632 820
Total exports to current markets	**R19 305 076 890**

Source: (ITC, 2018)

If the markets reflected in Table 4.1 are closed as a result of the presence of *B. dorsalis* and do not accept fruit from South Africa, all shipments to those markets will have to be redirected to other markets that do not view *B. dorsalis* as a quarantine pest. This will lead to additional costs for the handling of fruit and a decrease in its expected market prices. Some examples of these extra costs are: the decrease in the price paid for the fruit since some markets are already saturated and the premium prices of the special markets are lost; the extra shipment costs for redirecting the shipment; and the certification and inspection costs for the new market. Due to limited information, it was not possible to calculate the additional costs for this markets. For this cost-benefit analysis the total value of exports to these markets is used as the benefit.

4.2.2 Costs

While the *status quo* approach was used to calculate the benefits of the cost-benefit analysis, the costs are calculated by using the factors that are currently used to manage *B. dorsalis* in South Africa. The costs of exporting to special markets are also included.

4.2.2.1 Premium prices lost

For this financial cost-benefit analysis, the premium prices of the current special markets, which will be lost if *B. dorsalis* spread to the rest of South Africa are used to indicate the effect this will have on the industry. These premium prices are currently just estimations and are calculated as an average and not market price per export to special markets. The average premium price per ton currently used is R1 300 (Engelbrecht, 2018 *pers comm*). In Table 4.2 the total effect of the premium prices lost is indicated. The premium price lost in this table indicates the total amount of the premium price that is directly lost when there are no exports to special markets. The figure of R469 648 400 million is the effect that the loss of the special markets could have on the industry.

Table 4.2: Premium prices lost

Current exports	R19 305 076 890
Premium price lost	R469 648 400
	R18 835 428 490

Own calculations from: (Engelbrecht, 2018 *pers comm*; ITC, 2018)

4.2.2.2 Eradication and monitoring

Bactrocera dorsalis reacts to a parapheromone that attracts only males, called methyl eugenol. To attract both male and female to protein hydrolysate, the 3-component BioLure can be used (Manrakhan *et al.*, 2012).

4.2.2.2.1 Eradication costs

The major expenses of eradication control for *B. dorsalis* would be:

- Spraying bait sprays every week: The most expensive bait spray, GF-120, sells at R3 000 per 20-litre can. 1 litre per hectare is used per week.
- The aircraft and/or tractor costs that are used for spraying.
- Male Annihilation Technique (MAT) blocks, using methyl eugenol: 12 MAT blocks are placed per hectare. One MAT block costs R15.
- Orchard sanitation: Remove fruit which have fallen to the ground or those left on the trees after harvest. Fruit which have been stripped should be placed into plastic bags and be removed to a site where it can be buried at least 1 m underground (Manrakhan *et al.*, 2012; Alvarez et al., 2016; Manrakhan, 2018 *pers comm*).

4.2.2.2.2 Monitoring costs

The major expenses to monitor areas which are under eradication, areas of low pest prevalence and areas free of *B. dorsalis* would be:

- the cost of traps to monitor the adult population of *B. dorsalis,* being R80 for eight weeks; and
- labour costs for control and monitoring (Manrakhan *et al.*, 2018 *pers comm*).

When estimating the full costs of eradication and monitoring, the following assumptions should be made:

- All the materials that are listed in the action plan for *B. dorsalis*, are used (Manrakhan *et al.*, 2012).
- Prices used for the calculations are from Fruit Fly Africa (FFA).
- For the delimiting survey, all of the 25 km² (2 500 hectares) do not necessarily consist of host material, but for this calculation the assumption is that the whole 25 km² (2 500 hectares) are covered with bait spray.

If Grabouw is used as an area to calculate the cost of eradication and monitoring the cost of aerial application, which is the most effective option (Manrakhan *et al.*, 2012), costs of the aerial application amount to R58 per hectare. Using ground application methods, costs are R45 per hectare. The total cost of eradication and monitoring one *B. dorsalis* fruit fly specimen is R2.99 million when using aerial application and R2.73 million when using ground application (Baard, 2018a *pers comm*). This cost includes the aerial application and the materials used for the delimiting survey.

The eradication costs in the cost-benefit analysis are only calculated for ten eradications, using aerial application, and can differ from each situation depending on what the situation entails. For example, when only one male is found, it means that it is only necessary for surveillance and not eradication. If two flies are present, both eradication and surveillance are necessary (Addison, 2018 *pers comm*). For the financial cost-benefit analysis, the eradication cost is used as a fixed cost of R2.99 million for one *B. dorsalis* fruit fly. The total amount included for the ten eradications is R29.9 million.

4.2.2.3 Surveillance costs

Surveillance costs, provided by DAFF and depicted in Table 4.3 amount to R7 856 878, 88 for one year. This figure includes salaries, petrol, equipment required, food and beverages for people doing the surveillance (Venter, 2018 *pers comm*).

Table 4.3: Surveillance costs

Surveillance cost	
Equipment	R5 192 000,00
Travel expenses	R408 878,88
Labour	R1 800 000,00
Surveillance equipment	R456 000,00
Total surveillance cost	**R7 856 878,88**

Source: (Venter, 2018 *pers comm*)

4.2.2.4 Pre- and post-harvest treatments

Pests need to be managed to ensure access to certain markets. This means that pesticides need to be sprayed or set out as baiting traps in orchards prior to harvesting in order to minimise the risk of infection. Post-harvest treatment costs are the costs of treatment that are required by special markets to ensure that produce exported to those markets are pest free.

4.2.2.4.1 Pre-harvest treatments

Pre-harvest treatment costs were calculated using the pesticide costs provided by the different industry bodies and multiplied by the total amount of hectares, also provided by the different industry bodies, in Tables 2.5 - 2.8 in Chapter 2. Tables 4.4 - 4.7 below indicate the different pre-harvest treatment costs for each industry. These costs were either published by the industries or obtained from specialists.

Table 4.4: Pre-harvest cost of pesticides for table grapes

Table grapes	**Pre-harvest cost R/ha**	**Pre-harvest cost total**
Pesticides & herbicide control cost	R17 347	R341 284 878
Total Expenditure		**R341 284 878**

Own calculations based on: (SATI, 2017)

Table 4.5: Pre-harvest cost of pesticides for citrus fruits

Citrus	**Pre-harvest cost R/ha**	**Pre-harvest cost total**
Pesticides control cost	R19 000	R1 381 889 000
Total Expenditure		**R 1 381 889 000**

Own calculations based on: (CGA, 2017b; Van Zyl, 2018 *pers comm*; Baard, 2018b *pers comm*)

Table 4.6: Pre-harvest cost of pesticides for deciduous fruits

Deciduous fruit	**Pre-harvest cost R/ha**	**Pre-harvest cost total**
Apples	R10 316,00	R249 770 992
Pears	R13 262,00	R162 844 098
Apricot	R4 203,00	R11 928 114
Peaches/Nectarines	R8 933,00	R84 586 577
Plums	R4 144,00	R21 105 392
Total Expenditure		**R 530 235 173**

Own calculations based on: (Hortgro, 2016)

Table 4.7: Pre-harvest cost of pesticides for subtropical fruit

Subtropical fruit	**Pre-harvest cost R/ha**	**Pre-harvest cost total**
Avocado	R 8 000,00	R140 000 000
Mango	R 10 000,00	R70 000 000
Litchi*	R 2 500,00	R4 325 000
Total Expenditure		**R214 325 000**

*Contains only costs associated with fruit flies and Litchi moth.

Own calculations based on: (Bester, 2018 *pers comm*)

The production costs of the different industries include all the costs that are associated with pre-harvest pesticides. For a full cost-benefit analysis, these pesticide costs need to be categorised to determine the pre-harvest pesticide costs that are directly used to prevent *B. dorsalis* from damaging crops. To calculate these costs, a survey needs to be conducted, taking into account information provided by various growers and suppliers of pesticides.

4.2.2.4.2 Post-harvest treatments

Cold sterilisation can control members of the Tephritidae family (Pryke & Pringle, 2008). When exporting to special markets, cold sterilisation of fruit is required. The costs are as follows: normal cooling of a container amounts to R220, but when using cold sterilisation, the cost escalates to R553 per container for 72 hours. The use of cold sterilisation as post-harvest treatment has even further costs. The additional costs are for the inspection and for the DAFF and USDA staff doing the inspection. These costs vary between R80 and R186 per pallet, depending on the different markets. On average, it is R500 per pallet more expensive to export fruit to special markets, which require cold sterilisation, than to normal markets (Engelbrecht, 2018). The markets that require cold sterilisation are the USA, South Korea, Japan, China, Taiwan and Israel (DAFF, 2018b). In Tables 4.8 - 4.11 the post-harvest treatment costs of each industry to the special markets are provided.

