Assessment of the economic effects, non-commercial and environmental consequences of the entry of *Bactrocera dorsalis*

COSAVE

STDF Standards and Trade Development Facility

IICA

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CONTENT

ACRONYMS

APPPC	Asia and Pacific Plant Protection Commission
AQP	Absent quarantine pest
CABI	Centre for Agriculture and Biosciences International
CONAF	National Forest Corporation. Chile
COSAVE	Southern Cone Plant Health Committee
CPC	Crop Protection Compendium
CPPC	Caribbean Plant Protection Commission
EPPO	European and Mediterranean Plant Protection Organization
IAPSC	Inter-African Phytosanitary Council
IICA	Inter-American Institute for Cooperation on Agriculture
IPPC	International Plant Protection Convention
ISPM	International Standard for Phytosanitary Measures
NPPO	National plant protection organization
RIOPPAH	Regional International Organization for Plant Protection and Animal Health
PRA	Pest risk analysis
SINANPE	National Service of Natural Protected Areas. Peru.
SINASIP	National System of Protected Areas. Paraguay
SNAP	National System of Protected Areas. Uruguay

TABLES

ASSESSMENT TABLES

1. INTRODUCTION

This study aims to assess the non-commercial and environmental economic consequences of the introduction of *Bactrocera dorsalis* (Hendel, 1912). *Bactrocera dorsalis* was selected to assess the economic, noncommercial and environmental consequences, using the *Guidelines to assess the economic effects and non-commercial and environmental consequences of the entry of pests* in the framework of project STDF/PG/502 COSAVE: Strengthening the Implementation of Phytosanitary Measures and Market Access.

This pest is included in the Quarantine Pest List for the COSAVE Region, updated in November 2017, classified as an absent quarantine pest (AQP) in this region. The case study will only assess the impact, not the probability of introduction and spread; it is assumed that AQPs for the whole region are likely to be introduced and spread in all COSAVE member countries.

For the purpose of this assessment, the pest risk analysis (PRA) area will cover the whole COSAVE region, formed by Argentina, Bolivia, Brazil, Chile, Paraguay, Peru, and Uruguay.

1.1. CATEGORIES

1.1.1. PRESENCE OR ABSENCE OF THE PEST IN THE PRA AREA

No records of *Bactrocera dorsalis* have been found in the COSAVE countries; therefore, the pest is absent from the COSAVE region.

1.1.2. REGULATORY STATUS

The PRA area covers COSAVE member countries. As indicated above, this pest is included in the Quarantine Pest List for the COSAVE Region, updated in November 2017.

1.2. IDENTIFICATION OF THE PEST

Pest: *Bactrocera dorsalis* (Hendel, 1912)

Taxonomic position

Class: Insecta

Order: Diptera

Family: Tephritidae

Genus: *Bactrocera*

Species: *Bactrocera dorsalis*

Other scientific names:

Bactrocera (Bactrocera) dorsalis Drew & Hancock, 1994

Bactrocera (Bactrocera) invadens Drew et al., 2005

Bactrocera (Bactrocera) papayae Drew & Hancock, 1994

Bactrocera (Bactrocera) philippinensis Drew & Hancock, 1974

Bactrocera (Bactrocera) variabilis Lin & Wang

Bactrocera ferruginea Bezzi, 1913

Bactrocera invadens Drew, Tsuruta & White

Bactrocera papayae Drew & Hancock

Bactrocera philippinensis

Chaetodacus ferrugineus Bezzi, 1916

1.3. GEOGRAPHIC DISTRIBUTION

The oriental fruit fly, *Bactrocera dorsalis* (Hendel), is a native pest present throughout the tropics. In Asia, from India to southern China, across the East to Taiwan and across the South to Vietnam and Thailand (Leblanc et al., 2013).

According to CABI (2018), it is distributed in:

- Asia: Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China (Anhui, Chongqing, Fujian, Guangdong, Guangxi, Guizhou, Hainan, Hong Kong, Hubei, Hunan, Jiangsu, Jiangxi, Macau, Shanghai, Sichuan, Tibet, Yunnan, Christmas Island (Indian Ocean)), India (Andaman and Nicobar Islands, Andhra Pradesh, Assam, Bihar, Delhi, Goa, Guj Arat, Himachal Pradesh, Indian Punjab, Jammu, and Kashmir, Karnataka, Kerala, Madhya Maharashtra, Manipur, Odisha, Rajasthan, Sikkim, Tamil Nadu, Uttar Pradesh, Uttarakhand, West Bengal), Indonesia, Irian Jaya, major islands of the Sonda (Borneo, Java, Celebes, Sumatra), smaller islands of the Sonda, Laos, Malaysia (Peninsular Malaysia, Sabah), Myanmar, Nepal, Pakistan, Singapore, Sri Lanka, Taiwan, Thailand, Vietnam.
- Africa: Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo, Democratic Republic of the Congo, Côte d'Ivoire, Equatorial Guinea, Ethiopia, Gabon, Gambia, Ghana, Guinea, GuineaBissau, Kenya, Liberia, Madagascar, Mali, Mauritania, Mayotte, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sierra Leone, Sudan, Swaziland, Togo, Uganda, Zambia, Zimbabwe, United States (Hawaii).
- Oceania: French Polynesia, Palau, Papua New Guinea.

1.4. HOSTS

With more than 300 species of commercial/edible and wild hosts, *B. dorsalis* has the widest host range of *Bactrocera* species. It is a major pest for a wide range of fruit crops throughout its native range and where it has invaded. Due to the confusion between *B. dorsalis* and related species in Malaysia, the Philippines, Indonesia, southern India, and Sri Lanka, there are very few published records that refer exclusively to *B. dorsalis* hosts, unlike the misidentifications of related pest species in the *B. dorsalis* complex.

Taking China as an area where pest populations are definitely the true *B. dorsalis*, the main hosts are apple, guava, mango, peach, and pear (XJ Wang, unpublished data, 1988, as reported by White and Elson Harris (1994 cited in CABI, 2018)).

Chen et al. (2011) note that *B. dorsalis* is a polyphagous pest with a wide range of hosts, which can cause damage to more than 250 fruit and vegetable species belonging to 46 families such as citrus, guava, mango, banana, carambola, eggplant, peppers and potentially soft, yellow and ripe fruits.

1.5. ASSUMPTIONS

The following assumptions are made for the economic assessment:

1_ *Bactrocera dorsalis* has a probability of entering, establishing and spreading in all the countries of the COSAVE region; therefore, it is likely to have consequences.

2_ *Bactrocera dorsalis* has the potential to have economic, environmental and social impacts in the COSAVE countries.

3_ The assessment of the economic effects and noncommercial and environmental consequences of *Bactrocera dorsalis*, as presented in the assessment tables, will be carried out for the entire COSAVE region, based on the information collected by country.

4_ Of the many pest host species, this assessment considers citrus, mango and guava species. To facilitate the analysis, we follow the classification of FAOSTAT (2018), which consists of five groups of hosts:

- **a_** *Citrus x paradisi* (inc. grapefruits).
- **b_** *Citrus limon* and *Citrus aurantiifolia.*
- **c_** *Mangifera indica, Garcinia mangostana, Psidium guajava.*
- **d_** *Citrus sinensis.*
- **e_** *Citrus reticulata, Citrus clementina, Citrus unshiu*.

In addition, three scenarios have been developed to illustrate the use of the Guidelines:

- A0: Current situation, that is, without the pest
- A1: Situation with the presence of the pest in the COSAVE region, without control
- A2: Situation with the presence of the pest in the COSAVE region, with control

The rest of the study is organized following the Guidelines proposed by expert Dr. Gritta Schrader. Thus, section 2 presents the production impacts of the pest. Section 3 discusses the economic impacts associated with these production effects. Finally, section 4 analyzes the socioecological dimension. In each of the sections, the recommendations for the implementation of the Guidelines are highlighted. In addition, the database used for the case study is included as an annex.

2. IMPACT ON PRODUCTION

The objective of this section is to analyze, and quantify where possible, the production impacts of the pest. These impacts consider aspects including type of hosts, level of host susceptibility, type of damage on production, and quantification of damage. The details of each of these aspects are presented below.

a. Considering the results of section 1.4 Hosts, are any of these hosts of economic importance?

Most *B. dorsalis* host species are present in COSAVE countries. Due to the complexity of including data on planted area and yield for all host species in each COSAVE country, only data for most affected or susceptible species will be presented, citrus, mango and guava, according to the information provided by FAOSTAT[1] .

With respect to the economic relevance, we consider the average value (2010-2016 period) of the exports (in thousand USD), because this variable reflects the value of the production of the studied hosts in the economy. The information is presented in Table 1.

Table 1. Hosts by country: economic relevance

Country / Host	Export value (thousand USD) (2010-2016 average)
Argentina	
Citrus x paradisi (inc. grapefruits)	1,873.3
Citrus limon and *Citrus aurantiifolia*	208,658.7
Mangifera indica, Garcinia mangostana, Psidium guajava	16.0
Citrus sinensis	36,094.4
Citrus reticulata, Citrus clementina, Citrus unshiu	72,107.9
Bolivia	
Citrus limon and *Citrus aurantiifolia*	1,557.9
Citrus reticulata, Citrus clementina, Citrus unshiu	0.6

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[1] Available: http://www.fao.org/faostat/en

Brazil	
Citrus x paradisi (inc. grapefruits)	16.3
Citrus limon and *Citrus aurantiifolia*	73,552.9
Mangifera indica, Garcinia mangostana, Psidium guajava	153,749.9
Citrus sinensis	11,648.9
Citrus reticulata, Citrus clementina, Citrus unshiu	769.6
Chile	
Citrus x paradisi (inc. grapefruits)	1,126.3
Citrus limon and *Citrus aurantiifolia*	61,144.6
Citrus sinensis	63,158.0
Citrus reticulata, Citrus clementina, Citrus unshiu	74,111.7
Paraguay	
Citrus sinensis	299.7
Peru	
Citrus x paradisi (inc. grapefruits)	742.3
Citrus limon and *Citrus aurantiifolia*	3,434.4
Mangifera indica, Garcinia mangostana, Psidium guajava	141,130.1
Citrus sinensis	3,879.7
Citrus reticulata, Citrus clementina, Citrus unshiu	91,498.9
Uruguay	
Citrus x paradisi (inc. grapefruits)	81.1
Citrus limon and *Citrus aurantiifolia*	13,628.4
Mangifera indica, Garcinia mangostana, Psidium guajava	1.4
Citrus sinensis	31,224.7
Citrus reticulata, Citrus clementina, Citrus unshiu	33,371.3

Source: FAOSTAT, 2018.

b. Are some host species more susceptible than others?

The chemical ecology of female Tephritidae is not well understood. It is known that female fruit flies show some kind of host preference, which may vary according to the region or province (Goergen et al., 2011; Rwomushana et al., 2008 cited by Biasazin

(2017)). Fruit fly species range from specialists to generalists. For example, *B. dorsalis* is a generalist but prefers mango and guava to other species (Biasazin, 2017).

The order of preference of oriental fruit fly adults of different hosts for oviposition, feeding and level of damage is the following: guava (*Psidium guajava*)> carambola (*Averrhoa carambola*)> peach (*Prunus persica*)> mango (*Mangifera indica*)> Japanese medlar (*Eriobotrya japonica*)> orange (*Citrus sinensis*)> jujube (*Ziziphus lotus*)> pear (*Pyrus communis*)> citron (*Citrus medica*)> papaya (*Carica papaya*)> pomegranate (*Punica granatum*) (Chen et al., 2011).

In a study conducted during two years at 11 sites on three islands (Grande Comore, Anjouan and Mohéli) in the Comoros Archipelago, the dominant tephritid species detected was the invasive *Bactrocera dorsalis* Hendel followed by *Ceratitis capitata* (Wiedemann). The tephritidae species were generally more abundant during the hot and rainy seasons than during the cold and dry seasons. The number of B. *dorsalis* was higher on Grande Comore than on the other two islands. In Anjouan and Mohéli, the numbers of *B. dorsalis* were very low in 2014 but sharply increased in 2015, suggesting a recent invasion of these islands. Abundances were significantly related to the fruiting of mango, strawberry guava and guava, for *B. dorsalis* and to the fruiting of mango, guava and mandarin for *C. capitata*. *B. dorsalis* was more abundant in hot and humid low-altitude areas, while *C. capitata* was more abundant in the dry medium-altitude areas, suggesting the occurrence of climatic niche partitioning between the two species (Hassani et al*.,* 2016).

In a field research on *B. dorsalis* conducted during 2010-2013 in the Shapingba district of Chongqing in China with sexual attractants, the effects of climate and host plants on the population were analyzed. The incidence of *B. dorsalis* was seasonal. Populations were mainly found from May to November, peaking from August to October. Average monthly rainfall, temperature and host plants had significant effects in population change. The optimal conditions for *B. dorsalis* were 60-70% relative humidity, a temperature of 18-30° C and citrus fruits as a host plant (ZhiQiang et al., 2014).