Table 4.8: Deciduous fruit post-harvest treatment cost

Exports to special markets	Export volume (ton)	Cost per pallet	Ton per pallet	Total post-harvest treatment cost
Apples	123 344	R 500,00	1	R61 672 000,00
Pears	46 660	R 500,00	1	R23 330 000,00
Apricot*	33	R 500,00	0,87	R18 965,52
Peaches & Nectarines	467	R 500,00	0,87	R268 390,80
Plums	3 488	R 500,00	0,87	R2 004 597,70
Total Expenditure				**R87 293 954,02**

Own calculations based on: (Hortgro, 2016; Engelbrecht, 2018 *pers comm*)

Table 4.9: Table grape post-harvest treatment cost

Exports to special markets	Export volume (ton)	Cost per pallet	Ton per pallet	Total post-harvest treatment cost
Table grape	22 224	R500,00	0,87	R12 772 413,79
Total Expenditure				**R12 772 413,79**

Own calculations based on: (SATI, 2017; Engelbrecht, 2018 *pers comm*).

Table 4.10: Citrus post-harvest treatment cost

Exports to special markets	Export volume (tons)	Cost per pallet	Ton per pallet	Total post-harvest treatment cost
Oranges	69 343	R500,00	1,2	R28 892 916,67
Soft Citrus	18 271	R500,00	1,2	R7 612 916,67
Grape fruit	39 870	R500,00	1,2	R16 612 500,00
Lemons	36 185	R500,00	1,2	R15 077 083,33
Total Expenditure	**163 669**			**R68 195 416,67**

Own calculations based on: (CGA, 2017b; Engelbrecht, 2018 *pers comm*).

Table 4.11: Sup-tropical fruit post-harvest treatment cost

Exports to special markets	Export Volume (ton)	Cost per pallet	Ton per pallet	Total post-harvest treatment cost
Avocado	1 160	R500	1	R580 000
Mango	86	R500	1	R43 000
Litchi	137	R500	1	R68 500
Total Expenditure				**R691 500**

Own calculations based on: (DAFF, 2015a,b,c; Engelbrecht, 2018)

The export volumes were determined by using the information provided by the different industries. The industry bodies provided percentages of the total products which are exported to the different markets. These percentages are not directly attributable to the specific markets, but to a region. For this financial cost-benefit analysis the regions included are the USA and South East Asia. For a full cost-benefit analysis, this information will need to be more directly stipulated in respect of the different markets.

4.2.2.5 Other direct and indirect costs

In addition to the direct losses related to *B. dorsalis*, the indirect losses and damages affect socio-economic factors, and quarantine restrictions account for many of these indirect losses (Ekesi *et al.*, 2011). For this cost-benefit analysis the certification costs for the special markets and the levies paid to the industry bodies and the PPECB are reflected as other direct and indirect costs.

4.2.2.5.1 Certification costs for special markets

To be certified as an exporter for special markets requires additional costs. These costs are paid to DAFF and are valued at R106 per FBO (Johnson, 2018.) An FBO is registered with DAFF under the registered PUCs and PHCs for different producers. The number of PUCs and PHCs registered with DAFF are provided in Table 4.12 below.

Table 4.12: PUCs and PHCs registered with DAFF to export to special markets

Country	Citrus	Litchi's	Table grapes	Deciduous industry
Japan	763	26	358	2 252 producers of deciduous fruit
Korea	610			
USA	614		213	
China	276			
Israel			204	
Total	**2 263**	**26**	**571**	**2 252**

Source: (DAFF, 2018b; Hortgro, 2016)

It was not possible to gather the information regarding the number of deciduous fruit producers registered by DAFF as FBOs for special markets. The number of producers registered by Hortgro was therefore used to calculate the certification costs paid. As indicated in Table 4.12, there are 5 316 FBOs used to calculate the cost of certification to export to special markets, at R106 per FBO, the total amount paid by these FBOs being R563 496.

4.2.2.5.2 Levies paid

Table 4.13 shows the different levies paid to Hortgro and the PPECB by deciduous fruit producers. These levies are also used for research funding and information as well as for market access.

Table 4.13: Levies paid for deciduous fruit cartons passed for exports

Fruit type	Export volume (12,5 kg cartons)	DFPT levies (c/12,5 kg cartons)	PPECB levies (c/carton)	Total DFPT levies	Total PPECB levies
Apples	34 026 009	R0,88	R0,61	R29 942 887,92	R20 755 865,49
Pears	17 775 364	R0,88	R0,61	R15 642 320,32	R10 842 972,04
Apricots*	699 864	R1,23	R0,57	R860 832,72	R398 922,48
Peaches and Nectarines**	6 226 807	R0,77	R0,57	R4 794 641,39	R3 549 279,99
Plums***	11 074 164	R1,28	R0,57	R14 174 929,92	R6 312 273,48
Total Expenditure				**R65 415 612,27**	**R41 859 313,48**

Own calculations based on: (Hortgro, 2016)

* Per 4.75 kg cartons

** Per 2.5 kg cartons

*** Per 5.25 kg cartons

The levies paid for table grapes are displayed in

Table 4.14. For table grapes, these levies are paid to SATI and are used for the funding of market access, research and development and transformation, training and administration (DAFF, 2016e).

Table 4.14: Levies paid for table grape cartons passed for exports

Fruit type	Export volume (4,5kg cartons)	SATI levies (c/4,5 kg cartons)	PPECB levies (c/4,5 kg carton)	Total SATI levies	Total PPECB levies
Table grapes	65 448 439	R0,44	R0,61	R28 797 313,16	R39 923 547,79
Total Expenditure				**R28 797 313,16**	**R39 923 547,79**

Own calculations based on: (DAFF, 2016e; SATI, 2017)

Table 4.15 indicates the levies which are paid for citrus passed for exports. The CGA uses this for the funding of research and development, improvement of the plants, information and statistics and to maintain current markets and develop new markets for exports (CGA, 2017b; DAFF, 2016d).

Table 4.15: Levies paid for citrus cartons passed for exports

Fruit type	**Export volume (15 kg cartons)**	**CGA levies (c/15 kg cartons)**	**PPECB levies (c/15 kg carton)**	**Total CGA levies**	**Total PPECB levies**
Oranges	66 041 674	R0,68	R0,61	R44 908 338,32	R40 285 421,14
Soft citrus	12 181 003	R0,68	R0,61	R8 283 082,04	R7 430 411,83
Grapefruit*	11 726 522	R0,77	R0,61	R9 029 421,94	R7 153 178,42
Lemons	15 077 368	R0,68	R0,61	R10 252 610,24	R9 197 194,48
Total Expenditure	**105 026 567**			**R72 473 452,54**	**R64 066 205,87**

Own calculations based on: (CGA, 2017b; DAFF, 2016d)

* Carton equivalent 17 kg

Levies paid to the PPECB for exports are calculated by using Hortgro's information of R0.61 per carton. Litchis are exported in 2 kg cartons and mangos and avocados in 4 kg cartons. Export volumes are calculated using information from DAFF and Subtrop. The volumes and levies are presented in Table 4.16 below.

Table 4.16: Levies paid for subtropical fruit cartons passed for exports

Fruit type	Export Volume (4 kg cartons)	PPECB levy (c/4 kg carton)	Total PPECB levies
Avocado	14 461 250	R0,61	R8 821 362,50
Litchi*	2 077 500	R0,61	R1 267 275,00
Mango	823 000	R0,61	R502 030,00
Total Expenditure	**17 361 750**		**R10 590 667,50**

Own calculations based on: (DAFF, 2015a,b,c)

*2 kg cartons

4.3 Financial cost-benefit analysis

In Table 4.17 all the costs and benefits used for the calculation of the financial cost-benefit analysis are provided. It includes the results that were obtained from using the cost-benefit analysis process to indicate whether it would be feasible to establish areas free from *B. dorsalis* to ensure access to markets where this fruit fly is a quarantine pest. All costs and benefits previously mentioned, explained and calculated in this chapter are used in the table.

As indicated in Table 4.17, the results obtained from the financial cost-benefit analysis are positive. The benefit-cost ratio provided a positive result, being greater than one, and the net present value also returned with a positive value.

Table 4.17: Financial cost-benefit analysis on *Bactrocera dorsalis*

Benefits (South African rand)	
Market access	R19 305 076 890,00
TOTAL BENEFIT	**R19 305 076 890,00**
Costs (South African rand)	
Eradication and monitoring costs	R 29 900 000,00
Surveillance costs	R 7 856 878,88
Pre-harvest treatment costs:	
Deciduous fruit	R 530 235 173,00
Table grape	R 341 284 878,00
Citrus fruit	R 1 381 889 000,00
Sub-tropical fruit	R 214 325 000,00
Post-harvest treatment costs:	
Deciduous fruit	R 87 293 954,02
Table grape	R 12 772 413,79
Citrus fruit	R 68 195 416,67
Sub-tropical fruit	R 691 500,00
Levies paid to industry bodies:	
Deciduous fruit	R 65 415 612,27
Table grape	R 28 797 313,16
Citrus fruit	R 72 473 452,54
Levies paid to PPECB:	
Deciduous fruit	R 41 859 313,48
Table grape	R 39 923 547,79
Citrus fruit	R 64 066 205,87
Sub-tropical fruit	R 10 590 667,50
Premium prices lost	R469 648 400,00
Certification costs for special markets	R 563 496,00
TOTAL COST	**R 2 998 133 822,97**
Benefit-cost ratio	**6,43 : 1**
NPV	**R 16 306 943 067,03**

4.4 Sensitivity analysis

A sensitivity analysis was preformed to indicate how sensitive the specific model is to changes and the extent to which the results will change when there is a change in benefits or costs. The sensitivity to change is calculated according to the exchange rate, which could influence the results of the cost-benefit analysis.