In a study conducted by Galande et al. (2010), *B. dorsalis* (Hendel), *B. zonata* (Saunders), *B. correcta* (Bezzi) and, *B. versicolor* (Bezzi) fruit fly species were trapped in methyl eugenol traps, while the species *B. cucurbitae* (Coquillett), *B. tau* (Walker) and *B. gavisa* (Munro) were trapped in cue-lure traps in guava orchards in Pune, Maharashtra (India). The highest average catch in methyl eugenol traps was recorded for *B. dorsalis* (46.05%), followed by *B. zonata* (30.28%), *B. correcta* (14.81%) and B. versicolor (8.87%), while the highest average catch in cue-lure traps was for *B. cucurbitae* (52,32%), followed by *B. tau* (29.36%) and *B. gavisa* (18.32%). *B. dorsalis*, *B. zonata*, *B. correcta,* and *B. versicolor* species were also bred from infested fallen and harvested guava fruits, with the following results: 53.5% and 52.1%, 26.6% and 25.8%, 8.6% and 12.8% and 11.2%, and 9.1%, respectively.

These studies revealed that *B. dorsalis* was the dominant species infesting guava fruits in the Pune region of Maharashtra, followed by *B. zonata*, *B. correcta*, and *B. versicolor*. However, *B. cucurbitae*, *B. tau* and *B. gavisa* trapped in cue-lure traps were not bred from infested guava fruits, which indicates that these species did not use guava as a host and were exploiting other hosts grown in the region.

In a study in South Africa to determine the hosts of *B. dorsalis*, fruits were collected in seven plant species: two from commercial orchards: *Mangifera indica* cv. Tommy Atkins, Sensation, *Citrus sinensis* cv. Valencia and five other species: *Psidium guajava*, *Anacardium occidentale*, *Solanum mauritianum*, *Xylotheca kraussiana,* and *Vangueria infausta*. The fruit used by *B. dorsalis* was also infested or damaged by other species, which may indicate opportunistic pest behavior and potential competitive interactions (Theron et al., 2017).

Evidence indicates that some of the most affected or susceptible hosts are citrus, mango and guava; therefore, the analysis will focus on these species.

Table 2 presents information related to hosts, cultivated area and average yield (2010-2016), for each of the countries studied. To incorporate the time dimension, changes in cultivated areas for 2010-2016 are considered. The growth rate for that period is used to extend the analysis to 2020.

Table 2. Host by country (area and yield)

Country	Host	Area 2016 (ha)	Growth rate 2010-2016	Average yield 2010-2016 (kg/ha)
Argentina	*Citrus x paradisi* (inc. pomelos)	4,341	-8.60%	232,154
Argentina	*Citrus limon* and *Citrus aurantiifolia*	52,394	7.10%	322,597
Argentina	*Mangifera indica, Garcinia mangostana, Psidium guajava*	271	0.20%	79,598
Argentina	*Citrus sinensis*	47,823	0.50%	208,740
Argentina	*Citrus reticulata, Citrus clementina, Citrus unshiu*	41,107	3.70%	123,562
Bolivia	*Citrus x paradisi* (inc. pomelos)	435	-9.90%	94,010
Bolivia	*Citrus limon* and *Citrus aurantiifolia*	4,318	8.50%	76,297
Bolivia	*Mangifera indica, Garcinia mangostana, Psidium guajava*	2,144	7%	86,389
Bolivia	*Citrus sinensis*	22,864	-0.60%	73,788
Bolivia	*Citrus reticulata, Citrus clementina, Citrus unshiu*	26,796	12.10%	80,068
Brazil	*Citrus x paradisi* (inc. pomelos)	4,495	0.80%	178,405
Brazil	*Citrus limon* and *Citrus aurantiifolia*	47,279	1.80%	252,161
Brazil	*Mangifera indica, Garcinia mangostana, Psidium guajava*	78,961	2%	171,935
Brazil	*Citrus sinensis*	658,945	-2.90%	247,542
Brazil	*Citrus reticulata, Citrus clementina, Citrus unshiu*	49,232	-2.50%	193,495
Chile	*Citrus x paradisi* (inc. pomelos)	219	-4.10%	46,199
Chile	*Citrus limon and Citrus aurantiifolia*	5,993	-2.90%	221,217
Chile	*Mangifera indica, Garcinia mangostana, Psidium guajava*	0	0	0
Chile	*Citrus sinensis*	6,766	-1.40%	184,387
Chile	*Citrus reticulata, Citrus clementina, Citrus unshiu*	4,880	5.30%	146,803
Paraguay	*Citrus x paradisi* (inc. pomelos)	1,053	1.30%	445,740
Paraguay	*Citrus limon* and *Citrus aurantiifolia*	465	0.90%	202,264

Paraguay	*Mangifera indica, Garcinia mangostana, Psidium guajava*	0	0	0
Paraguay	*Citrus sinensis*	7,715	0.60%	298,216
Paraguay	*Citrus reticulata, Citrus clementina, Citrus unshiu*	1,945	0.90%	243,714
Peru	*Citrus x paradisi* (inc. pomelos)	820	3.60%	73,342
Peru	*Citrus limon* and *Citrus aurantiifolia*	25,700	0.05%	114,014
Peru	*Mangifera indica, Garcinia mangostana, Psidium guajava*	23,072	-1.00%	131,849
Peru	*Citrus sinensis*	30,860	2.60%	156,979
Peru	*Citrus reticulata, Citrus clementina, Citrus unshiu*	14,666	5.60%	242,277
Uruguay	*Citrus x paradisi* (inc. pomelos)	85	-9.30%	112,101
Uruguay	*Citrus limon* and *Citrus aurantiifolia*	1,585	-2.40%	226,288
Uruguay	*Mangifera indica, Garcinia mangostana, Psidium guajava*	4,198	1%	76,579
Uruguay	*Citrus sinensis*	7,418	-1.10%	183,872
Uruguay	*Citrus reticulata, Citrus clementina, Citrus unshiu*	5,760	-1.90%	176,533

Source: FAOSTAT, 2018

c. What are the types and the level of damage caused by the pest, and how often does damage occur?

The damage caused by the pest occurs after oviposition, causing necrosis around the puncture mark (“sting”). This is followed by decomposition of the fruit (CABI, 2018).

According to research by Chen et al. (2011), the average damage rate in guava is 50 to 60%, which can reach 80-100% in mature guava fruit in natural state during the period of maximum growth of *B. dorsalis*. In general, each fruit has about 10 larvae, and 20 to 30 larvae in severe conditions. In the case of home gardens, the level of damage is higher. When food is abundant and weather conditions are appropriate, the pest usually occurs in the right place with reduced less long-distance migration. However, when food is scarce and the weather is dry, adults migrate long distances to find suitable living environments.

Female adults of the oriental fruit fly lay their eggs in fruit before fruit maturity. The eggs hatch into larvae inside the fruit, damaging the pulp, causing the fruit to rot or yellow before ripening, causing early falling. In addition, oviposition of adults forms a wound on fruit surface, causing large fruit juice spillage and surface scarring, affecting fruit quality. The wound caused by adult oviposition also easily lead to pathogen invasion, causing rotting and falling. The closer to maturity fruit varieties are, the more fruit will be damaged. People who eat rotten fruit can be accidentally infected and experience bowel inflammation, leading to abdominal pain and diarrhea (Chen et al., 2011).

After hatching, the larvae of *B. dorsalis* become concentrated in the fruit and eat the pulp vertical and horizontally. The number of larvae in the same fruit goes from 10 to 100 or more, and can reach as many as 500-1000 in papaya (Liu et al., 2011).

In a study conducted in India, where mango is the most economically important fruit crop, assessments carried out between 2007 and 2009 showed that average fruit fly infestation was 48.3% in selected mango cultivars grown in Srinivasapura (India).

d. Does the pest cause crop losses, in terms of production and quality? What economic losses can be expected?

Table 3 provides information on production losses as recorded by several researchers. Given the difficulty of finding related production information for the *B. dorsalis* species for all the hosts, this table includes information on other fruit fly species, which could have, in terms of magnitude, the same effects as the species of interest.

Table 3. Host: yield losses

Host	Species	Yield loss %	Reference
Mangifera indica	B. dorsalis	27	Kumar et al., 1994
Mangifera indica	B. dorsalis	31–86	Mann 1996
Mangifera indica	B. dorsalis	1–3	Shukla et al., 1984
Mangifera indica	B. dorsalis	5–7	Tandon & Verghese 1996
Psidium guajava	B. dorsalis	60–80	Jalaluddin et al., 1999
Psidium guajava	B. dorsalis	19–42	Arora et al., 1998
Citrus sinensis	A. ludens	10.5%	Salcedo (2010)
Citrus reticulata	A. ludens	10.5%	Salcedo (2010)
Citrus x paradisi	A. ludens	10%	Salcedo (2010)
Mangifera indica	A. ludens	10%	Salcedo (2010)
Mangifera indica	A. ludens	20%	Salcedo (2010)

Source: Verghese et al., 2002, IICA Mexico Office (Salcedo, 2010).

Using the information in Table 3, the expected productivity impacts in the COSAVE area were calculated for 2017-2020, where the estimate assumes that the number of hectares evolves according to the information presented in Table 2[2]. Country details are presented in Table 4.

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[2] This report includes a database containing the estimates here in Annex.

Table 4. Hosts: expected changes in production by country

Country	Host	Change in productivity	Yield (kg/ha)	Production (tons)			
				2017	2018	2019	2020
Argentina	*Citrus x paradisi* (inc. grapefruits)	-10%	208,939	829,000	757,706	692,543	632,985
Argentina	*Citrus limon* and *Citrus aurantiifolia*	10.5%	356,469	16,201,449	17,351,751	18,583,726	19,903,170
Argentina	*Mangifera indica, Garcinia mangostana, Psidium guajava*	-20%	63,679	17,291	17,326	17,361	17,395
Argentina	*Citrus sinensis*	-10.5%	186,822	8,979,075	9,023,970	9,069,090	9,114,436
Argentina	*Citrus reticulata, Citrus clementina, Citrus unshiu*	-10%	111,206	4,740,472	4,915,870	5,097,757	5,286,374
Bolivia	*Citrus x paradisi* (inc. grapefruits)	-10%	84,609	33,161	29,878	26,920	24,255
Bolivia	*Citrus limon* and *Citrus aurantiifolia*	10.5%	84,308	394,987	428,561	464,988	504,512
Bolivia	*Mangifera indica, Garcinia mangostana, Psidium guajava*	-20%	69,111	158,546	169,645	181,520	194,226
Bolivia	*Citrus sinensis*	-10.5%	66,041	1,500,893	1,491,888	1,482,936	1,474,039
Bolivia	*Citrus reticulata, Citrus clementina, Citrus unshiu*	-10%	72,061	2,164,586	2,426,501	2,720,108	3,049,241
Brazil	*Citrus x paradisi (inc. grapefruits)*	-10%	160,565	727,513	733,333	739,199	745,113
Brazil	*Citrus limon* and *Citrus aurantiifolia*	10.5%	278,638	13,410,870	13,652,265	13,898,006	14,148,170
Brazil	*Mangifera indica, Garcinia mangostana, Psidium guajava*	-20%	137,548	11,078,140	11,299,703	11,525,697	11,756,211
Brazil	*Citrus sinensis*	-10.5%	221,550	141,755,691	137,644,776	133,653,077	129,777,138
Brazil	*Citrus reticulata, Citrus clementina, Citrus unshiu*	-10%	174,146	8,359,193	8,150,213	7,946,458	7,747,796
Chile	*Citrus x paradisi (inc. grapefruits)*	-10%	41,579	8,732	8,374	8,031	7,702
Chile	*Citrus limon* and *Citrus aurantiifolia*	10.5%	244,445	1,422,476	1,381,225	1,341,169	1,302,275
Chile	*Mangifera indica, Garcinia mangostana, Psidium guajava*	-20%	0	0	0	0	0
Chile	*Citrus sinensis*	-10.5%	165,026	1,100,935	1,085,522	1,070,324	1,055,340
Chile	*Citrus reticulata, Citrus clementina, Citrus unshiu*	-10%	132,123	678,933	714,916	752,807	792,706
Paraguay	*Citrus x paradisi (inc. grapefruits)*	-10%	401,166	427,919	433,482	439,117	444,826
Paraguay	*Citrus limon* and *Citrus aurantiifolia*	10.5%	223,502	104,864	105,808	106,760	107,721
Paraguay	*Mangifera indica, Garcinia mangostana, Psidium guajava*	-20%	0	0	0	0	0
Paraguay	*Citrus sinensis*	-10.5%	266,903	2,071,514	2,083,943	2,096,447	2,109,025
Paraguay	*Citrus reticulata, Citrus clementina, Citrus unshiu*	-10%	219,343	430,462	434,336	438,245	442,189
Peru	*Citrus x paradisi (inc. grapefruits)*	-10%	66,008	56,075	58,094	60,185	62,352
Peru	*Citrus limon* and *Citrus aurantiifolia*	10.5%	125,985	3,239,535	3,241,251	3,242,969	3,244,688
Peru	*Mangifera indica, Garcinia mangostana, Psidium guajava*	-20%	105,479	2,409,280	2,385,187	2,361,335	2,337,722
Peru	*Citrus sinensis*	-10.5%	140,496	4,448,437	4,564,097	4,682,763	4,804,515
Peru	*Citrus reticulata, Citrus clementina, Citrus unshiu*	-10%	218,049	3,376,994	3,566,106	3,765,808	3,976,693
Uruguay	*Citrus x paradisi (inc. grapefruits)*	-10%	100,891	7,778	7,055	6,399	5,804
Uruguay	*Citrus limon* and *Citrus aurantiifolia*	10.5%	250,049	386,815	377,532	368,471	359,628
Uruguay	*Mangifera indica, Garcinia mangostana, Psidium guajava*	-20%	61,264	259,756	262,354	264,977	267,627
Uruguay	*Citrus sinensis*	-10.5%	164,565	1,207,316	1,194,036	1,180,901	1,167,911
Uruguay	*Citrus reticulata, Citrus clementina, Citrus unshiu*	-10%	158,879	897,757	880,700	863,967	847,551

Source: Prepared by the authors.

e. Are there biotic factors (for example, adaptability, mobility, and virulence of the pest) that influence damage and losses?

There is evidence in the literature that *B. dorsalis* is recognized as one of the most harmful fruit fly pests in the world, especially due to its wide range of hosts, high reproductive potential, high mobility, and climate adaptability (Seewooruthun et al., 1997).

The invasion of *B. dorsalis* in new niches containing different food sources (a process known as host change) can cause population genetic differentiation and sympatric speciation[3]. In an attempt to infer it experimentally, test populations were established by transferring a subset of original populations that had been grown in banana for many generations, to orange, and then subculturing the orange population and the banana population for at least 20 generations. The results indicated that the genetic differentiation of the population occurred after host change, albeit at a low level. The biogeography and taxonomy of the *B. dorsalis* complex revealed that its speciation might be closely associated with host change, (Wan et al., 2014).

After its introduction, *B. dorsalis* can be easily dispersed as it has a high reproductive potential, a high biotic potential (short life cycle, up to 10 generations of descendants per year depending on temperature), high flight capacity (up to 50-100 km) and a wide range of hosts. It has been shown that *B. dorsalis* is highly competitive with native fruit flies where it has established, quickly becoming the dominant pest among fruit flies (Duyck et al., 2004, Vargas et al., 2007; Vayssières et al., 2015 cited by CABI, 2018).

f. Are there any abiotic factors (for example, climate, crop rotation) that influence damage and losses?

In tropical and subtropical regions, there are hot and rainy climates where annual temperatures range from 16 to 28°C, with an annual minimum average temperature higher than or equal to 5°C, annual average rainfall of 750-2000 mm and a variety of tropical fruits that grow all year round, the damage caused by *B. dorsalis* occurs throughout the year. With different temperatures accumulated in different regions, they complete three to nine generations per year and the population peak is observed late in the summer and early in the autumn. Under adverse circumstances in winter when temperatures are low and the supply of host fruits is limited, *B. dorsalis* may still maintain a certain population level in most of Southeast Asia, southern India, Hawaii, and other regions.

The environmental adaptability and life-cycle strategy of *B. dorsalis*, due to polyphagia, polyvoltism, high fecundity and some tolerance to high and low temperatures, enable this species to maintain dominance with large populations and strong competitiveness under different ecological environments in tropical and subtropical regions, which is also the main reason of the expansion of its distribution range and pest epidemic (Liu et al., 2011).

Mishra et al. (2012) determined that the correlation between *B. dorsalis* and weather conditions is not significant at maximum temperatures, while this pest shows a significant positive correlation with minimum temperature, relative humidity and rainfall. The findings of Rajitha and Viraktamath (cited by Mishra et al., 2012), were similar, but they reported populations *of B. dorsalis* with positive correlation with

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[3] Sympatric speciation groups of the same ancestral population evolve into separate species without any geographical separation (Khan Academy, 2018).

minimum temperature and relative humidity but negative correlation with maximum temperature.

Wei et al. (2017) indicate that, living in a wide geographic range, *B. dorsalis* can adapt well to extreme temperatures. Eggs have a high level of tolerance to high temperatures (Li et al., 2013 cited by Wei et al., 2017), and pupae can be tolerant to low temperatures (Wang et al*.,* 2014 cited by Wei et al., 2017). Fruit flies become more tolerant to low temperatures in the prewinter stage (Wang et al., 2014 cited by Wei et al., 2017). The host plant where the larval occurs may influence cold resistance in the next generation (Ren et al., 2006 cited by Wei et al., 2017). A study revealed that many oxidoreductases, binding proteins and transferases were present abundantly in adults treated with extremely high and/or low temperatures, which gave physiological protection to adults (Wei et al., 2015 cited by Wei et al., 2017). Studies also showed that antioxidant enzymes, such as superoxide dismutase (SOD), probably play an important role in the reduction of oxidation in *B. dorsalis* under thermal stress (Gao et al*.,* 2013; Jia et al., 2011 cited by Wei et al., 2017).

B. dorsalis can also adapt to a wide range of humidity. For example, hatching would not be delayed after third instar larvae experience desiccation in dry soils (Xie and Zhang 2009 cited by Wei et al., 2017). Larvae reduce their weight within two hours after treatment to reduce damage from desiccation. Most pupae would survive and develop healthily in a wide range of relative humidity, from 10% to 60% (Hou et al., 2006 cited by Wei et al., 2017). Pupae are more resistant to moisture variation compared to larvae (Ren et al., 2007; Tian et al., 2005 cited by Wei et al., 2017).

g.What is the rate of reproduction and spread of the pest and how does it affect damage and losses? Also consider the number of life cycles.

In China, *B. dorsalis* completes three to eleven generations per year, and in most areas four to eight generations (Wang et al., 2009 cited by Wei et al., 2017). It has the potential to expand northwards and southwards to the country's cold areas in the future.

Female remating is a widespread phenomenon in insects, through which the female can get more supplementary nutrients secreted by the male accessory gland, thereby substantially increasing their fitness. In *B. dorsalis* females there is also a remating inhibition. Remated females with a remating refractory period would produce more offspring (Wei et al., 2015 cited by Wei et al. (2017)). This may be one of the main reasons for the rapid population development of *B. dorsalis* in the wild (Wei et al., 2017)

Many members of the family Tephritidae are frugivorous (fruit diet), and most important pests species have a high capacity to disperse to and colonize new areas. There are three main characteristics, according to Malavasi et al. (2013), that give Tephritidae a status of good potential invasive species:

1_ A large and rapid rate of population growth. This allows many species of Tephritidae to dramatically increase the size of their population in a short period of time. In addition to the increase in density, one or a few gravid females can rapidly infest a large number of hosts, expanding their population distribution from a single point (e.g., a yard or garden tree) to adjacent areas and commercial groves.

2_ High natural dispersion capacity. Some fruit flies are strong fliers and can spread quickly and in large numbers when there is no availability of hosts or they are out of season. Well-fed adults (males and females) can fly long distances to reproduce, in search of oviposition sites or for protection. Using the marker-release-capture methodology has shown that both males and females can travel many kilometers when environmental conditions are inadequate. In addition, physically strong adults can be carried long distances by the wind, hurricanes and warm air masses, a fairly common phenomenon in the atmosphere. Due to these events, Japan maintains a monitoring network on the southernmost island of its archipelago, near Taiwan. The distance between Taiwan and Yonaguni Island is 180 km. Japan is a fruit fly-free country, as it carried out a large eradication program some decades ago, and Taiwan remains infested by some Bactrocera species. Although the distance is long, the trapping system of the Ministry of Agriculture, Forestry and Fisheries occasionally catches adult Bactrocera on islands near the strait.

3_ High anthropogenic anthropic dispersion. The egg and larval stages of the fruit fly are inside the fresh fruit. It is not always possible to distinguish when a fruit is infested with fruit fly eggs or larvae. Some fruits, such as guavas (*Psidium guajava* L.), carambolas (*Averrhoa caramboa* L.) and oranges (*Citrus sinensis*), do not usually reveal external evidence that they are infested unless they are at an advanced stage of maturity. Others, such as apples (*Malus × domesticum)*, peaches (*Prunus persica* L.) and papayas (*Carica papaya* L.), show that they are infested in early stages.

B. dorsalis and *B. cucurbitae* are present in the Hawaiian Archipelago and are classified as polyphagous and oligophagous, respectively. Registration of outbreaks of this two species in California, USA, is about 10:1, giving a good measure of the relative aggressiveness of both species (Malavasi et al., 2013.).

Assessment table 1 presents a summary of the expected impacts **on production** for each of the scenarios considered.

Assessment table 1. Impact on production assessment

Impact rating (%)	Production impact (%) in different assessment scenarios		
	A0	A1	A2
Insignificant (0-4.9)	100	0	25
Moderate (5-19.9)	0	25	50
Major (20-49.9)	0	50	25
Massive (50-100)	0	25	0
Sum of ratings	100	100	100

The previous assessment is based on the evidence presented, which highlights the characteristics of the pest: highly invasive pest, high reproduction rate, and high number of cycles. In this context, and in the absence of control actions, a high probability of significant production impacts is expected. On the other hand, when control actions are established, a greater probability of observing insignificant moderate production impacts is expected, mainly due to the effectiveness of control actions.

3. ECONOMIC IMPACT

The objective of this section is to analyze and quantify, where possible, the economic impacts derived from the production impacts identified in the previous section. These impacts consider aspects related to the effects and costs of control measures, impact on domestic markets, impact on export markets, and impacts on consumer demand. The details of each of these aspects are presented below.

3.1. CONTROL MEASURES

a. What measures are there to control the pest? Would its eradication or containment be possible? What is their effectiveness and cost?

The following measures are used in China's fruit fly-free areas, in the event of an outbreak of fruit fly. In the southern provinces, these measures are used to control native fruit flies (Biosecurity Australia, 2009):

- Use of pesticides to suppress fruit fly
- Removal of fallen fruit
- Soil treatment with pesticides to control pupae
- Use of sticky traps
- Bagging of fruit in some areas to protect it against fruit fly attack[4]
- National quarantine restrictions in the movement of fruit fly host commodities
- Cold disinfestation is occasionally used to treat the fruit harvested after the outbreak in the areas where the fruit is to be moved from the outbreak area. However, this fruit is usually sent for processing or consumed within the area of the outbreak.

Studies conducted in India by Verghese et al. (2002) indicate that, for small-scale crops and local markets, pre- harvest management of *B. dorsalis* is sufficient, whereas for export markets a combination of pre and post-harvest management is needed.

The same authors indicate the following pre-harvest management:

- **Cultural practices:** Common recommendations include picking up infested fruit, tilling or raking the ground under and between the trees in the summer and early harvest of ripe fruit (Butani 1979; Nair 1995; Srivastava 1997 cited by Verghese et al., 2002). The other recommendation is the bagging of fruit, which prevents oviposition by fruit flies (Srivastava 1997, Godse et al., 2002 cited by Verghese et al., 2002). In an experiment conducted by Makhmoor and

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[4] This type of control is not economically efficient in lands of large production area (data provided by NPPO Argentina).

Singh (1997 cited by Verghese et al., 2002) in a guava garden, soil-raking once a day, once every three days and at weekly intervals, resulted in 80%, 70% and 43% of pupal mortality, respectively. It was also observed that the pupal mortality was higher in argillaceous areas than in sandy soils.

- **Chemical control:** in the process of integrated control, the use of pesticides for pest control is an emergency measure, but spraying should be stopped 10-12 days before fruit harvest. The pesticides used to control the pest are the following: 1) organophosphorus dichlorvos, trichlorfon, chlorpyrifos (nurelle) quinalphos malathion, phoxim; 2) pyrethroid cypermethrin, cyhalothrin, deltamethrin; 3) abamectin [abamectin; agrimek; affirm; avomec; avid; ivermectin; ivomec; zephyl (merck sharp and dohme); avermectins; merck 1-676893; merck mk-932; Mk-936 (avermectin b); 1676895]; 4) Carbamate carbosulfan (Marshal; FMC35001); 5) spinosad bait, cyromazine. These agents should be used interchangeably with the addition of sexual attractant, hydrolyzed proteins and brown sugar in appropriate proportions, which may increase the insecticidal effect (Chen et al., 2011).
- **Treatment with soil insecticides:** the surface of the soil in the whole orchard is sprayed with insecticide before adults emerge in spring or after fruit harvest, in combination with the cleaning of fruit that falls to the ground. Available reagents include phoxim, diazinon, malathion, isophenphosmethyl, chlorpyrifos (Lorsban), and isazophos (Chen et al., 2011).

Suppression technologies at the farm and village level are effective, low-cost, profitable in the short term and sustainable in the long term, with minimal use of insecticides and minimal risk to human health and beneficial domestic organisms (such as honey bees and natural enemies of pests) (Verghese et al., 2002), as well as minimal collateral damage such as the development of pesticide resistance by fruit fly populations, benefits for Indian agriculture of these products will be increased fruit availability, increasing rural incomes, and reduced pesticide use through the use of integrated pesticide residue management systems.

Research by Leblanc et al. (2013), notes that four *Bactrocera* species have sequentially invaded French Polynesia: *B. kirki* (Froggatt) in 1928, B. *tryoni* (Froggatt) in 1970, B. *dorsalis* (Hendel), detected in Tahiti in 1996 and *B. xanthodes* (Broun), detected on the Austral Islands in 1998. After a failed attempt to eradicate *B. dorsalis*, it established in the area and became the dominant fruit fly, displacing *B. kirki* and *B. tryoni*. Two braconid parasitoids were introduced from Hawaii and established there: *Fopius arisanus* (Sonan) (published in 2002) and *Diachasmimorpha longicaudata* (Ashmead) (published in 2007). For 2009, in Tahiti, for guava fruit (*Psidium guajava*), Tahitian chestnut (*Inocarpus fagifer*) and tropical almond (*Terminalia catappa*) infested with fruit fly, the average parasitism was 70% and the 95% of emerging parasitoids were *F. arisanus*. The number of *B. dorsalis* trapped by methyl eugenol in guava, Tahitian chestnut and tropical almond was reduced by 87%, 89%, 88% and 91-94%, respectively against 2002-2003 peaks.