When exporting products to foreign countries, money is received in foreign currency. The exchange rate of these currencies is volatile. These currencies are all provided in United States dollar (USD) in Trade Map, which were then converted to South African rand. It is therefore needed to test the sensitivity of the model when the rand is stronger, since the rand was weaker in 2016 and 2017, which meant that the income in rand was higher when exporting products during that period.

For the original cost-benefit analysis, the exchange rate used was the average dollar to rand exchange rate of 2017, i.e. R13.31: USD1 (Hortgro, 2017). The average exchange rate of 2004 up to 2016 will be used for the sensitivity analysis to indicate the sensitivity of the model. Another exchange rate which will be used is the exchange rate of 2016, when the exchange rate was at its highest yet at R14.72 : USD1 (Hortgro, 2017). The current exchange rate, as on 30 August 2018, which was R14.328: USD1 is also used in the analysis to test the sensitivity. (ABSA, 2018).

Table 4.18: Results of the sensitivity analysis

Analysis	Benefit cost ratio	NPV
Original analysis: Exchange rate of USD1 : R13.31	6.43:1	R 16 306 943 067,03
Sensitivity analysis 1: Exchange rate of USD1 : R8.78	4.25:1	R 9 736 544 997,03
Sensitivity analysis 2: Exchange rate of USD1 : R14.72	7.12:1	R18 352 033 857,03
Sensitivity analysis 3: Exchange rate of USD1 : R14.328	6.93:1	R17 783 469 609,03

As indicated in Table 4.18, the model is sensitive for change in the exchange rate. However, the outcome of the sensitivity analysis indicates that even when the average USD to ZAR exchange rate from 2004 to 2016 is used, the cost-benefit analysis still has a positive outcome. Although the cost-benefit analysis is sensitive to changes, this sensitivity analysis shows that by including the average exchange rate of the past 12 years, the outcome is still positive. This indicates that establishing and maintaining pest-free areas or areas of low pest prevalence make financial sense with regard to *B. dorsalis*.

4.5 Conclusion

The result of the cost-benefit analysis was provided in this chapter. Given the assumptions of this model, the financial cost-benefit analysis showed that for every R1 of cost there is a R6,43 benefit. The net present value of the financial cost-benefit analysis is R 16 306 943 067,03. This means that establishing and maintaining fruit fly free areas will have a positive effect and is cost efficient. When interpreting this result, it is important to remember and take into account, that this financial cost-benefit analysis only accounts for costs directly related to fruit flies and does not include all other costs.

If pest-free areas and areas of low pest prevalence are not established and *B. dorsalis* spreads to all fruit-growing parts of South Africa, it will lead to the loss of specified export markets or lead to more additional post-harvest treatment costs. The South African infrastructure will not currently be able to handle the additional tons of fruit that will require post-harvest treatment if *B. dorsalis* spreads more rapidly. Other costs that deserve consideration are the additional costs if a *B. dorsalis* fruit fly is found within a shipment. Such shipment would need to be redirected to another market, at additional transport and inspection costs, where the fruit will be sold at lower price.

In the sensitivity analysis, the exchange rate from USD to ZAR is used to calculate the sensitivity of benefits to costs. The exchange rate has a significant influence on the result since it is sensitive to change. As indicated in Table 4.18, even though the exchange rate affects the result of the cost-benefit analysis, the result remains positive.

The positive results returned by the financial cost-benefit analysis indicate that it will be beneficial to establish and maintain pest-free areas and areas of low pest prevalence for *B.*

dorsalis in South Africa. This also indicates that when a more comprehensive cost-benefit analysis is conducted, the outcome will most probably be positive, but should provide a clearer indication of the cost margins within which the management of a pest-free area or an area of low pest prevalence should be managed. One of the features lacking in this financial benefit-cost analysis is the potential effect that the redirection of fruit to alternative markets could have on the market price in the “new” country of destination.

Chapter 5 : Conclusion, summary and recommendations

5.1 Conclusion

As indicated in Chapter 1, the reason for commencing the project of establishing areas free from *B. dorsalis* in South Africa, is to assess the benefits of ensuring that trade to countries where *B. dorsalis* is a quarantine pest will continue. Prior to commencing with any project, it is advisable that the feasibility of the project is determined. The financial cost-benefit analysis tool was used to determine the feasibility of the project. The main question which needs to be answered, is whether it would be feasible to endeavour to establish areas free from *B. dorsalis* in South Africa.

There are risks involved when trading produce with other countries, a major risk being the potential spreading of invasive pests. New pests can be introduced into a country through trade, which is the very way in which *B. dorsalis* was introduced into South Africa. The horticultural industry of South Africa contributed 33% of South Africa's agricultural exports in 2017, confirming the significant value the agricultural industry adds to the country's macro-economic performance. *Bactrocera dorsalis* is a fruit fly of major economic importance, given its impact on said industry. It accounts for major economic losses in the fresh fruit industry due to the damage it causes to fruit. Another detrimental factor is the import restrictions applicable to trade with fruit infested by *B. dorsalis* - the latter having been declared a quarantine pest in some countries. *Bactrocera dorsalis* is commonly found in areas with a Mediterranean climate. The Western Cape, where South Africa's deciduous fruit (including table grapes), citrus fruit and subtropical fruit are produced, also has a Mediterranean climate. This fruit fly is already prevalent in certain areas in South Africa, and if this incidence spreads further, it could lead to some export markets being closed to South African exports. Should preventative measures not be taken, *B. dorsalis* could spread to areas where the pest does not currently occur.

It is still possible to establish pest-free areas and areas of low pest prevalence of *B. dorsalis* in South Africa. This research project provides a financial cost-benefit analysis, which specifically calculates the financial feasibility of this project only, and therefore is not a comprehensive economic cost-benefit analysis. The cost-benefit analysis technique has been used since Jules Dupuit developed it in 1844 to determine the feasibility of a project. This technique was continually improved since its inception, up to the present day. The cost-benefit analysis technique has been widely applied in agriculture, including for the establishment of pest-free areas and areas of low pest prevalence, but not in Africa or South Africa yet. The application of the cost-benefit analysis is to identify the costs and benefits applicable to a project, to discount all the costs and benefits to present value (if needed), to determine the benefit-cost ratio, and to determine the net present value and the internal rate of return.

Due to the fact that *B. dorsalis* is not yet prevalent in all parts of South Africa, it is important to calculate the financial feasibility of the establishment of pest-free areas and areas of low pest prevalence in the country. This can be used to design cost-effective methods aimed at ensuring that *B. dorsalis* does not spread any further within the country. In order to calculate this financial feasibility, this research project employed a financial cost-benefit analysis to establish whether it will be financially feasible and cost-beneficial to establish such areas in South Africa. The *status quo* approach was followed in respect of the financial cost-benefit analysis of this project, i.e. the current situation in South Africa where *B. dorsalis* is only present in some parts of the country, was used. The different categories of the financial cost-benefit analysis were identified by the stakeholders of the project for the STDF. This was conducted during two different workshops, and by reviewing previous studies where the cost-benefit analysis was used to determine the benefits of establishing areas free from pests.

If the pest-free areas or areas of low pest prevalence in South Africa could be maintained, it could result in job creation. Job creation might be further enhanced if additional areas were identified. The increase in job creation could be attained due to an increase in the number of people employed per hectare as a result of less damage caused to fruit by *B. dorsalis*. There is thus an expected increase in packing out percentage for the whole affected area. If the markets which are currently accessible due to the absence of *B. dorsalis* can expand, this could promote economic growth. In many rural areas the agricultural industry is the main economic contributor to local municipalities' revenue, and it also is the main source of employment in the area. The potential detrimental impact of a new invasive pest could therefore be appreciated, as the whole area will suffer economically as a result.

The bulk of the data for the financial cost-benefit analysis was provided by the following industry bodies: CGA, Hortgro, SATI and Subtrop. Data provided by the industry bodies includes the pre-harvest treatment cost of deciduous fruit, percentages of exports to special markets, hectares planted with the crops in question, and export levies paid. Where it was impossible to access required data due to it not being in the public domain, relevant specialists were consulted to obtain such information. Costs pertaining to eradication, surveillance, pre-harvest treatment of citrus and subtropical fruit, post-harvest treatment and certification were provided by such specialists. On the positive side, data related to markets which can be currently accessed due to the absence and monitoring of *B. dorsalis,* could be used to good effect.