The IICA report for Mexico (Salcedo, 2010) discusses efficient fruit fly control, as part of the economic assessment that was developed for the National Campaign of Eradication. The information on the damage that persists after control measures are implemented (residual damage) is presented in Table 5 for *A. ludens.*

Table 5. Residual damage (%)

Host	Residual damage (%)
Citrus x paradisi (inc. pomelos)	1
Citrus limon y Citrus aurantiifolia	10
Mangifera indica, Garcinia mangostana, Psidium guajava	7.5
Citrus sinensis	2
Citrus reticulata, Citrus clementina, Citrus unshiu	1

b. What effect could the pest have on current production practices used in the PRA area? Changes in production methods and associated costs considered.

Chen et al. (2011) point out that *B. dorsalis* control should follow the principle of prevention first and integrated prevention. By using the combined methods of monitoring dynamics, agricultural control, physical control, and chemical control, the pest can be controlled economically, safely, effectively and continuously.

According to this principle, accompanying control measures should be adopted, basically including: a) selection of varieties, the main challenge of which is how to improve and increase fruit quality. In addition, the planting of late-maturing varieties to avoid peak occurrence of *B. dorsalis* can also effectively reduce damage rates; b) blocking of food sources, c) management improvements, promoting the vigorous growth of trees through fertilization and irrigation, d) timely pruning, which may reduce moisture, creating an unfavorable environment for fruit fly reproduction, e) cleaning by removing infested fruit.

On this basis, assumptions will be established for variation in practices for production of *B. dorsalis* host fruit species, which may occur with the presence of the pest.

1_ Plant selection: the choice of *B. dorsalis*- resistant varieties.

2_ Soil preparation: inclusion of an insecticide treatment to the soil.

3_ Management improvement: fertilization, irrigation and timely pruning.

4_ Pre-harvest: elimination of infested fruit.

5_ Early fruit harvest.

All these additional tasks in fruit crop cultivation may increase production costs.

c. Does the presence of the pest generate an increase in cost due to additional practices?

The presence of the pest will probably generate control actions, such as:

- Physical control: a) release of sterile males, pupae *B. dorsalis* are treated with Co ray under 95 Gy radiation, male adults infertile are released into the garden, which leads to female infertility, b) yellow traps, when fruit changes color, yellow sticky traps are placed in the garden to catch adults.

- Chemical control: a) death of males by sexual attractant, b) capture of adults by toxic bait, c) use of pesticides d) soil treatment with insecticide.
- Biological control: many species of natural enemies of the eastern fruit fly have been found, such as parasitoids, nematodes and fungi.

All the measures described are in addition to the usual management within fruit orchards; therefore, it is estimated that there could be an increase in costs.

d. Will resources be needed for complementary research and consultations?

A recent publication with the collaboration of members of the International Plant Protection Convention describes the economic importance of *B. dorsalis* in several geographical regions and discusses a series of phytosanitary treatment programs that have been shown to be effective against *B. dorsalis*. The document also suggests future research directed at the development of additional phytosanitary treatments and coordinated actions worldwide to reduce the economic impact of this invasive species. The research proposals are intended to address both the needs of exporting country farmers and industries to trade commodities that arrive at their destination in their intended state and quality, and those of the importing countries to receive commodities free of devastating pests (Dohino et al., 2016).

Assessment table 2 presents a summary of the expected impacts on methods and control costs for each of the scenarios considered.

Assessment table 2. Control cost assessment

Impact range (%)	Control cost (%) in each scenario		
	A0	A1	A2
Insignificant (0-4.9)	100	100	0
Moderate (5-19.9)	0	0	0
Major (20-49.9)	0	0	50
ive (50-100)	0	0	50
Sum of ratings	100	100	100

The above assessment is based on the evidence presented, where the fact of considering null is highlighted the impact control scenarios for A0 (no infestation) and A1 (with pest, no control). In this context, for the A2 scenario (with pest, with control), considerable/significant control costs are expected, which would be justified by the high production costs of the pest. Thus, given the decrease in the production impacts generated by the control actions, the measures would be justified to avoid pest damage (benefits for avoided costs).

3.2 IMPACT ON MARKETS AND CONSUMERS

a. How likely is an introduction of the pest to cause effects on domestic markets?

It is estimated that the damage caused by the pest deteriorates the quality of the affected fruit because it spoils it so much that it makes it unsuitable for consumption, mainly due to the presence of larvae inside the fruit. Thus, consumers dispose of the fruit and prefer other fruits of greater quality with the losses that this means for the producer.

In this area, there is a high level of uncertainty because there is no evidence that quantifies changes in the preferences of consumers and, therefore, how the consumer demand could change. Given this level of uncertainty, generated mainly by lack of information, it is assumed that the production impact generated by the pest will not have an effect on the price or on the perception of consumers about the general quality of the product (i.e., consumers assume that if the product has reached the market, it is because it was not affected by the pest). So consumers will eat everything farmers bring to the market. Therefore, the final impact on domestic demand will be equivalent to the production impact of the pest (see Table 4).

Assessment table 3 presents a summary of the expected impacts on the domestic market for each of the scenarios considered.

Assessment table 3. Impact assessment on the internal market

Impact range (%)	Impact on the internal market (%) in each scenario		
	A0	A1	A2
Insignificant (0-4.9)	100	0	25
Moderate (5-19.9)	0	50	50
Major (20-49.9)	0	25	25
Massive (50-100)	0	25	0
Sum of ratings	100	100	100

As in the previous cases, under scenario A0, complete certainty is assumed regarding the impact of the pest at an insignificant level. While recognizing a level of uncertainty of the effect of the pest (without control) on the domestic market, it is more likely to restrict the impact to a moderate level. The distribution of probabilities of the effects of the pest with control moves to lower levels (insignificant moderate) mainly due to the effectiveness of the control actions.

b. How likely is an introduction of the pest to cause effects on export markets, in particular access to these markets?

It is a devastating pest: it has been classified as the most important quarantine pest in many countries and regions of the world (Chen et al., 2011). Thus, *B. dorsalis* is of quarantine importance for the countries of the European Plant Protection Organization (EPPO), the Asia and Pacific Plant Protection Commission (APPPC), the Southern Cone Plant Health Committee (COSAVE), the Caribbean Plant Protection

Commission (CPPC), the Inter-African Phytosanitary Council (IAPSC), and the Regional International Organization for Plant Protection and Animal Health (RIOPPAH) (CABI, 2018).

Mau and Matin (2007) point out that the economic importance of *B. dorsalis* cannot be fully assessed from the point of view of the actual damage to the various crops affected. It should also be considered from the point of view of quarantine. Quarantine regulations to prevent the establishment of the oriental fruit fly in areas where it is not present are continuously applied. The United States Government has strict laws that regulate the movement of certain commodities to prevent the establishment of the oriental fruit fly in continental United States. The Japanese Government restricts the entry into its country of untreated hosts for this type of pest.

In the African region, *B. dorsalis* was detected in 2003 and represents a major phytosanitary challenge due to the threat that the pest represents for the region's exports, particularly avocado, banana, guava, and mango. It is believed that trade bans on imports to the region alone are causing around $ 2 billion annually. After the introduction, *B. dorsalis* can spread easily because it has a high reproductive potential, a high biotic potential (short life cycle, up to 10 generations of offspring per year depending on the temperature), high dispersal ability, high competitiveness with native fruit flies, and a wide range of hosts (IPPC, 2017).

Areas with higher risk of invasion by *B. dorsalis* include South and Central America, Mexico, the southern tip of the United State, parts of the Mediterranean coast, parts of southern and eastern Australia and the North Island of New Zealand. Areas with low risk of invasion include most of Africa and Australia (De Villiers et al., 2016).

Due to the above, it is expected that the establishment of the pest will restrict access to international markets. Given the assessment of control measures, the restriction to markets is expected to be severe in the short term, potentially losing all exports, but as control measures are applied, the restriction to markets will tend to be equivalent to production losses (see Table 4).

Assessment table 4 presents a summary of the expected impacts on the external market for each of the scenarios considered.

Assessment table 4. Impact assessment on the external market

Impact range (%)	Impact on the external market (%) in each scenario		
	A0	A1	A2
Insignificant (0-4.9)	100	0	0
Moderate (5-19.9)	0	0	25
Major (20-49.9)	0	25	50
Massive (50100)	0	75	25
Sum of ratings	100	100	100

As noted, considerable impacts are expected in the scenario with pest and without control, mainly due to the damage suffered by farmers when subjected to quarantine measures. Once control actions are established (scenario A2) and despite their effectiveness, access to international markets may remain affected, which is reflected in the new distribution of probabilities, where some probability of moderate impact is considered. This effect is not indefinite, as it may be reversed through official control activities.

c. Could the introduction of the pest cause changes in domestic or foreign consumer demand for a product as a result of changes in quality, loss of marketability and/or diversion of the product to a lower value end-use?

The damage caused to crops by *B. dorsalis* is due to 1) the oviposition in the fruit and the soft tissues of the vegetative parts of certain plants, 2) feeding by larvae and 3) the destruction of the plant tissue by the invasion of secondary microorganisms.

Larval feeding in fruits is the most harmful damage. It usually consists of tissue destruction and internal rot associated with larval infestation, but it varies according to the type of fruit attacked (Mau and Matin, 2007). Infested young fruit becomes distorted, become callused and generally falls. Attacked ripe fruit develop a water soaked appearance. Larval tunnels provide entry points for bacteria and fungi that cause the fruit to rot. When only a few larvae develop, damage consists of an unsightly appearance and reduced marketability because of the egg laying punctures or tissue break down due to the decay (Steiner, 1957).

Thus, changes in domestic and external demand for the products affected by the pest can be expected. This change will depend on the intensity of the pest, the effectiveness of control measures and the ability of farmers to deal with the reputational risk involved in producing in an area where the pest is present, in order to maintain the demand for their products[5]. The quantification of these impacts requires detailed market studies to identify the “sensitivity” of the demand on the attributes affected by the pest.

Assessment Table 5 presents a summary of the expected impacts on consumer demand for each of the scenarios considered.

Assessment table 5. Impact assessment on consumer demand

Impact range (%)	Impact assessment on consumer demand (%) in each scenario		
	A0	A1	A2
Insignificant (0-4.9)	100	25	25
Moderate (5-19.9)	0	25	25
Major (20-49.9)	0	25	25
Massive (50-100)	0	25	25
Sum of ratings	100	100	100

As indicated in the justification, there is a high level of uncertainty regarding consumer preferences (internal and external markets), which is reflected in the distribution of probabilities used (uniform).

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[5] In this context, reputational harm to farmers refers to the difficulty of doing business (in this case exporting) due to a negative market perception resulting from the implementation of quarantine measures.

4. SOCIOENVIRONMENTAL IMPACT

The objective of this section is to analyze and quantify, where possible, the social and environmental impacts derived from the production and economic impacts identified in the previous sections. These effects involve aspects related to impacts on other species, on ecosystem services, and on protected areas. In addition, in the social area, aspects related to employment, migration and tourism, among others, are considered. The details of each of these aspects are presented below.

4.1. ENVIRONMENTAL IMPACT

Environmental impact assessment should focus on the result of direct or indirect effects on plants. These may be less significant than the effects of the pest on other organisms or systems, but regulation of pests based only on the effects on other (non-plant) organisms or systems (for example, human or animal health) is beyond of the scope of the ISPM 11.

a. Could the pest cause reduction, displacement or elimination of key or native plant species, or of key components in the ecosystem (in terms of abundance, size or economic importance)?

USDA-ARS (2015) states that *Psidium guajava* L. (guava) is native in: Argentina, Bolivia, Brazil, Paraguay, Peru (COSAVE member countries), among other countries. *B. dorsalis*, has among its susceptible hosts *P. guajava*, according to the references cited above.

Regarding the probability of *B dorsalis* affecting native species, it is important to note that these species may never have been moved out of its native range, in this case the COSAVE region. Therefore, there is no historical evidence of the direct effects of the pest on such species, which may indicate that native hosts of other fruit fly species of the same family, Tephritidae, could also be hosts of *B. dorsalis*.

Some evidence is presented regarding native plants affected by Tephritidae in COSAVE member countries.

ARGENTINA

The *Toxotrypana* species (Diptera, Tephritidae) that are known in Argentina were described by Blanchard (1960), classified by Foote (1967) and also cited by Bartolucci (2008). Among them are: *T. australis* Blanchard present in Tucumán, Corrientes, Buenos Aires and Santiago del Estero; *T. littoralis* Blanchard in Corrientes; *T. picciola* Blanchard in Tucumán; *T. proseni* Blanchard in Jujuy and Buenos Aires; *T. pseudopicciola* in Cordoba, and *T. nigra* in Jujuy and Entre Ríos (2, 6). Blanchard (1960) also described *T. pseudopicciola*, from Cordoba, currently considered synonymous with *T. nigra*, according to Norrbom et al. (1999b). None of them is of economic importance, because they are not considered pests of fruit trees (Zucchi et al., 2017). The same author notes that, according to Blanchard (1960), the hosts of both species (*T. australis* and *T. nigra*) are the native vines of the genus Morrenia (commonly known as “Tasi”) of the Apocynaceae family, with natural distribution in the province of Santa Fe.

BOLIVIA

Studies conducted in Bolivia show that the percentage of damage caused by fruit flies varies between 0 and 84.11%. Fruits with a considerable percentage of damage are guava (*P. guajava*) 84.11%, mandarin (C*. reticulata*) 63.54%, Guinea guava (*P. araca*) 50.0% and uvaia (*E. pyriformis*) 46.67%, the most significant among sampled fruit species (Ledezma et al., 2013). Some native fruit fly host species that are mentioned in this research are, for example, *Spondias purpurea* (purple mombin), *Campomanesia aromotica* (strawberry guava), *Psidium aroca* (common guava), and *Inga edulis* (ice-cream bean).

BRAZIL

A study carried out in Brazil on fruit infestation indices shows that infestation by tephritidae occurred in only eight out of the 21 hosts: imbu (*Spondias tuberosa*), acerola (*Malpighia emarginata*), purple mombin (*Spondias purpurea*), mombin (*Spondias* sp.), guava (*Psidium guajava*), juá (*Ziziphus joazeiro*), almond (Prunus armeniaca) and mango (*Mangifera indica*). Infestation by Tephritidae was highest in purple mombin, jua and imbu (Falcão de Sá et al., 2008), which are native species.

In Brazil, intensive surveys conducted in the State of Goiás, located in the central region of this country and with a particular plant formation called cerrado, found new hosts for the South American fruit fly (*Anastrepha fraterculus*): araza (*Psidium australicum* (Myrtaceae)), bacupari (*Salasia campestris* (Hipocrataceae)), cagaiteira (*Eugenia dysenterica* (Myrtaceae)), curriola (*Pouteria ramiflora* (Sapotaceae)), all of which are native to the region (Zucchi et al., 1999).

CHILE

In Chile, four species of the genus *Rhagoletis* Loew (Diptera: Tephritidae) have been described, all of them belonging to the nova group and associated with Solanaceae. To determine the geographical distribution of these species, collections were made from the I region to XI region and south of Argentina (Bariloche). These collections covered the entire range of distribution of both hosts in Chile. *Solanum tomatillo*, is an endemic species of Chilean origin (Hoffmann 1978, Navas 1979 cited by Frias, 2001). The other host, *S. nigrum,* is a plant native of Europe, adapted to temperate climates in Chile (Frías, 2001).

PARAGUAY

Excluding its introduced hosts, A*. ludens,* for example, has an important relationship with native plants in the Rutaceae family; *A. obliqua* occurs especially in the Anacardiaceae; *A. fraterculus* and *A. suspensa* in the Myrtaceae; and *A. serpentina* in the Sapotaceae, according to Hernández-Ortiz and Aluja (1993). *A. fraterculus* are found in Paraguay and Peru; *A. serpentine* in Peru.

Among the species belonging to the Myrtaceae family, described by Pérez de Molas (2015) present in native forests in Paraguay, are the following: *Blepharocalyx* O. Berg, *Calycorectes* O. Berg, *Calyptranthes* Sw., *Campomanesia* Ruiz & Pav., Eugenia L., *Gomidesia* O. Berg, *Hexachlamys* O. Berg, *Myrceugenia* O. Berg, *Myrcia* DC., *Myrcianthes* O. Berg, *Myrciaria* O. Berg, *Paramyrciaria* Kausel, *Plinia* L., *Psidium* L. Another publication that lists native species of popular use refers to *Campomanesia xanthocarpa, Eugenia myrcianthes*, *Eugenia uniflora*, *Myrciaria cauliflora*, *Myrciaria rivularis* (Schvartzman and Santander, 1996).

PERU

Norrbom et al. (2015) describe and illustrate 28 new *Anastrepha* species : *A. acca* (Bolivia, Peru), *A. adami* (Peru), *A. ampidentata* (Bolivia, Peru), *A. annonae* (Peru), *A. breviapex* (Peru), *A. caballeroi* (Peru), *A. camba* (Bolivia, Peru), *A. cicra* (Bolivia, Peru), *A. disjuncta* (Peru), *A. durantae* (Peru), *A. echaratiensis* (Peru), *A. eminens* (Peru), *A. ericki* (Peru), *A. gonzalezi* (Bolivia, Peru), A. guevarai (Peru), *A. gusi* (Peru), *A. kimi* (Colombia, Peru), *A. korytkowskii* (Bolivia, Peru), *A. latilanceola* (Bolivia, Peru), *A. melanoptera* (Peru), *A. mollyae* (Bolivia, Peru), *A. perezi* (Peru), *A. psidivora* (Peru), *A. robynae* (Peru), *A. rondoniensis* (Brazil, Peru), *A. tunariensis* (Bolivia, Peru), *A. villosa* (Bolivia) and *A. zacharyi* (Peru). In addition, they registered the following host plants: *A. amplitude* of *Spondias mombin* L. (Anacardiaceae); *A. caballeroi* of *Quararibea malacocalyx*, *A. robyns* of *S. Nilsson* (Malvaceae); *A. annonae* from *Annona mucosa* Jacq. and *Annona* sp. (Annonaceae); A. Durantae of *Duranta peruviana* Moldenke (Verbenaceae); and *A. psidivora* of *Psidium guajava* L. (Myrtaceae). Another author, points to *Spondias mombin* L. (Anacardiaceae), *Annona mucosa* Jacq. and *Annona* sp. (Annonaceae) and *Psidium guajava* as species native to Peru (González, n.d.).

URUGUAY

In Uruguay there is a history of other Tephritidae, such as *Ceratitis capitata* and *A. fraterculus* which are hosted by native fruit species such as cattley guava (*Psidium littorale*), cherry guava (*Psidium cattleianum*), guabiyú (*Myrcianthes pungens*), pineapple guava (*Acca sellowiana*) (Delgado et al., 2014). The same study indicates that, in general, *A. fraterculus* is detected more frequently on native fruits, whereas *C. capitata* is present in almost all the hosts. While pineapple guava (*Acca sellowiana*) is the host where the highest abundance of both species was found, *C. capitata* appears late in this host, when commercial fruit species are not present because they have been harvested or because they are not close to ripening. In *A. sellowiana* and *Acanthosyris spinescens* (sombra de touro) the presence of both fly species was recorded in the same fruit.

Assessment table 6 presents a summary of the expected impacts on native species for each of the scenarios considered.

Assessment table 6. Impact assessment on native species

Impact range (%)	Impact assessment on native species (%) in each scenario		
	A0	A1	A2
Insignificant (0-4.9)	100	50	75
Moderate (5-19.9)	0	50	25
Major (20-49.9)	0	0	0
Massive (50-100) %	0	0	0
Sum of ratings	100	100	100

The assessment in scenario A1 (with pest, no control) indicates that the level of impact is negligible to moderate, as under the assumption that *B. dorsalis* affected native species in the COSAVE region, it would not cause plant death but only fruit damage, probably reducing propagules and population, but not the extinction of the species. With the incorporation of control measures, the probability of impact concentrating in a range of negligible impacts increases.

b. How likely is the pest to have significant effects on plant communities through competition for resources?

Due to the competition for food, *B. dorsalis* would displace other less aggressive fruit fly species. Duyck et al. (2004), cited by CABI (2018), suggested that the r-K gradient could be used as a predictor of the potential invasive capacity of a species. Species with K-type demographic traits, such as *Bactrocera* species, would adapt to compete in saturated habitats. Duyck et al. (2004), cited by CABI (2018) reported that, in all cases where the species farther along the r-K gradient, such as *B. dorsalis*, have invaded, the selected species, such as *Ceratitis capitata*, were displaced—never the other way around (CABI, 2018).

c. How likely is the pest to have significant effects on environmentally protected areas?

A protected area can be defined as a clearly defined, recognized, dedicated, and managed geographical space, through legal means or other effective means to achieve the long-term conservation of nature and its environmental services and associated cultural values (Borrini Feyerabend et al., 2015)

- Argentina: 47 protected areas - Total area 4,591,377 ha (Administration of National Parks, 2018).
- Bolivia: the estimated area of protected areas is 17,206,927.68 (ha).
- Brazil: the area of the Brazilian territory protected by conservation units exceeds 100 million hectares. In addition, in 2006, the Federal Government, with the approval of the National Strategic Plan for Protected Areas, began to recognize the importance of indigenous lands, totaling more than 105 million hectares, for the conservation of biodiversity and has been working to strengthen the integration of these lands with conservation planning and management in Brazil (Gonçalves, 2007).
- Chile: Chile's natural wealth is protected within the National System of Protected Wild Areas of the State, administered by the National Forestry Corporation, CONAF. The System currently has 101 units, distributed in 36 National Parks, 49 National Reserves and 16 Natural Monuments. These units cover an approximate area of 14.5 million hectares, 19.2% of the continental territory of Chile (CONAF, 2018).
- Paraguay: has made progress in the establishment of the National System of Protected Areas (SINASIP). To date there are 94 protected wildlife areas under some form of protection and management in an area of 2,755,613 hectares, which represent 6.8% of the country's area, organized in a) Subsystem under Public Domain, b) Subsystem under Private Domain and c) Subsystem under an Autonomous Entity Entity (Itaipú and Yacyretá). If biosphere reserves are included, the percentage reaches 15.2%.
- Peru: the total area of Natural Protected Areas established is 19,456,554.91 ha (SENANPE, 2018).
- Uruguay: the area under the National System of Protected Areas (SNAP), with 15 areas entered, is today 279,516 hectares, including the land and marine areas,

> reaching 0.878% of the territory. Despite the low surface coverage in protected areas of the National System of Protected Areas in the national territory, the percentage of landscapes represented is over 70% of the country, and the percentage of ecosystems and priority threatened species for conservation represented is over 30% of the total. It is worth saying that, with a still small system, the representation of significant elements is high. This is the result of work that is done with scientific criteria and modern and appropriate methodologies (SNAP, 2018).

Based on the percentages of area covered by protected areas of COSAVE countries and the high number of *B. dorsalis* host species, the pest is likely to affect the fruit of present species. However, the level of damage does not kill the plant, consequently it is estimated that the effects would not be significant.

d. How likely is the pest to have significant environmental and other undesired effects due to the control measures?

The main option for farmers in the Asian region for the control of flies of the genus *Bactrocera*, says Vijaysegaran (2016), has been the application of insecticides to protect their crops. Unfortunately, this practice of small farmers results in several harmful side effects such as high pesticide residues in harvested products, indiscriminate killing of beneficial and non-target organisms, such as pollinators, parasitoids and predators and, toxicity to farmers and their families, who often do not use adequate protection methods for the application of pesticides. What these farming communities desperately need is a safe, easy-to-apply fruit and vegetable control technology for users and the environment that is consistently effective, reliable and inexpensive.

In relation to the possibility of populations becoming resistant to a given insecticide treatment, Chou et al. (2010) state that it is a major problem for all insect pest species. In Hawaii, for example, organophosphate insecticides have been the most commonly applied chemical treatment against *B. dorsalis*, since the 1950s. In addition, spinosad spraying treatments were adopted as a major control strategy in the fruit-fly pest management program throughout the Hawaiian area from 2000 onwards. To determine the current level of tolerance to spinosad and organophosphate of wild populations of *B. dorsalis*, bioassays were performed with flies collected in a range of geographical locations in the Hawaiian Islands. Adult *B. dorsalis* flies were examined to determine the level of susceptibility to spinosad using LC50 diagnostic criteria and to detect the presence of ace gene alleles that had previously been shown to be associated with organophosphate resistance. Regarding tolerance to spinosad, only flies of Puna, the only area that lacked prior exposure to spinosad, showed a significant difference compared to controls and here the difference was only in terms of non-overlapping reference limit values of 95%. With respect to organophosphate tolerance, specific mutations in the ace gene associated with resistance to these insecticides were found in only two populations, and in both cases, these alleles occurred at relatively low frequencies. These results suggest that at present *B. dorsalis* populations in Hawaii show no evidence of having acquired resistance to insecticides widely used in control programs.

The use of chemical insecticides is an important method for the control of *B. dorsalis*, state Wei et al. (2017). However, due to the long and very frequent applications of certain chemicals, this insect has developed high levels of resistance to insecticides, which in turn leads to new outbreaks (Jin et al., 2011 cited by Wei et al., 2017). For example, in 2007 and 2008, it was detected that *B. dorsalis* developed a high level of resistance to trichlorfon in Guangdong (China) and a high level of resistance to βcypermethrin in Jiangsu (China) (Jin et al., 2011 cited by Wei et al., 2017). Resistance to malathion, βcypermethrin and abamectin has also occurred in recent years (Wang et al., 2013; Chen et al., 2015 cited by Wei et al., 2017). In addition, high resistance to cyantraniliprol (a new diamidic anthranilic insecticide) in Hubei (Zhang et al., 2014 cited by Wei et al. (2017)). Resistance to insecticides increasingly represents a serious threat to the control of *B. dorsalis*.

e. How likely is the pest to cause costs associated with environmental restoration?

Environmental restoration is the process of reducing, mitigating and even reversing, in some cases, the damage produced in the physical environment to return as far as possible to the structure, functions, diversity, and dynamics of the original ecosystem. In this case, where the damage caused by *B. dorsalis* occurs after oviposition, causing necrosis around the puncture mark and subsequent fruit decomposition, the pest does not cause plant death; therefore, there would be no plants that need restoration. Assuming that there was damage to native plants, it would not be necessary to replace affected plants or restore degraded areas, landscape restoration or recovery of habitats for wildlife.

Assessment table 7 shows a summary of the expected impacts on other environmental components (plant communities, protected areas, undesired effects of control measures, environmental restoration) for each of the scenarios considered.