The cost-benefit analysis was constructed using Microsoft Excel, allowing for the integration of all salient information. The detail and input regarding the cost-benefit analysis were captured onto this spreadsheet. All the components are interlinked, ensuring instant changes in the results of the cost-benefit analysis as a consequence of a change in any of the input parameters. The spreadsheet model provides the benefit-cost ratio and the net present value of the prevailing situation regarding *Bactrocera dorsalis* in South Africa. These measurements indicate profitability and whether the project is financially beneficial.

The objectives of this research project are to conduct a financial cost-benefit analysis of the *status quo* regarding the *B. dorsalis* situation in South Africa, and to recommend possible improvements of the initial financial cost-benefit analysis and the costs and benefits which need consideration for a comprehensive cost-benefit analysis. The objectives of this project were successfully met.

Using the *status quo* of current pest dispersion as example, the method met the requirements to answer the research question. In order to allow for variations or external factors which can influence the cost-benefit ratio and net present value, a sensitivity analysis was included. The sensitivity analysis assesses the influence that exchange rate fluctuations have on the cost-benefit ratio. Having concluded the sensitivity analysis on the financial cost-benefit analysis, the results proved to remain consistent when compared with the results of the original financial cost-benefit analysis. This finding indicates that the cost-benefit ratio is not too sensitive to changes in exchange rates, and it therefore remains positive in respect of the establishment of pest-free areas and areas of low pest prevalence.

The outcome of the analysis is positive, indicating that it will be feasible to maintain the areas that are still pest free areas and areas where there are a low prevalence of *B. dorsalis* in South Africa. Utilising the sensitivity analysis, it was possible to calculate whether the outcome of the analysis will remain positive if exchange rates change. Following the application of the sensitivity analysis, the outcome remained positive. This indicates that it will be feasible to keep the areas free from *B. dorsalis* or to maintain the status of areas of low pest prevalence.

The main conclusions arrived at as a result of the cost-benefit analysis were:

- Taking the current situation of *B. dorsalis* in South Africa into account, it will be beneficial to establish and maintain pest-free areas and areas of low pest prevalence from *B. dorsalis*. This is indicated by the cost-benefit ratio and the net present value of the financial cost-benefit analysis.
- The costs used in the analysis need to be more refined for inclusion in a full-fledged cost-benefit analysis. Other costs that need to be included are mentioned in Chapter 4.
- The results of the sensitivity analysis of the financial cost-benefit analysis indicate that the cost-benefit ratio is not too sensitive to changes in exchange rates, and it therefor remains positive.
- The cost-benefit ratio as such provides sufficient evidence for the establishment of pest-free areas.
- As regards a comprehensive cost-benefit analysis, the market price transmission should be considered for both the market of initial intention and the new market destination. The decrease in volume in the original market could increase the price sufficiently to strengthen the measures applied in maintaining the pest free area. The market price response in the "new" market could result in lower prices, and losses might be incurred as a result of such redirection.

5.2 Summary

International trade is critical for any country to secure foreign currency, particularly in view of its ability to eventually stimulate economic growth. Economic growth is one of the key elements of economic, social and political stability. There are some risks inherent in trading with fresh produce. These risks include the spread of invasive pest species, even while food trade is important to facilitate food security globally *via* the export of food to other countries. Trade in fresh produce resulted in *B. dorsalis* spreading from Sri Lanka to the rest of the world. Since it was detected in Kenya in 2003, *B. dorsalis* quickly spread to South Africa.

When first detected in South Africa in 2010 in the northern parts of the Limpopo Province, eradication procedures were put in place. In 2013, *B. dorsalis* was also declared present in the Vhembe district of the Limpopo Province in South Africa. Eradication and surveillance continue in these areas. Since *B. dorsalis* was declared present in South Africa, it has spread to five of its nine provinces. There are still areas within these five provinces that enjoy pest-free area status, however.

The presence *of B. dorsalis* in South Africa resulted in trade restrictions to countries where *B. dorsalis* are not yet established. These trade restrictions are the result of specific countries insisting that imported fruit must originate from areas which are free from *B. dorsalis.* If the area of export is not free from this fruit fly, the fruit originating from that area must go through post-harvest treatment processes and be inspected to ensure that the fruit do not contain any *B. dorsalis*. The USA insists that fruit that originate from pest-free areas must be subjected to cold sterilisation as a post-harvest treatment before any fresh produce can be exported to the USA. If *B. dorsalis* continues to spread throughout the country, it will lead to an increased demand for the specified post-harvest treatment of all fresh produce, which South Africa's current post-harvest treatment infrastructure cannot accommodate.

Since only a number of areas in South Africa are infested with *B. dorsalis,* it is still possible to create or keep certain areas free from *B. dorsalis* to ensure that trade can continue to countries where *B. dorsalis* have been declared a quarantine pest. It is therefore necessary to assess the feasibility of establishing and maintaining these pest-free areas and areas of low pest prevalence. The feasibility of the establishment of pest-free areas and areas of low pest prevalence can be determined by commencing a financial cost-benefit analysis. The point of departure of this research project is that some areas in South Africa are still pest-free areas, and aims to determine the cost and benefits of maintaining the current situation in South Africa regarding the *B. dorsalis* fruit fly.

The reason for constructing a financial cost-benefit analysis instead of an economic cost-benefit analysis, is due to constraints and limited information. It was more useful and time efficient to construct a financial cost-benefit analysis instead of an economic cost-benefit analysis. A financial cost-benefit analysis differs from an economic cost-benefit analysis in the sense that the financial cost-benefit analysis focuses on the project itself and not on the whole economy. The economic cost-benefit analysis takes the whole economy into account through shadow pricing when constructing the cost-benefit analysis. The concept of the cost-benefit analysis was first developed in 1844 by a French engineer, Jules Dupuit. The method used by Jules Dupuit was called the "marginal analysis". This analysis was used to measure costs and benefits to contribute to the decision-making process. Since this concept of the cost-benefit analysis was established, it was expanded and continuously renewed by adding new features. In 1936, the actual technique of the cost-benefit analysis was formulated by the United States Flood Control Act, following which cost-benefit studies were widely applied, and remain popular.

The technique of the cost-benefit analysis has been widely applied in agriculture. There are a few studies were this technique has been applied for the establishment of pest-free areas and areas of low pest prevalence for certain agricultural pests, but it has not been done in South Africa yet. Each of these studies differs in terms of the focus pest, the geographical areas, and also the specific costs and benefits which are taken into account.

Limitations highlighted by previous studies of the cost-benefit analysis included the transparency of the data used, the choices concerning different variables that needs to be included in the analysis, and the specific model which is used. It is important that the abovementioned factors are transparent in this financial cost-benefit analysis. In this regard, this research project indicates the necessity of a more comprehensive cost-benefit analysis.

The different costs and benefits used for the financial cost-benefit analysis in this research project were identified by the stakeholders of the programme during two different workshops and also by analysing the literature regarding the establishment of pest-free areas and areas of low pest prevalence.

Since the *status quo* approach was used to calculate the financial cost-benefit analysis, the current market access to countries which either require fruit from pest-free areas and the special markets which require post-harvest treatment for *B. dorsalis*, are included as a benefit. It can be argued that the benefit is overestimated, since it is possible that when exports to one of the special markets or countries where *B. dorsalis* is a quarantine pest are stopped or banned, this fruit could be exported to alternative markets, albeit at higher cost. However, this is not included in the financial cost-benefit of this research project. The cost component of the financial cost-benefit analysis includes all the different costs which are currently applicable to maintaining the situation of keeping areas free from *B. dorsalis*. These costs include pre-harvest treatment costs, post-harvest treatment costs, premium prices lost, levies paid for exports and levies to different industry bodies, certification costs for exports, and eradication and surveillance costs.

These costs were supplied by the different industry bodies: SATI (Southern African Table Grape Industry), Hortgro, CRI (Citrus Research International), CGA (Citrus Growers Association) and Subtrop (South African Subtropical Growers' Association). If the costs were not available or not provided by the industry bodies, experts within the respective fields were contacted to provide the information needed to complete the financial cost-benefit analysis.

Microsoft Office's Excel software was used for this research project to calculate the financial cost-benefit analysis of the *status quo* situation in South Africa regarding *B. dorsalis*. Applicable formulas were used to integrate all the components on the spreadsheets. The data collected was imported into the cost-benefit model, and the cost-benefit ratio was determined by dividing the total value of benefits by the total value of costs. The cost-benefit ratio provides an indication whether it will be feasible to continue or commence with a project.

If the cost-benefit ratio is greater than one, it indicates that the net present value and internal rate of return from the particular project will be positive. The net present value of the cost-benefit analysis is calculated by subtracting the total costs from the total benefits. The internal rate of return in this project cannot be determined, since no initial investments were made to maintain the current prevalence status of *B. dorsalis* in South Africa. The results are therefore interpreted by using the cost-benefit ratio and net present value of the financial cost-benefit analysis.

After constructing the financial cost-benefit analysis and all the information needed have been incorporated in the spreadsheet, the cost-benefit ratio and the net present value were calculated by using all the relevant information in the spreadsheet. The outcome of the cost-benefit ratio is positive as the ratio is greater than one. This indicates that the project is financially feasible. The expected net present value is also positive. This indicates that it is feasible to maintain these areas free and under low prevalence from *B. dorsalis* to ensure that trading with countries where this fruit fly is not yet established or declared as a quarantine pest, can continue.

There are a few costs and benefits which are not included in this financial cost-benefit analysis. These costs and benefits include:

- The social impact of this project, including potential job losses and the impact of these job losses on a community and all its dependants. Job creation can be included as a benefit.
- Other direct and indirect costs, such as human health, backyard growers and management costs.
- Research costs related to the establishment of pest-free areas and areas of low pest prevalence.
- The crop and production losses that may result from potential outbreaks of *B. dorsalis*.
- The market price impact of redirecting exports to alternative markets.

The costs mentioned above are not included in the financial cost-benefit analysis of this project due to limited information. Should a more comprehensive cost-benefit analysis be conducted, it is recommended that these costs are included in that analysis to make it more detailed and comprehensive.

5.3 Recommendations

This research project focuses on the financial cost-benefit analysis regarding the establishment of pest-free areas and areas of low pest prevalence of *B. dorsalis*, using the current situation in South Africa. Should a full-fledged cost-benefit analysis be required, more detailed information on costs and benefits would be required.

When using the current market access as the benefit component for a more comprehensive cost-benefit analysis, the benefit component can be calculated by using the current market access, and subtracting the amount which can be gained when the load that contains *B. dorsalis* is redirected to another market. In such instance, additional costs will be incurred in terms of transport to the new market, inspection costs and repackaging costs. These costs should be included in the cost component of the analysis. Market access will need to be more thoroughly explained and refined, and the additional losses due to saturated markets will need to be determined. The loss of market access also needs to be more specifically determined.

Crop losses should also be included. These losses need to be determined by surveys to establish if it will have a social impact, and what the extent of such impact would be. If *B.*

dorsalis is not yet established in an area, the reduced crop losses and reduced costs of pre- and post-harvest treatments will also be associated with the benefit component. Another possible benefit is that the reduction in pre-harvest treatments will generate more than one advantage, e.g. a reduction in costs associated with pre-harvest treatment, with consequent benefits for the environment.

Costs that still need to be incorporated in the financial cost-benefit analysis are:

- The research costs - the total costs that will be paid for the research regarding the establishment of pest-free areas for fruit fly.
- The social impacts - this will include labour costs and the impact of potential job losses, including the effect it will have on all dependants of the employees whose jobs will be lost.
- Creating awareness - the costs that are associated with creating awareness of pest-free areas and areas of low pest prevalence.

All costs used for the current financial cost-benefit analysis need to be refined if it will be included in the comprehensive economic cost-benefit analysis. It also needs to be determined which entity will be responsible for which expense - the industry, producers, or government - as this will influence the possible funding of a full-fledged cost-benefit analysis.

It is recommended that a broader analysis should be undertaken to determine all the possible impacts and effects of all the above mentioned costs and to take all the benefits into account, both on national and community levels.

In such comprehensive cost-benefit analysis, different scenarios should be taken into account, as opposed to this financial cost-benefit analysis in which the only scenario taken into account is the current situation regarding *B. dorsalis* in South Africa. Scenarios can include:

- The “do-nothing” action, which can result in *B. dorsalis* easily spreading through the whole of South Africa.
- The establishment of areas of low pest prevalence in South Africa regarding *B. dorsalis*.
- Establishment of pest-free areas in South Africa regarding *B. dorsalis*, with different success rates.

When a more comprehensive cost-benefit analysis is needed, a discounted rate should be used to determine the value of costs and benefits over time. The net present value should be calculated by discounting the benefits and costs to present value and subtract the discounted costs from the discounted benefits. Should it not be possible to monetarize all costs and benefits in a more comprehensive cost-benefit analysis, the multiple-criteria decision analysis (MCDA) should be used in conjunction with the cost-benefit analysis to incorporate all costs and benefits which can influence the results of the decision-making process. The MCDA allows for the inclusion of information which is not quantifiable. It is also needed that it be clearly stipulated who would carry which costs, i.e. industry, government or the producers.

References

Abdalla, A., Millist, N., Buetre, B. & Bowen, B. 2012. *Benefit – Cost Analysis Of The National Fruit Fly Strategy Action Plan*. Canberra.

Absa Bank. 2018. *Exchange Rates*. [Online], Available: https://www.absa.co.za/indices/exchange-rates/ [2018, August 31].

Aceng, J. 2014. *Testing Multi – Criteria Approaches for Food Safety Decision Making*. Uganda.

ADB. Asian Development Bank. 1992. Financial Benefit-Cost Analysis. *Handbook for the Economic Analysis of Water Supply Projects*. 122–135.

Alvarez, S., Evans, E.A. & Hodges, A.W. 2016. *Estimated Costs and Regional Economic Impacts of The Oriental Fruit Fly Outbreak In Miami-Dade County, Florida*. Florida.

Anandarup, R. 1990. *Cost-Benefit Analysis*. C. Houle & J.H. Carrol (eds.). London: World Bank.

Argyrous, G. 2017. Cost-Benefit Analysis as Operationalized Neoclassical Economics: From Evidence To Folklore. *Journal of Australian Political Economy*. 80:201–212.

Baldos, U.L.C. & Hertel, T.W. 2015. The Role of International Trade in Managing Food Security Risks From Climate Change. *Food Security*. 7(2):275–290.

Barclay, H.J. & Hargrove, J.W. 2005. Probability Models To Facilitate a Declaration of pest-Free Status, With Special Reference To Tsetse (Diptera: Glossinidae). *Bulletin of Entomological Research*. 95(1):1–11.

Bizoza, A.R. & De Graaff, J. 2012. Financial Cost-Benefit Analysis of Bench Terraces In Rwanda. *Land Degration & Development*. 23:103–115.

Blanquart, S. 2009. Role of Multicriteria Decision-Aid (MCDA) To Promote Sustainable Agriculture : Heterogeneous Data and Different Kinds of Actors In a Decision Process. *International Journal Agricultural Resources, Governance and Ecology*. 8(2):258–281.

Boardman, A., Greenberg, D., Vining, A. & Weimer, D. 2017. *Cost-Benefit Analysis: Concepts and Practises*. 4th ed. A. Boardman (ed.). Cambridge, Massachusetts: Cambridge University Press.

Brans, J.-P. & Mareschal, B. 2005. Promethee Methods. In 78th ed. S. Greco, M. Ehrgott, & J.R. Figueira (eds.). New York: Springer. *Multiple Criteria Decision Analysis: State of the Art Surveys*. 164–195.

CABI. Centre for Agriculture and Biosciences International. 2018. *Bactrocera Dorsalis (Oriental Fruit Fly)*. [Online], Available: https://www.cabi.org/isc/datasheet/17685 [2018, September 03].

CGA. Citrus Growers Association. 2017a. *Key Industry Statistics for Citrus Growers*. Hillcrest, South Africa:.

CGA. Citrus Growers Association. 2017b. *Annual report*. Hillcrest, South Africa.

Clarke, A.R., Armstrong, K.F., Carmichael, A.E., Milne, J.R., Raghu, S., Roderick, G.K. & Yeates, D.K. 2005. Invasive Phytophagous Pests Arising Through a Recent Tropical Evolutionary Radiation: The *Bactrocera dorsalis* Complex of Fruit Flies. *Annual Review of Entomology*. 50(1):293–319.

Cook, D.C. & Fraser, R.W. 2015. Eradication Versus Control of Mediterranean Fruit Fly In Western Australia. *Agricultural and Forest Entomology*. 17(2):173–180.

Cook, D.C., Hurley, M., Liu, S., Siddique, A.M., Lowell, K.E. & Diggle, A. 2010. *Enhanced Risk Analysis Tools*. Bruce, Australia: Cooperative Research Centre for National Plant Biosecurity.

DAFF. Department of Agriculture, Forestry and Fisheries. 2010. Step-by-Step *Export Manual of South African Fruit Industry*. Pretoria: Department of Agriculture Forestry and Fisheries and Fresh Produce Exporters' Forum (FPEF).

DAFF. Department of Agriculture, Forestry and Fisheries. 2015a. *A Profile of the South African Litchi Market Value Chain*. Pretoria, South Africa.

DAFF. Department of Agriculture, Forestry and Fisheries. 2015b. *A Profile of the South African Mango Market Value Chain*. Pretoria, South Africa.

DAFF. Department of Agriculture, Forestry and Fisheries. 2015c. *A Profile of the South African Avocado Market Value Chain*. Pretoria, South Africa.