Assessment table 7. Impact assessment on other environmental components

Impact range (%)	Impact assessment on other environmental components (%) in each scenario		
	A0	A1	A2
Insignificant (0-4.9)	100	75	50
Moderate (5-19.9)	0	25	50
Major (20-49.9)	0	0	0
Massive (50-100)	0	0	0
Sum of ratings	100	100	100

As in the previous case, and given the expected impacts on other environmental components, an insignificant level of impacts is expected. Unlike the previous cases, the introduction of control actions implies a series of negative impacts, which is reflected in the increase in the probability of finding moderate impacts.

f. Does the pest have a significant impact on ecosystem services?

Ecosystem services are the benefits that human beings derive from the natural environment and the proper functioning of ecosystems. They can be grouped into four different categories: *provision services*, for example, the production of food, fibers and clean water; *regulating services*, for example, climate control, erosion and diseases; *support services*, for example, nutrient cycles and pollination; and *cultural services*, such as spiritual and recreational benefits.

Considering the classification of ecosystem services, the presence of the pest will affect the *provision service*, in this case, the production of fruits for human consumption (see Table 4 for expected effects).

Other impacts on ecosystem services are expected as a consequence of chemical control measures to control the pest. In this case, effects are expected on *regulating services* (air pollution and water), *provision services* (directly affecting other plant species, and indirectly due to the impact of insecticides on pollinators) and eventually on *cultural services*, if the consequences of pest control are developed nearby, or in recreation areas.

Assessment table 8 presents a summary of the expected impacts on ecosystem services for each of the scenarios considered.

Assessment table 8. Impact assessment on ecosystem services

Impact range (%)	Impact assessment on ecosystem services (%) in each scenario		
	A0	A1	A2
Insignificant (0-4.9)	100	50	75
Moderate (5-19.9)	0	50	25
Major (20-49.9)	0	0	0
Massive (50-100)	0	0	0
Sum of ratings	100	100	100

The above assessment is based on the effect of the pest without control (scenario A1) on the ecosystem service of food provision, which is reflected in the production impact of the pest. Given that the provision service represents only part of the affected ecosystem services, the highest probability is observed in the insignificant moderate impact range. This distribution was concentrated in insignificant impacts, when control measures are established.

4.2. SOCIAL IMPACT

When determining the social impact, the following aspects should be taken into account:

- Loss of employment
- Effects on migration
- Loss of real estate
- Effects on tourism, loss of profit in hotels
- Effects on relative cultural events
- Specific crops (for example, grapes)
- Risks to human health and harmful effects on human wellbeing (for example, *Halyomorpha halys*: odor)
- Reduction or loss of availability of traditional plants for cultural purposes, cultural heritage
- Impact on consumption habits: healthy food, vegetables, harmful effects on food
- Conducting school educational program for certain crops (for example, HLB included in the curriculum to teach about this pest)
- Negative effects on organic farming
- Loss of trust, for example, NPPO, effects on the credibility of an organization

Given the existing information restrictions, a qualitative estimate of the social impacts considered to be of interest will be carried out. The analysis includes the main social impacts (employment, migration, tourism, consumption habits, organic agriculture, and confidence in the NPPO), while quantitative analysis will be conducted to analyze health risks resulting from pest control actions.

As discussed throughout this case study, given the characteristics of the selected pest, serious production impacts can be expected on the hosts analyzed. Given this production impact, and depending on the intensity of labor use, there may be negative impacts on the level of agricultural employment. In addition, with reduced production these impacts may extend to secondary markets (transport and marketing), thereby increasing the negative impact on employment. Depending on the geographical concentration of production, the increase in unemployment could generate migratory pressure to other regions. However, these negative impacts should decrease in the medium term, once control measures are put in place.

Furthermore, as discussed above, it is possible that the pest generates negative impacts on natural areas. Where these natural areas are used for tourism/recreational purposes, pest presence may reduce the economic benefits that these areas provide, both in terms of use and nonuse.

Against this background—resistance to malathion, βcypermethrin and abamectin, according to Wang et al. 2013; Chen et al. 2015 cited by Wei et al. (2017), this phenomenon is increasingly serious threat to current efforts to control *B. dorsalis* (Wei et al., 2017).

On the other hand, studies indicate that foliar applications of GF-120 NF natural fruit fly bait (spinosad), in all the rows (every two trees) or every fifth row (every tree), combined with good sanitation, can effectively reduce *B. dorsalis* infestation in papaya orchards in Hawaii (Piñero et al., 2009).

As regards health impacts, as indicated in previous sections, pest control can be developed by applying insecticide (spinosad), which could have impacts on human health. For the specific case of spinosad, significant impacts should not be expected, given the characteristics of the product. However, there are locations where malathion, which has higher levels of toxicity, is still used. Thus, for the quantification of health effects, the worst scenario was considered (use of malathion). An IICA report on the fruit fly campaign in Mexico (Salcedo, 2010) discusses deaths associated with the application of malathion. According to this study, 5.15 people would be affected for every 1000 liters of insecticide. Table 6 presents information on the number of people affected by insecticide use. A dose of 1.5 liters of malathion per hectare is used for the calculation, where the use of insecticide develops at the same rate as the area under cultivation (see Table 4).

Table 6. **Affected people (2017-2020)**

Country	Insecticide use (l)				Affected people (N)			
	2017	2018	2019	2020	2017	2018	2019	2020
Argentina	220,174	221,451	222,735	224,027	1,134	1,140	1,147	1,154
Bolivia	87,737	90,737	93,841	97,050	452	467	483	500
Brazil	1,256,355	1,254,344	1,252,337	1,250,334	6,470	6,460	6,450	6,439
Chile	26,621	26,456	26,292	26,129	137	136	135	135
Paraguay	16,891	17,016	17,142	17,269	87	88	88	89
Peru	145,774	148,938	152,171	155,474	751	767	784	801
Uruguay	27,786	27,025	26,284	25,564	171	166	162	157

In addition, there is the possibility of consumption outside the market—where consumers grow their own fruit—in some regions, where hosts are urban trees. In this case, when consuming infected fruit, it is possible to contract gastrointestinal diseases, causing inflammatory bowel disease, leading to abdominal pain and diarrhea (Chen et al., 2011).

Other potential effects of the pest are related to changes in the consumption habits of the population. The intensity of this impact will depend on the existence of substitute products (the greater the number of substitutes, the lower the impact), and the opportunity to implement the control measures (the shorter the implementation time, the lower the impact). Finally, a serious impact that can result from the introduction of the pest is related to the loss of credibility of the NPPO, which would imply a major institutional failure with effects that are difficult to quantify.

Assessment table 9 shows a summary of the expected social impacts for each of the scenarios considered.

Assessment table 9. Social impact assessment

Impact range (%)	Social impact assessment (%) in each scenario		
	A0	A1	A2
Insignificant (0-4.9)	100	25	25
Moderate (5-19.9)	0	25	25
Major (20-49.9)	0	25	25
Massive (50-100) %	0	25	25
Sum of ratings	100	100	100

The assessment of social impacts is especially complex, as it requires quantification of second order changes (e.g., employment) based on first order changes (e.g., production impact). The fundamental point is that second order changes are also affected by other factors (e.g., economic cycle). Thus, for both scenarios A1 and A2, the assessment seeks to reflect the existing uncertainty.

5. CONCLUSION

The result of the assessment of the economic, environmental and social impact has been expressed in qualitative terms, without monetary values.

5.1. OVERALL IMPACT ASSESSMENT

According to the assessment, the effects of the pest will be significant at both the economic and the environmental level (20-49.9%), the effects on the domestic market will be within the range from moderate to significant (5-49.9%), while external markets could be significantly affected by the pest (20-100%). In the case of environmental variables, mild effects are expected (0-4.9%) for impacts on native species, protected natural areas, and environmental restoration. In addition, a high level of uncertainty was identified for the social effects of the pest, which could increase the level of risk.

Comparing the scenarios A1 and A2 (pest without control and pest controlled), a decrease is found in estimated impacts when pest control is established. This conclusion does not apply to social impacts, in which a high level of uncertainty persists, with and without control (scenario A1 and A2).

5.2. GENERAL ASSESSMENT OF UNCERTAINTY

The analysis found that the level of uncertainty increased as a larger number of dimensions were considered. For example, there is uncertainty at the level of production impact; however, such uncertainty is less than that associated with economic impacts, and these in turn involve less uncertainty than that associated with socioenvironmental impacts. The details of each of the dimensions analyzed are presented below.

Impacts on production:

- The high number of *B. dorsalis* host species, is contrasted with the species for which there are studies on the damage generated, which generates uncertainty about those species that are truly capable of sustaining the pest, under natural conditions. There is a significant degree of uncertainty regarding the susceptibility of a broad list of species that qualify as hosts.
- The literature describes percentages of losses caused by *B. dorsalis* of 1-86% for mango and 19-80% for guava (see Table 3), which may indicate a high level of uncertainty regarding the variability of the data. However, more accurate data are recorded for the losses caused by another fly, *Anastrepha ludens,* in citrus and mango, which may be due to more research on this pest. These data differences are considered a source of uncertainty.

Economic impacts:

- In relation to chemical control, there is no certainty about the level of preferences for different insecticides. One of the most toxic but more commonly used ones is malathion. There are more environmentally friendly options, such as spinosad. We work in the worst-case scenario, with a high level of uncertainty about the current control measures implemented by each COSAVE member country.

- Regarding the effect of the pest on domestic markets, there is a high level of uncertainty because there is no evidence to quantify changes in consumer preferences and, therefore, how consumer demand could change.

Socioenvironmental impact

- The level of susceptibility and vulnerability of native species within the COSAVE region is unknown, there is also uncertainty about the likelihood of native species being affected as the pest is not currently present in the habitat of the native species.
- There is no information about the species present in the protected areas and their level of susceptibility to the action of the pest. Due to this lack of information, it is not possible to estimate the impact of the pest on natural areas that are used for tourism/recreational purposes.
- High uncertainty results from the lack of data to quantify changes in variables such as employment, level of migration based on changes in production impact, confidence in the NPPO, and health impacts, since there are other factors that could affect these variables, thus hindering identification of specific pest impacts.

5.3. CONCLUSION REGARDING THE AREAS IN DANGER

The area in danger is that part of the PRA area where ecological conditions and other conditions favor the establishment of a pest whose presence will result in economically important losses. To define the area in danger, the results of the assessments of potential distribution and potential impact must be considered. The area in danger can be all or a part of the PRA area.

According to the assumptions at the beginning of this assessment, the pest has the potential to establish and have economic impact in all COSAVE member countries; therefore, the area in danger covers the entire region. At this point a series of assumptions need to be established, in some cases restrictive, due to lack of specific information and the difficulties in carrying out a case study for such an extensive and diversified area as the COSAVE region.

According to the assumptions made, the likelihood of entry, establishment and spread of the pest could go from medium to high. Considering the percentages of consequences computed, the resulting level of risk is likely to be high. With this level of risk for the region, the development of a contingency plan for *B. dorsalis* is justified, with the objective of acting in an effective and timely manner in the event of pest detection in the COSAVE region, in order to apply phytosanitary measures for control and containment.

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ANNEX

Table: Evaluation Scenario

Scenarios	
1	Business as usual
2	Pest - No Policy
3	Pest - Policy

Table: Impact assessment: assumptions used and information sources

Production Impacts		
Information Source	FAO Stat	http://www.fao.org/faostat/en/#home
Cultivated area change	According to average change 2010-2016	
Yield used scenario 1	Average yield 2010-2016	
Yield used scenario 2	Assumptions from Mexico Study	http://repiica.iica.int/docs/B2041e/B2041e.pdf
Yield used scenario 3	Assumptions from Mexico Study	http://repiica.iica.int/docs/B2041e/B2041e.pdf
Production	yield * area	
Prices used	Average values 2010-2016	

Health Impacts		
1 ton of insecticides	1000 lts	
Insecticide use change	The same than area change	
Desease rate	Assumption from mexico study	http://repiica.iica.int/docs/B2041e/B2041e.pdf
VSL	Data from OCDE Meta-analysis	http://www.oecd.org/env/tools-evaluation/env-value-statistical-life.htm

Table: Host by country

Country/Host	Export Value (M USD) (avergae 2010-2016)
Argentina	
Citrus x paradisi (includes grapefruit)	1,873.3
Citrus limon and *Citrus aurantiifolia*	208,658.7
Mangifera indica, Garcinia mangostana, Psidium guajava	16.0
Citrus sinensis	36,094.4
Citrus reticulata, Citrus clementina, Citrus unshiu	72,107.9
Bolivia	
Citrus limon y Citrus aurantiifolia	1,557.9
Citrus reticulata, Citrus clementina, Citrus unshiu	0.6
Brazil	
Citrus x paradisi (includes grapefruit)	16.3
Citrus limon and *Citrus aurantiifolia*	73,552.9
Mangifera indica, Garcinia mangostana, Psidium guajava	153,749.9
Citrus sinensis	11,648.9
Citrus reticulata, Citrus clementina, Citrus unshiu	769.6
Chile	
Citrus x paradisi (includes grapefruit)	1,126.3
Citrus limon and *Citrus aurantiifolia*	61,144.6
Citrus sinensis	63,158.0
Citrus reticulata, Citrus clementina, Citrus unshiu	74,111.7
Paraguay	
Citrus sinensis	299.7
Peru	
Citrus x paradisi (includes grapefruit)	742.3
Citrus limon and *Citrus aurantiifolia*	3,434.4
Mangifera indica, Garcinia mangostana, Psidium guajava	141,130.1
Citrus sinensis	3,879.7
Citrus reticulata, Citrus clementina, Citrus unshiu	91,498.9
Uruguay	
Citrus x paradisi (includes grapefruit)	81.1
Citrus limon and *Citrus aurantiifolia*	13,628.4
Mangifera indica, Garcinia mangostana, Psidium guajava	1.4
Citrus sinensis	31,224.7
Citrus reticulata, Citrus clementina, Citrus unshiu	33,371.3