DAFF. Department of Agriculture, Forestry and Fisheries. 2016a. *Economic Review of South African Agriculture*. Pretoria, South Africa.

DAFF. Department of Agriculture, Forestry and Fisheries. 2016b. *A Profile of the South African Table Grapes Market Value Chain*. Pretoria, South Africa.

DAFF. Department of Agriculture, Forestry and Fisheries. 2016c. *A profile of the South African citrus market value chain*. Pretoria, South Africa.

DAFF. Department of Agriculture, Forestry and Fisheries. 2016d. Establishment of Statutory Measure And Determentation of Guidline Prices: Levies on Fresh Citrus Fruit Intended For Export. *Government Gazette*. December(40460):11–14. Pretoria, South Africa.

DAFF. Department of Agriculture, Forestry and Fisheries. 2016e. Establishment of Statutory Measures And Determination of Levies On Table Grapes. *Government Gazette*. October(40376):27–29. Pretoria, South Africa

DAFF. Department of Agriculture, Forestry and Fisheries. 2018a. Outbreak of The Oriental Fruit Fly (OFF) In The Grabouw Area, Western Cape Province. *Department of Agriculture Forestry and Fisheries Republic of South Africa*. (February):1–2.

DAFF. Department of Agriculture, Forestry and Fisheries. 2018b. *Producers Database for Export to the Special Markets*. [Online], Available: http://www.daff.gov.za/daffweb3/Branches/Agricultural-Production-Health-Food-Safety/Plant-Health/Exporting-from-SA/Producers [2018, June 01].

Dantsis, T., Douma, C., Giourga, C., Loumou, A. & Polychronaki, E.A. 2010. A Methodological Approach To Assess And Compare The Sustainability Level of Agricultural Plant Production Systems. *Ecological Indicators*. 10(2):256–263.

De Meyer, M. 2017. *Project Preparation Grant: Establishment and Maintenance of Fruit Production Areas Free and Under Low Prevalence of Fruit Fly Pests in Southern Africa*. Stellenbosch, South Africa.

De Meyer, M., Mohamed, S. & White, I.M. 2014. *A Diagnostic Tool And Information Reference For The Four Asian Species of Fruit Fly (Diptera, Tephritidae) That Have Become Accidentally Established As Pests In Africa, Including The Indian Ocean Islands.* [Online], Available: http://www.africamuseum.be/fruitfly/AfroAsia.htm [2018, June 18].

De Rus, G. 2010. *An Introduction To Cost Benefit Analysis*. 3rd ed. E. Elgar (ed.). Northampton, Massachusetts: Edward Elgar Publishing.

De Villiers, M., Hattingh, V., Kriticos, D.J., Brunel, S., Vayssières, J.F., Sinzogan, A., Billah, M.K., Mohamed, S. A., Mwatawala, M., Abdelgader, H., Salah, F.E.E. & De Meyer, M. 2016. The Potential Distribution Of *Bactrocera Dorsalis*: Considering Phenology And Irrigation Patterns. *Bulletin of Entomological Research*. 106(1):19–33.

Dohino, T., Hallman, G., Grout, T.G., Clarke, A.R., Hernandez, E., Follett, P.A., Cugala, D.R., Tu, D.M., Murdita, W., Myers, SW. & Pereira, R.. 2016. Phytosanitary Treatments Against *Bactrocera Dorsalis* (Diptera : Tephritidae): Current Situation And Future Prospects. *Journal of Economic Entomology*. 100(1):1–13.

Dooley, A., Smeaton, D., Sheath, G. & Ledgard, S. 2009. Application of Multiple Criteria Decision Analysis In The NewZealand Agricultural Industry. *Journal of MultiCriteria Decision Analysis*. 16(1-2):39–53.-

Drew, R.A.I., Tsuruta, K. & White, I.M. 2005. A New Species Of Pest Fruit Fly (Diptera : Tephritidae : Dacinae) From Sri Lanka And Africa. *African Entomology*. 13(1):149–154.

Ekelund, R.B. 1968. Jules Dupuit And The Early Theory Of Marginal Cost Pricing. *Journal of Political Economy*. 76(3):462–471.

Ekesi, S., Vayssieres, J.-F., Hanna, R., De Meyer, M., Goergen, G. & Malacrida, A. 2010. Status of *Bactrocera Dorsalis* Management In Africa : Recent Advances. Paper presented at the 8th International Symposium on Fruit Flies of Economic Importance, 96. Valencia, Spain.

Ekesi, S., Maniania, N.K. & Mohamed, S.A. 2011. Efficacy of Soil Application of Metarhizium Anisopliae And The Use of GF-120 Spinosad Bait Spray For Suppression of *Bactrocera Invadens* (Diptera : Tephritidae) In Mango Orchards. *Biocontrol Science Technology*. 21(3):299–316.

Enkerlin, W., Gutiérrez-Ruelas, J.M., Cortes, A.V., Roldan, E.C., Midgarden, D., Lira, E., López, J.L.Z., Hendrichs, J., Liedo, P. & Arriaga, F.J.T. 2015. Area Freedom In Mexico From Mediterranean Fruit Fly (Diptera: Tephritidae): A Review of Over 30 Years of a Successful Containment Program Using an Integrated Area-Wide SIT Approach. *Florida Entomologist*. 98(2):665–681.

FAO. Food and Agriculture Organisation of the United Nations. 2001. *Economic Impacts of Transboundary Pests and Diseases*. [Online], Available: http://www.fao.org/docrep/003/x9800e/x9800e14.htm#P0_0 [2018, May 18]

Fischhoff, B. 1977. Cost Benefit Analysis and The Art of Motorcycle Maintenance. *Policy Sciences*. 8:177–202.

Florec, V., Sadler, R. & White, B. 2010. *Area-Wide Management of Fruit-Flies : What Are A the Costs and the Benefits ?* (School of Agricultural and Resource Economics No.1008). Crawley, Autralia: The University of Western Austrailia.

Florec, V., Sadler, R.J., White, B. & Dominiak, B.C. 2013. Choosing The Battles: The Economics of Area Wide Pest Management For Queensland Fruit Fly. *Food Policy*. 38(1):203–213.

FPEF. Fresh Produce Exporters Forum. 2017. *General Information*. [Online], Available: https://www.fpef.co.za/general-information/ [2018, May 23].

Goergen, G., Vayssières, J.-F., Gnanvossou, D. & Tindo, M. 2011. *Bactrocera Invadens* (Diptera: Tephritidae), A New Invasive Fruit Fly Pest For The Afrotropical Region: Host Plant Range and Distribution in West And Central Africa. *Environmental Entomology*. 40(4):844–854.

Gómez-Limón, J.A., Riesgo, L. & Arriaza, M. 2004. Multi-Criteria Analysis of Input Use in Agriculture. *Journal of Agricultural Economics*. 55(3):541–564.

Grout, T., Daneel, J., Mohamed, S., Ekesi, S., Nderitu, P., Stephen, P. & Hattingh, V. 2011. Cold Susceptibility and Disinfestation of *Bactrocera invadens* (Diptera : Tephritidae) in Oranges. *Journal of Economic Entomology*. 140(4):1180–1187.

Ha, A., Larson, K., Harvey, S., Fisher, B. & Malcom, B. 2010. *Benefit-Cost Analysis of Options For Managing Queensland Fruit Fly In Victoria*. Melbourne.

Hansjürgens, B. 2004. Economic Valuation Through Cost-Benefit Analysis - Possibilities And Limitations. *Toxicology*. 205(3):241–252.

Hardy, D.E. 1969. Taxonomy And Distribution Of The Oriental Fruit Fly And Related Species (Tephritidae-Diptera). *Hawaiian Entomological Society*. 20(2):395–428.

Harvey, S., Fisher, B., Larson, K. & Malcolm, B. 2010. A Benefit Cost Analysis On Management Strategies For Queensland Fruit Fly : Methods And Observations. Paper presented at the 54th Australasian Agricultural & Resource Economics [AARES] National Conference. 1–17. Adelaide, Austrailia.

Hassen, E.-K. 2017. *Manufacture of Pesticides and Other Agro-Chemical Products*. [Online], Available: https://www.whoownswhom.co.za/store/info/4486?segment [2018, November 29].

Hause, J.C. 1975. The Theory of Welfare Cost Measurement. *Journal of Political Economy*. 83(6):1145–1182.

Henson, S. & Masakure, O. 2009. *Guidelines On The Use Of Economic Analysis To Inform SPS-Related Decision-Making*. Paper prepared for a workshop of the Standards and Trade Development Facility [STDF]. Geneva, Switzerland.

Hortgro. 2016. *Key Deciduous Fruit Statistics*. Paarl, South Africa.

Hortgro. 2017. *Monitoring Bactrocera Dorsalis*. [Online], Available: https://www.hortgro.co.za/news-room-industry-news/monitoring-bactrocera-dorsalis/# [2018, May 14].

ICIPE. International Centre of Insect Physiology and Ecology. 2013. *The African Fruit Fly Program - A Fruit-Full Future for Africa*. Nairobi, Kenya.