Table: Production Impacts: Evolution of cultivated areas

Country	Fruit	Area 2016 (ha)	Avge Change 2010-2016	Area 2017	Area 2018	Area 2019	Area 2020	Average Yield 2010-2016 (kg/ha)
Argentina	*Citrus x paradisi* (includes grapefruit)	4.341	-8,60%	3.967,67	3.626,45	3.314,58	3.029,53	232.154
Argentina	*Citrus limon* and *Citrus aurantifolia*	52.394	7,10%	56.113,97	60.098,07	64.365,03	68.934,95	322.597
Argentina	*Mangifera indica, Garcinia mangostana, Psidium guajava*	271	0,20%	271,54	272,09	272,63	273,17	79.598
Argentina	*Citrus sinensis*	47.823	0,50%	48.062,12	48.302,43	48.543,94	48.786,66	208.740
Argentina	*Citrus reticulata, Citrus clementina, Citrus unshiu*	41.107	3,70%	42.627,96	44.205,19	45.840,79	47.536,89	123.562
Bolivia	*Citrus x paradisi* (includes grapefruit)	435	-9,90%	391,94	353,13	318,17	286,67	94.010
Bolivia	*Citrus limon* and *Citrus aurantifolia*	4.318	8,50%	4.685,03	5.083,26	5.515,33	5.984,14	76.297
Bolivia	*Mangifera indica, Garcinia mangostana, Psidium guajava*	2.144	7%	2.294,08	2.454,67	2.626,49	2.810,35	86.389
Bolivia	*Citrus sinensis*	22.864	-0,60%	22.726,82	22.590,46	22.454,91	22.320,18	73.788
Bolivia	*Citrus reticulata, Citrus clementina, Citrus unshiu*	26.796	12,10%	30.038,32	33.672,95	37.747,38	42.314,81	80.068
Brazil	*Citrus x paradisi* (includes grapefruit)	4.495	0,80%	4.530,96	4.567,21	4.603,75	4.640,58	178.405
Brazil	*Citrus limon* and *Citrus aurantifolia*	47.279	1,80%	48.130,02	48.996,36	49.878,30	50.776,11	252.161
Brazil	*Mangifera indica, Garcinia mangostana, Psidium guajava*	78.961	2%	80.540,22	82.151,02	83.794,04	85.469,93	171.935
Brazil	*Citrus sinensis*	658.945	-2,90%	639.835,60	621.280,36	603.263,23	585.768,60	247.542
Brazil	*Citrus reticulata, Citrus clementina, Citrus unshiu*	49.232	-2,50%	48.001,20	46.801,17	45.631,14	44.490,36	193.495
Chile	*Citrus x paradisi* (includes grapefruit)	219	-4,10%	210,02	201,41	193,15	185,23	46.199
Chile	*Citrus limon* and *Citrus aurantifolia*	5.993	-2,90%	5.819,20	5.650,45	5.486,58	5.327,47	221.217
Chile	*Mangifera indica, Garcinia mangostana, Psidium guajava*	0	0	0,00	0,00	0,00	0,00	0
Chile	*Citrus sinensis*	6.766	-1,40%	6.671,28	6.577,88	6.485,79	6.394,99	184.387
Chile	*Citrus reticulata, Citrus clementina, Citrus unshiu*	4.880	5,30%	5.138,64	5.410,99	5.697,77	5.999,75	146.803
Paraguay	*Citrus x paradisi* (includes grapefruit)	1.053	1,30%	1.066,69	1.080,56	1.094,60	1.108,83	445.740
Paraguay	*Citrus limon* and *Citrus aurantifolia*	465	0,90%	469,19	473,41	477,67	481,97	202.264
Paraguay	*Mangifera indica, Garcinia mangostana, Psidium guajava*	0	0	0,00	0,00	0,00	0,00	0
Paraguay	*Citrus sinensis*	7.715	0,60%	7.761,29	7.807,86	7.854,70	7.901,83	298.216
Paraguay	*Citrus reticulata, Citrus clementina, Citrus unshiu*	1.945	0,90%	1.962,51	1.980,17	1.997,99	2.015,97	243.714
Peru	*Citrus x paradisi* (includes grapefruit)	820	3,60%	849,52	880,10	911,79	944,61	73.342
Peru	*Citrus limon* and *Citrus aurantifolia*	25.700	0,05%	25.713,62	25.727,25	25.740,88	25.754,53	114.014
Peru	*Mangifera indica, Garcinia mangostana, Psidium guajava*	23.072	-1,00%	22.841,28	22.612,87	22.386,74	22.162,87	131.849
Peru	*Citrus sinensis*	30.860	2,60%	31.662,36	32.485,58	33.330,21	34.196,79	156.979
Peru	*Citrus reticulata, Citrus clementina, Citrus unshiu*	14.666	5,60%	15.487,30	16.354,58	17.270,44	18.237,59	242.277
Uruguay	*Citrus x paradisi* (includes grapefruit)	85	-9,30%	77,10	69,93	63,42	57,52	112.101
Uruguay	*Citrus limon* and *Citrus aurantifolia*	1.585	-2,40%	1.546,96	1.509,83	1.473,60	1.438,23	226.288
Uruguay	*Mangifera indica, Garcinia mangostana, Psidium guajava*	4.198	1%	4.239,98	4.282,38	4.325,20	4.368,46	76.579
Uruguay	*Citrus sinensis*	7.418	-1,10%	7.336,40	7.255,70	7.175,89	7.096,95	183.872
Uruguay	*Citrus reticulata, Citrus clementina, Citrus unshiu*	5.760	-1,90%	5.650,56	5.543,20	5.437,88	5.334,56	176.533

Table: Production Impacts: Evolution of production levels (without the pest)

Country	Fruit	Yield Change 1	Production 2017 (t)	Production 2018 (t)	Production 2019 (t)	Production 2020 (t)
Argentina	*Citrus x paradisi* (includes grapefruit)	0	921.111,39	841.895,81	769.492,77	703.316,39
Argentina	*Citrus limon* and *Citrus aurantifolia*	0	18.102.177,22	19.387.431,81	20.763.939,47	22.238.179,17
Argentina	*Mangifera indica, Garcinia mangostana, Psidium guajava*	0	21.614,31	21.657,54	21.700,85	21.744,25
Argentina	*Citrus sinensis*	0	10.032.485,89	10.082.648,31	10.133.061,56	10.183.726,86
Argentina	*Citrus reticulata, Citrus clementina, Citrus unshiu*	0	5.267.191,61	5.462.077,70	5.664.174,57	5.873.749,03
Bolivia	*Citrus x paradisi* (includes grapefruit)	0	36.845,81	33.198,07	29.911,46	26.950,23
Bolivia	*Citrus limon* and *Citrus aurantifolia*	0	357.454,20	387.837,81	420.804,02	456.572,37
Bolivia	*Mangifera indica, Garcinia mangostana, Psidium guajava*	0	198.183,05	212.055,86	226.899,77	242.782,76
Bolivia	*Citrus sinensis*	0	1.676.975,39	1.666.913,54	1.656.912,06	1.646.970,58
Bolivia	*Citrus reticulata, Citrus clementina, Citrus unshiu*	0	2.405.095,87	2.696.112,47	3.022.342,08	3.388.045,47
Brazil	*Citrus x paradisi* (includes grapefruit)	0	808.347,28	814.814,06	821.332,57	827.903,23
Brazil	*Citrus limon* and *Citrus aurantifolia*	0	12.136.533,73	12.354.991,34	12.577.381,18	12.803.774,04
Brazil	*Mangifera indica, Garcinia mangostana, Psidium guajava*	0	13.847.674,67	14.124.628,17	14.407.120,73	14.695.263,14
Brazil	*Citrus sinensis*	0	158.386.246,84	153.793.045,68	149.333.047,36	145.002.388,98
Brazil	*Citrus reticulata, Citrus clementina, Citrus unshiu*	0	9.287.992,19	9.055.792,39	8.829.397,58	8.608.662,64
Chile	*Citrus x paradisi* (includes grapefruit)	0	9.702,76	9.304,95	8.923,44	8.557,58
Chile	*Citrus limon* and *Citrus aurantifolia*	0	1.287.308,96	1.249.977,00	1.213.727,67	1.178.529,56
Chile	*Mangifera indica, Garcinia mangostana, Psidium guajava*	0	0,00	0,00	0,00	0,00
Chile	*Citrus sinensis*	0	1.230.094,57	1.212.873,24	1.195.893,02	1.179.150,51
Chile	*Citrus reticulata, Citrus clementina, Citrus unshiu*	0	754.369,82	794.351,42	836.452,05	880.784,01
Paraguay	*Citrus x paradisi* (includes grapefruit)	0	475.465,53	481.646,58	487.907,99	494.250,79
Paraguay	*Citrus limon* and *Citrus aurantifolia*	0	94.899,42	95.753,52	96.615,30	97.484,84
Paraguay	*Mangifera indica, Garcinia mangostana, Psidium guajava*	0	0,00	0,00	0,00	0,00
Paraguay	*Citrus sinensis*	0	2.314.540,86	2.328.428,10	2.342.398,67	2.356.453,06
Paraguay	*Citrus reticulata, Citrus clementina, Citrus unshiu*	0	478.290,73	482.595,35	486.938,70	491.321,15
Peru	*Citrus x paradisi* (includes grapefruit)	0	62.305,86	64.548,87	66.872,63	69.280,04
Peru	*Citrus limon* and *Citrus aurantifolia*	0	2.931.705,44	2.933.259,24	2.934.813,87	2.936.369,32
Peru	*Mangifera indica, Garcinia mangostana, Psidium guajava*	0	3.011.599,93	2.981.483,93	2.951.669,09	2.922.152,40
Peru	*Citrus sinensis*	0	4.970.321,09	5.099.549,44	5.232.137,72	5.368.173,30
Peru	*Citrus reticulata, Citrus clementina, Citrus unshiu*	0	3.752.215,61	3.962.339,69	4.184.230,71	4.418.547,63
Uruguay	*Citrus x paradisi* (includes grapefruit)	0	8.642,40	7.838,66	7.109,66	6.448,47
Uruguay	*Citrus limon* and *Citrus aurantifolia*	0	350.058,95	341.657,53	333.457,75	325.454,77
Uruguay	*Mangifera indica, Garcinia mangostana, Psidium guajava*	0	324.695,12	327.942,08	331.221,50	334.533,71
Uruguay	*Citrus sinensis*	0	1.348.956,71	1.334.118,18	1.319.442,88	1.304.929,01
Uruguay	*Citrus reticulata, Citrus clementina, Citrus unshiu*	0	997.508,05	978.555,40	959.962,84	941.723,55

Table: Production Impacts: Evolution of production levels (with the presence of the pest, without control)

Country	Fruit	Yield Change 2 Pest -no policy	Yield 2	Production 2017 (t)	Production 2018 (t)	Production 2019 (t)	Production 2020 (t)
Argentina	*Citrus x paradisi* (includes grapefruit)	-10%	208.939	829.000	757.706	692.543	632.985
Argentina	*Citrus limon* and *Citrus aurantifolia*	-10,5%	288.724	16.201.449	17.351.751	18.583.726	19.903.170
Argentina	*Mangifera indica, Garcinia mangostana, Psidium guajava*	-20%	63.679	17.291	17.326	17.361	17.395
Argentina	*Citrus sinensis*	-10,5%	186.822	8.979.075	9.023.970	9.069.090	9.114.436
Argentina	*Citrus reticulata, Citrus clementina, Citrus unshiu*	-10%	111.206	4.740.472	4.915.870	5.097.757	5.286.374
Bolivia	*Citrus x paradisi* (includes grapefruit)	-10%	84.609	33.161	29.878	26.920	24.255
Bolivia	*Citrus limon* and *Citrus aurantifolia*	10,5%	84.308	394.987	428.561	464.988	504.512
Bolivia	*Mangifera indica, Garcinia mangostana, Psidium guajava*	-20%	69.111	158.546	169.645	181.520	194.226
Bolivia	*Citrus sinensis*	-10,5%	66.041	1.500.893	1.491.888	1.482.936	1.474.039
Bolivia	*Citrus reticulata, Citrus clementina, Citrus unshiu*	-10%	72.061	2.164.586	2.426.501	2.720.108	3.049.241
Brazil	*Citrus x paradisi* (includes grapefruit)	-10%	160.565	727.513	733.333	739.199	745.113
Brazil	*Citrus limon* and *Citrus aurantifolia*	10,5%	278.638	13.410.870	13.652.265	13.898.006	14.148.170
Brazil	*Mangifera indica, Garcinia mangostana, Psidium guajava*	-20%	137.548	11.078.140	11.299.703	11.525.697	11.756.211
Brazil	*Citrus sinensis*	-10,5%	221.550	141.755.691	137.644.776	133.653.077	129.777.138
Brazil	*Citrus reticulata, Citrus clementina, Citrus unshiu*	-10%	174.146	8.359.193	8.150.213	7.946.458	7.747.796
Chile	*Citrus x paradisi* (includes grapefruit)	-10%	41.579	8.732	8.374	8.031	7.702
Chile	*Citrus limon* and *Citrus aurantifolia*	10,5%	244.445	1.422.476	1.381.225	1.341.169	1.302.275
Chile	*Mangifera indica, Garcinia mangostana, Psidium guajava*	-20%	0	0	0	0	0
Chile	*Citrus sinensis*	-10,5%	165.026	1.100.935	1.085.522	1.070.324	1.055.340
Chile	*Citrus reticulata, Citrus clementina, Citrus unshiu*	-10%	132.123	678.933	714.916	752.807	792.706
Paraguay	*Citrus x paradisi* (includes grapefruit)	-10%	401.166	427.919	433.482	439.117	444.826
Paraguay	*Citrus limon* and *Citrus aurantifolia*	10,5%	223.502	104.864	105.808	106.760	107.721
Paraguay	*Mangifera indica, Garcinia mangostana, Psidium guajava*	-20%	0	0	0	0	0
Paraguay	*Citrus sinensis*	-10,5%	266.903	2.071.514	2.083.943	2.096.447	2.109.025
Paraguay	*Citrus reticulata, Citrus clementina, Citrus unshiu*	-10%	219.343	430.462	434.336	438.245	442.189
Peru	*Citrus x paradisi* (includes grapefruit)	-10%	66.008	56.075	58.094	60.185	62.352
Peru	*Citrus limon* and *Citrus aurantifolia*	10,5%	125.985	3.239.535	3.241.251	3.242.969	3.244.688
Peru	*Mangifera indica, Garcinia mangostana, Psidium guajava*	-20%	105.479	2.409.280	2.385.187	2.361.335	2.337.722
Peru	*Citrus sinensis*	-10,5%	140.496	4.448.437	4.564.097	4.682.763	4.804.515
Peru	*Citrus reticulata, Citrus clementina, Citrus unshiu*	-10%	218.049	3.376.994	3.566.106	3.765.808	3.976.693
Uruguay	*Citrus x paradisi* (includes grapefruit)	-10%	100.891	7.778	7.055	6.399	5.804
Uruguay	*Citrus limon* and *Citrus aurantifolia*	10,5%	250.049	386.815	377.532	368.471	359.628
Uruguay	*Mangifera indica, Garcinia mangostana, Psidium guajava*	-20%	61.264	259.756	262.354	264.977	267.627
Uruguay	*Citrus sinensis*	-10,5%	164.565	1.207.316	1.194.036	1.180.901	1.167.911
Uruguay	*Citrus reticulata, Citrus clementina, Citrus unshiu*	-10%	158.879	897.757	880.700	863.967	847.551