IPPC. International Plant Protection Convention. 2005. *ISPM 22: Requirements For The Establishment Of Areas Of Low Pest Prevalence*. Rome, Italy

IPPC. International Plant Protection Convention. 2015. *ISPM 26: Establishment Of Pest Free Areas For Fruit Flies (Tephritidae)*. Rome, Italy.

IPPC. International Plant Protection Convention. 2016. *ISPM 5: Glossary Of Phytosanitary Terms*. Rome, Italy.

IPPC. International Plant Protection Convention. 2018a. *About The IPPC*. [Online], Available: https://www.ippc.int/en/structure/ [2018, June 12].

IPPC. International Plant Protection Convention. 2018b. *ISPM 35: Systems approach for pest risk management of fruit flies (Tephritidae)*. Rome, Italy.

IPPC. International Plant Protection Convention. 2018c. Eradication of Bactrocera dorsalis in the Grabouw area, Western Cape province, South Africa. [Online], Available: https://www.ippc.int/en/countries/south-africa/pestreports/2018/05/eradication-of-bactrocera-dorsalis-in-the-grabouw-area-western-cape-province-south-africa/ [2019, January 20].

ITC. International Trade Centre. 2018. *Trade Map*. [Online], Available: https://www.trademap.org/Index.aspx [2018, May 21].

Ivess, R.J. 2004. The International Plant Protection Convention and Invasives. In Rome: IPPC *Food and Agriculture Organization of the United Nations*. 2–62.

Kamala Jayanthi, P.D., Kempraj, V., Aurade, R.M. & Bruce, T.J.A. 2017. Evaluation of Synthetic Oviposition Stimulants To Enhance Egg Collection of The Oriental Fruit Fly, *Bactrocera Dorsalis* (Diptera: Tephritidae). *Journal of Pest Science*. 90(3):781–786.

Keefe, K., Alavalapati, J. A. A. & Pinheiro, C. 2012. Is Enrichment Planting Worth Its costs? A Fnancial Cost-Benefit Analysis. *Forest Policy and Economics*. 23:10–16.

Kibira, M., Affognon, H., Njehia, B., Muriithi, B., Mohamed, S. & Ekesi, S. 2015. Economic Evaluation of Integrated Management of Fruit Fly in Mango Production in Embu County, Kenya. *African Journal of Agricultural and Resource Economics*. 10(4):343–353.

Kiker, G.A., Bridges, T.S., Varghese, A., Seager, T.P. & Linkov, I. 2005. Application of Multicriteria Decision Analysis in Environmental Decision Making. *Integrated Environmental Assessment and Management*. 1(2):95.

Kim, H.-W. & Kankanhalli, A. 2009. Investigating User Resistance to Information Systems Implementation : A Status Quo Bias Perspective. *MIS Quaterly*. 33(3):567–582.

Kim, C.S., Lubowski, R.N., Lewandrowski, J., E., E.M. & Eiswerth, M.E. 2006. Prevention or Control: Optimal Government Policies for Invasive Species Management. *Agricultural and Resource Economics Review*. 35(1):29–40.

Kleynhans, E., Grové, T. & Booysen, P.J.. 2014. Evaluating Monitoring Systems for Economically Important Fruit Fly Species on Mango in South Africa. 1–21.

Lichtenberg, E. & Lynch, L. 2006. Exotic Pests and Trade: When is Pest-Free Status Certification Worthwhile? *Agricultural and Resource Economics Review*. 35(1):52–62.

Linkov, I., Varghese, A., Jamil, S., Seager, T.P., Kiker, G. & Bridges, T. 2004. *Multi-Criteria Decision Analysis: A Framework for Structuring Remedial Decisions at Contaminated Sites*. Dordrecht, The Netherlands: Kluwer.

Maneschi, A. 1996. Jules Dupuit: A Sesquicentennial Tribute to the Founder of Benefit-Cost Analysis. *European Journal of the History of Economic Thought*. 3(3):411–432.

Mankad, A., Loechel, B. & Measham, P.F. 2017. Psychosocial Barriers and Facilitators for Area-Wide Management of Fruit Fly in Southeastern Australia. *Agronomy for Sustainable Development*. 37(67):1–12.

Manrakhan, A. 2016. *Fruit fly*.Citrus Research International. Nelspruit, South Africa.

Manrakhan, A., Venter, J.-H. & Hattingh, V. 2012. *Action Plan For the Control of the African Invader Fruit Fly*. Pretoria.

Manrakhan, A., Venter, J.H. & Hattingh, V. 2015. The progressive invasion of *Bactrocera dorsalis* (Diptera: Tephritidae) in South Africa. *Biological Invasions*. 17(10):2803–2809.

McMaugh, T. 2005. *Guidelines for surveillance for plant pests in Asia and the Pacific*. The Australian Centre for International Agricultural Research. 103–192. Canberra, Australia: Union Offset.

Mishan, E.J. & Quah, E. 2007. *Cost-Benefit Analysis*. 5th ed. E.J. Mishan & E. Quah (eds.). New York: Routledge.

Molloy, J., Young, D. & John, C. 1997. *Benefit-Cost Analysis of South Australia's Fruit Fly Protection Programme*. South Australian Centre for Economic Studies.

Mumford, J.D. 2002. Economic Issues Related To Quarantine in International Trade. *European Review of Agricultural Economics*. 29(3):329–348.

Mumford, J.D. 2005. Application of Benefit/Cost Analysis to Insect Pest Control Using The Sterile Insect Technique. In V.A. Dyck, J. Hendrichs, & A.S. Robinson (eds.). Dordrecht, The Netherlands: Springer *Sterile Insect Technique: Principles and Practice in Area-Wide Integrated Pest Management*. 481–498.

Myers, J.H., Savoie, A. & Van Randen, E. 1998. Eradication and Pest Management. *Annual Review of Entomology*. 43(1):471–491.

Nas, T.F. 2016. *Cost-Benefit Analysis: Theory and Application*. 2nd ed. Lanhame Maryland: Lexington Books.

Ndlela, A.S., Mohamed, S., Ndegwa, P.N., Amo, G.O.O. & Ekesi, S. 2016. Male Annihilation Technique Using Methyl Eugenol for Field Suppression of *Bactrocera Dorsalis* (Hendel) (Diptera : Tephritidae) on Mango in Kenya. *African Entomology*. 24(2):437–447.

Pearce, D.W. 1998. Cost-Benefit Analysis and Environmental Policy. *Oxford Review of Economic Policy*. 14(4):84–100.

Pearce, D., Atkinson, G. & Mourato, S. 2006. *Cost-Benefit Analysis and The Environment: Recent Developments*. Vol. 115. J.-P. Barde (ed.). Paris, France: Organisation for Economic Co-Operation and Development.

PPECB. Perishable Produce Export Certification Agency. 2017. *Cold Treatment Container Protocols*. [Online], Available: https://ppecb.com/wp-content/uploads/2015/03/Cold-Treatment-Protocols-Rev-68-23102017.pdf [2018, May 04].

Pryke, J.S. & Pringle, K.L. 2008. Postharvest Disinfestation Treatments for Deciduous and Citrus Fruits of the Western Cape, South Africa: A Database Analysis. *South African Journal of Science*. 104(April):85–89.

Roberto, F. & Garcia, M. 2009. Fruit fly : Biological and Ecological Aspects. In Vol. 661. R.R. Bandeira (ed.). Kerala, India: Transworld Research Network *Current Trends in Fruit Fly Control on Perennial Crops and Research Prospects*. 1–35.

Saarikoski, H., Mustajoki, J., Barton, D.N., Geneletti, D., Langemeyer, J., Gomez-baggethun, E., Marttunen, M., Antunes, P., Keune, H. & Santos, Rui. 2016. Multi-Criteria Decision Analysis and Cost-Benefit Analysis : Comparing Alternative Frameworks for Integrated Valuation of Ecosystem Services. *Ecosystem Services*. 22(October):238–249.

Samuelson, W. & Zeckhauser, R. 1988. Status Quo Bias in Decision Making. *Journal of Risk and Uncertainty*. 1(1):7–59.

SATI. South African Table Grape Industry. (2017). *Sati Statistics Booklet*. Paarl, South Africa.

Schrader, G. & Unger, J.G. 2003. Plant Quarantine as a Measure Against Invasive Alien Species: The Framework of the International Plant Protection Convention and The Plant Health Regulations in The European Union. *Biological Invasions*. 5(4):357–364.

Schutze, M.K., Aketarawong, N., Amornsak, W., Armstrong, K.F., Augustinos, A. a., Barr, N., Bo, W., Bourtzis, K., Boykin, L.M., Cacerec, C., Cameron, S.L., Chapman, T.A., Chinvinijkul, S., Chomič, A., De Meyer, M., Drosopoulou, E., Englezou, A., Ekesi, S., Gariou-Papalexiou, A., Geib, S.M., Hailstones, D., Hasanuzzaman, M., Haymer, D., Hee, A.K.W., Hendrichs, J., Jessup, A., Ji, Q., Khamis, F.M., Krosch, M.N., Leblanc, L., Mahmood, K., Malacrida, A.R., Mavragani-Tsipidou, P., Mwatawala, M., Nishida, R., Ono, H., Reyes, J., Rubinoff, D., San Jose, M., Shelly, T.E., Srikachar, S., Tan, K.H., Thanaphum, S., Haq, I., Vijaysegaran, S., Wee, S.L., Yesmin, F., Zacharopoulou, A. & Clarke, A.R. 2015. Synonymization of Key Pest Species Within the *Bactrocera Dorsalis* Species Complex (Diptera: Tephritidae): Taxonomic Changes Based on a Review of 20 Years of Integrative Morphological, Molecular, Cytogenetic, Behavioural and Chemoecological Data. *Systematic Entomology*. 40(2):456–471.

STDF. Standards and Trade Development Facility. 2009. *STDF Briefing*. Geneva, Switzerland.

Stephens, A.E.A., Kriticos, D.J. & Leriche, A. 2007. The Current and Future Potential Geographical Distribution of the Oriental Fruit Fly, *Bactrocera Dorsalis* (Diptera: Tephritidae). *Bulletin of Entomological Research*. 97(4):369–378.

Stošić, I., Đuričin, S., Beraha, I. & Residues, W. 2017. Financial Cost-Benefit Analysis of Investment Possibilities in District Heating System on. *Industrija*. 45(32):183–207.

Van Ittersum, M.K., Cassman, K.G., Grassini, P., Wolf, J., Tittonell, P. & Hochman, Z. 2013. Yield gap analysis with local to global relevance — A review. *Field Crops Research*. 143:4–17.

Vargas, R.. I., Mau, R.F.L., Jang, E.B., Faust, R.M. & Wong, L. 2008. The Hawaii Fruit Fly Areawide Pest Management Programme. In O.Koul, G.W. Cuperus & N. Elliott. *Areawide Pest Management: Theory and Implementation*. Oxfordshire, United Kingdom: Cabi Publishing.(16):300–325.

Vargas, R.I., Leblanc, L. & Pinero, J.C. 2015. An Overview of Pest Species of *Bactrocera* Fruit Flies (Diptera: Tephritidae) and the Integration of Biopesticides with Other Biological Approaches for Their Management with a Focus on the Pacific Region. *Insects*. 6:297–318.

Venter, J.H. 2017. *Bactrocera dorsalis : Current status National exotic fruit fly surveillance program*. Pretoria, South Africa.

Verghese, A., Tandon, P.L. & Stonehouse, J.M. 2004. Economic Evaluation of the Integrated Management of the Oriental Fruit Fly *Bactrocera Dorsalis* (Diptera: Tephritidae) in Mango in India. *Crop Protection*. 23(1):61–63.

Verghese, A., Sreedevi, K. & Nagaraju, D.K. (2006), September). Pre and Post-Harvest IPM for the Mango Fruit Fly, *Bactrocera Dorsalis* (Hendel). Paper presented at the7th International Symposium on Fruit Flies of Economic Importance, 179–182. Salvador, Brazil.

Vijaysegaran, S. 2008. *Final Report: Establishment of Fruit Fly Pest-Free Areas*. Canberra, Australia.

Wan, X., Liu, Y. & Zhang, B. 2012. Invasion History of the Oriental Fruit Fly, *Bactrocera Dorsalis*, in the Pacific-Asia Region: Two Main Invasion Routes. *PLoS ONE*. 7(5):1–10.

Wan, X., Nardi, F., Zhang, B. & Liu, Y. 2011. The Oriental Fruit Fly, *Bactrocera Dorsalis*, in China: Origin and Gradual Inland Range Expansion Associated with Population Growth. *PLoS One*. 6(10):1–10.

Wei, D., Dou, W., Jiang, M. & Wang, J. 2017. Oriental Fruit Fly *Bactrocera Dorsalis* (Hendel).In F.Wan, M.Jiang & A. Zhan (Eds.), *Biological Invations and its Management in China*. (April):219–228. Dordrecht, The Netherlands: Springer.

Western Cape Government. 2017. *Socio-Economic Profile of the Cederberg Municipality 2017*.[Online], Available: https://www.westerncape.gov.za/general-publication/socio-economic-profile-municipalities-2017. [2018, October 27]

Witzenberg Municipality. 2017. *Integrated Development Plan 2017 – 2022*.[Online], Available: http://witzenberg.gov.za/resource-category/integrated-development-plan [2018, October 27]

WTO. World Trade Organization. 2010. *Sanitary and Phytosanitary Measures*. [Online], Available: https://www.wto.org/english/tratop_e/sps_e/sps_e.htm [2018, April 25].

Youm, O., Vayssières, J., Togola, A., Robertson, S.P. & Nwilene, F.E. 2011. International Trade and Exotic Pests : The Risks for Biodiversity and African Economies. *Outlook on Agriculture*. 40(1):59–70.

Personal communication (Direct, telephonic or per email)

Addison, P. 2018. Personal communication. Entomologist at Stellenbosch University. Stellenbosch.

Baard, N. 2018a. Personal communication. Manager of Fruitfly Africa. Stellenbosch.

Baard, R. 2018b. Personal communication. Agrochemical consultant, Citrusdal.

Bester, A. 2018. Personal communication. Subtrop, Tzaneen.

Donkin, D. 2018. Personal communication. Managing Director of Subtrop, Tzaneen.

Engelbrecht, S. 2018. Personal communication. Managing Director of Everseason, Citrusdal.

Groenewald, R. 2018. Personal communication. Managing Director of Riverside Holdings, Louna. Paarl.

Johnson, S. 2018. Personal communication. Research Associate of Hortgro. Stellenbosch.

Manrakhan, A. 2018. Personal communication. Citrus Research International. Nelspruit.

Page, JJ. 2018 Personal communication. Frudata, Stellenbosch.

Van Zyl, JP. 2018. Personal communication. Farmer, Citrusdal.

Venter, JH. 2018. Personal communication. Directorate plant health, DAFF. Nelspruit.

Annexures

Annexure A*:* Detail regarding workshops that were attended

Workshops attended

First workshop

Place: Devonvale Golf Estate, Stellenbosch

Date: 27-28 November 2017

Introduction of the project to stakeholders, identifying different criteria and invasive pests that should be included. The aim of the workshop was to address stakeholders who would have an influence on the project and stakeholders whose input would be needed.

Workshop participants:

Name	Surname	Organisation
Marc	De Meyer	Royal Museum for Central Africa
Pia	Addison	Stellenbosch University
Domingos	Cugala	E Mondlane University, Mozambique
Jan Hendrik	Venter	DAFF
Phumudzo	Tshikhudo	DAFF
Kgabo	Matlala	DAFF
Rejoice	Muavhi	DAFF
Maanda	Rambauli	DAFF
Welma	Pieterse	DAFF
Edmond	Qaba	DAFF
Noel	Layman	DAFF
Aruna	Manrakhan	Citrus Research International
Leslie	Brown	Stellenbosch University
Nando	Baard	Fruitfly Africa
Antonia	Vaz Tombolane	Recento do IIAM
Hugh	Campbell	HortGro
Matthew	Addison	HortGro
Lindi	Benic	HortGro
Vaughan	Hattingh	Citrus Research International
Tarryn	Wettergreen	SATGI
Elsje	Joubert	Subtrop
Tertia	Grové	ARC ITSC
Joaquim	Maquival	Companhia de Vanduzi
Antonio Junior	Tembe	FrutSul, Mozambique
Amilcar Charle	Mafumo	Ministry Agriculture, Pemba
Solomon	Gebeyehu	Private consultant, USDA Pretoria
Willem	Hoffmann	Stellenbosch University
Jo Bridget	Van Zyl	Stellenbosch University
Andrew	Yessup	Private consultant, Australia

Second workshop

Place: Orange Hotel, Nelspruit

Date: 5-7 June 2018

The report for the STDF was finalised, and matters that were still unknown and needed to be included in the final project, were addressed. The cost-benefit analysis was presented to the participants.

Workshop participants:

First name	Surname	Organisation
Marc	De Meyer	Royal Museum for Central Africa
Pia	Addison	Stellenbosch University
Domingos	Cugala	E Mondlane University, Mozambique
Jan Hendrik	Venter	DAFF
Maanda	Rambauli	DAFF
Partick	Magadani	DAFF
Aruna	Manrakhan	Citrus Research International
Nando	Baard	Fruitfly Africa
Antonia	Vaz Tombolane	Recento do IIAM
Matthew	Addison	HortGro
Tertia	Grové	ARC ITSC
Joaquim	Maquival	Companhia de Vanduzi
Antonio Junior	Tembe	FrutSul, Mozambique
James	Mehl	Subtrop
Solomon	Gebeyehu	Private consultant, USDA Pretoria
Jo Bridget	Van Zyl	Stellenbosch University