Table: Production Impacts: Evolution of production levels (with the presence of the pest, with control)

Country	Fruit	Yield Change 3 Pest-policy	Yiled 3	Production 2017 (t)	Production 2018 (t)	Production 2019 (t)	Production 2020 (t)
Argentina	*Citrus x paradisi* (includes grapefruit)	-1%	229.832	911.900,28	833.476,85	761.797,84	696.283,23
Argentina	*Citrus limon* and *Citrus aurantifolia*	2%	329.049	18.464.220,77	19.775.180,44	21.179.218,26	22.682.942,75
Argentina	*Mangifera indica, Garcinia mangostana, Psidium guajava*	-8%	73.629	19.993,24	20.033,22	20.073,29	20.113,44
Argentina	*Citrus sinensis*	-2%	204.565	9.831.836,17	9.880.995,35	9.930.400,32	9.980.052,33
Argentina	*Citrus reticulata, Citrus clementina, Citrus unshiu*	-1%	122.326	5.214.519,69	5.407.456,92	5.607.532,83	5.815.011,54
Bolivia	*Citrus x paradisi* (includes grapefruit)	-1%	93.070	36.477,35	32.866,09	29.612,35	26.680,73
Bolivia	*Citrus limon* and *Citrus aurantifolia*	-10%	68.667	321.708,78	349.054,03	378.723,62	410.915,13
Bolivia	*Mangifera indica, Garcinia mangostana, Psidium guajava*	-8%	79.910	183.319,32	196.151,67	209.882,29	224.574,05
Bolivia	*Citrus sinensis*	-2%	72.313	1.643.435,88	1.633.575,27	1.623.773,82	1.614.031,17
Bolivia	*Citrus reticulata, Citrus clementina, Citrus unshiu*	-1%	79.267	2.381.044,91	2.669.151,35	2.992.118,66	3.354.165,02
Brazil	*Citrus x paradisi* (includes grapefruit)	-1%	176.621	800.263,81	806.665,92	813.119,24	819.624,20
Brazil	*Citrus limon* and *Citrus aurantifolia*	-10%	226.945	10.922.880,36	11.119.492,20	11.319.643,06	11.523.396,64
Brazil	*Mangifera indica, Garcinia mangostana, Psidium guajava*	-8%	159.040	12.809.099,07	13.065.281,05	13.326.586,67	13.593.118,41
Brazil	*Citrus sinensis*	-2%	242.591	155.218.521,90	150.717.184,77	146.346.386,41	142.102.341,20
Brazil	*Citrus reticulata, Citrus clementina, Citrus unshiu*	-1%	191.560	9.195.112,27	8.965.234,47	8.741.103,60	8.522.576,01
Chile	*Citrus x paradisi* (includes grapefruit)	-1%	45.737	9.605,73	9.211,90	8.834,21	8.472,01
Chile	*Citrus limon* and *Citrus aurantifolia*	-10%	199.096	1.158.578,06	1.124.979,30	1.092.354,90	1.060.676,61
Chile	*Mangifera indica, Garcinia mangostana, Psidium guajava*	-8%	0	0,00	0,00	0,00	0,00
Chile	*Citrus sinensis*	-2%	180.699	1.205.492,68	1.188.615,78	1.171.975,16	1.155.567,50
Chile	*Citrus reticulata, Citrus clementina, Citrus unshiu*	-1%	145.335	746.826,13	786.407,91	828.087,53	871.976,17
Paraguay	*Citrus x paradisi* (includes grapefruit)	-1%	441.282	470.710,87	476.830,11	483.028,91	489.308,28
Paraguay	*Citrus limon* and *Citrus aurantifolia*	-10%	182.038	85.409,48	86.178,17	86.953,77	87.736,35
Paraguay	*Mangifera indica, Garcinia mangostana, Psidium guajava*	-8%	0	0,00	0,00	0,00	0,00
Paraguay	*Citrus sinensis*	-2%	292.252	2.268.250,04	2.281.859,54	2.295.550,70	2.309.324,00
Paraguay	*Citrus reticulata, Citrus clementina, Citrus unshiu*	-1%	241.277	473.507,82	477.769,39	482.069,32	486.407,94
Peru	*Citrus x paradisi* (includes grapefruit)	-1%	72.609	61.682,80	63.903,38	66.203,90	68.587,24
Peru	*Citrus limon* and *Citrus aurantifolia*	-10%	102.612	2.638.534,89	2.639.933,32	2.641.332,48	2.642.732,39
Peru	*Mangifera indica, Garcinia mangostana, Psidium guajava*	-8%	121.960	2.785.729,93	2.757.872,63	2.730.293,91	2.702.990,97
Peru	*Citrus sinensis*	-2%	153.839	4.870.914,67	4.997.558,45	5.127.494,97	5.260.809,84
Peru	*Citrus reticulata, Citrus clementina, Citrus unshiu*	-1%	239.854	3.714.693,46	3.922.716,29	4.142.388,40	4.374.362,15
Uruguay	*Citrus x paradisi* (includes grapefruit)	-1%	110.980	8.555,98	7.760,27	7.038,57	6.383,98
Uruguay	*Citrus limon* and *Citrus aurantifolia*	-10%	203.659	315.053,05	307.491,78	300.111,98	292.909,29
Uruguay	*Mangifera indica, Garcinia mangostana, Psidium guajava*	-8%	70.836	300.342,99	303.346,42	306.379,88	309.443,68
Uruguay	*Citrus sinensis*	-2%	180.194	1.321.977,57	1.307.435,82	1.293.054,03	1.278.830,43
Uruguay	*Citrus reticulata, Citrus clementina, Citrus unshiu*	-1%	174.767	987.532,97	968.769,84	950.363,21	932.306,31

Table: Production Impacts: Evolution of production value (without the pest)

Country	Fruit	Producer Price Avge USD/ton 2010-2016	Production Value 2017 (MM USD)	Production Value 2018 (MM USD)	Production Value 2019 (MM USD)	Production Value 2020 (MM USD)
Argentina	*Citrus x paradisi* (includes grapefruit)	142,0	131	120	109	100
Argentina	*Citrus limon* and *Citrus aurantifolia*	148,0	2.679	2.869	3.072	3.291
Argentina	*Mangifera indica, Garcinia mangostana, Psidium guajava*	139,8	3	3	3	3
Argentina	*Citrus sinensis*	101,2	1.015	1.021	1.026	1.031
Argentina	*Citrus reticulata, Citrus clementina, Citrus unshiu*	146,5	772	800	830	861
Bolivia	*Citrus x paradisi* (includes grapefruit)	144,0	5	5	4	4
Bolivia	*Citrus limon* and *Citrus aurantifolia*	317,4	113	123	134	145
Bolivia	*Mangifera indica, Garcinia mangostana, Psidium guajava*	284,5	56	60	65	69
Bolivia	*Citrus sinensis*	139,9	235	233	232	230
Bolivia	*Citrus reticulata, Citrus clementina, Citrus unshiu*	227,5	547	613	688	771
Brazil	*Citrus x paradisi* (includes grapefruit)	154,8	125	126	127	128
Brazil	*Citrus limon* and *Citrus aurantifolia*	220,7	2.678	2.726	2.775	2.825
Brazil	*Mangifera indica, Garcinia mangostana, Psidium guajava*	296,4	4.104	4.187	4.270	4.356
Brazil	*Citrus sinensis*	167,9	26.600	25.828	25.079	24.352
Brazil	*Citrus reticulata, Citrus clementina, Citrus unshiu*	251,4	2.335	2.276	2.219	2.164
Chile	*Citrus x paradisi* (includes grapefruit)	666,9	6	6	6	6
Chile	*Citrus limon* and *Citrus aurantifolia*	638,5	822	798	775	752
Chile	*Mangifera indica, Garcinia mangostana, Psidium guajava*	0,0	0	0	0	0
Chile	*Citrus sinensis*	522,1	642	633	624	616
Chile	*Citrus reticulata, Citrus clementina, Citrus unshiu*	813,2	613	646	680	716
Paraguay	*Citrus x paradisi* (includes grapefruit)	107,2	51	52	52	53
Paraguay	*Citrus limon* and *Citrus aurantifolia*	229,4	22	22	22	22
Paraguay	*Mangifera indica, Garcinia mangostana, Psidium guajava*	154,2	0	0	0	0
Paraguay	*Citrus sinensis*	295,9	685	689	693	697
Paraguay	*Citrus reticulata, Citrus clementina, Citrus unshiu*	214,5	103	104	104	105
Peru	*Citrus x paradisi* (includes grapefruit)	179,5	11	12	12	12
Peru	*Citrus limon* and *Citrus aurantifolia*	297,0	871	871	872	872
Peru	*Mangifera indica, Garcinia mangostana, Psidium guajava*	181,0	545	540	534	529
Peru	*Citrus sinensis*	192,2	955	980	1.006	1.032
Peru	*Citrus reticulata, Citrus clementina, Citrus unshiu*	355,3	1.333	1.408	1.487	1.570
Uruguay	*Citrus x paradisi* (includes grapefruit)	687,4	6	5	5	4
Uruguay	*Citrus limon* and *Citrus aurantifolia*	736,6	258	252	246	240
Uruguay	*Mangifera indica, Garcinia mangostana, Psidium guajava*	0,0	0	0	0	0
Uruguay	*Citrus sinensis*	505,8	682	675	667	660
Uruguay	*Citrus reticulata, Citrus clementina, Citrus unshiu*	630,5	629	617	605	594

Table: Production Impacts: Evolution of production value (with the presence of the pest, without control)

Country	Fruit	Production Value 2017 (MM USD)	Production Value 2018 (MM USD)	Production Value 2019 (MM USD)	Production Value 2020 (MM USD)
Argentina	*Citrus x paradisi* (includes grapefruit)	118	108	98	90
Argentina	*Citrus limon* and *Citrus aurantifolia*	2.397	2.568	2.750	2.945
Argentina	*Mangifera indica, Garcinia mangostana, Psidium guajava*	2	2	2	2
Argentina	*Citrus sinensis*	909	913	918	923
Argentina	*Citrus reticulata, Citrus clementina, Citrus unshiu*	695	720	747	775
Bolivia	*Citrus x paradisi* (includes grapefruit)	5	4	4	3
Bolivia	*Citrus limon* and *Citrus aurantifolia*	125	136	148	160
Bolivia	*Mangifera indica, Garcinia mangostana, Psidium guajava*	45	48	52	55
Bolivia	*Citrus sinensis*	210	209	208	206
Bolivia	*Citrus reticulata, Citrus clementina, Citrus unshiu*	493	552	619	694
Brazil	*Citrus x paradisi* (includes grapefruit)	113	114	114	115
Brazil	*Citrus limon* and *Citrus aurantifolia*	2.959	3.013	3.067	3.122
Brazil	*Mangifera indica, Garcinia mangostana, Psidium guajava*	3.284	3.349	3.416	3.485
Brazil	*Citrus sinensis*	23.807	23.116	22.446	21.795
Brazil	*Citrus reticulata, Citrus clementina, Citrus unshiu*	2.101	2.049	1.998	1.948
Chile	*Citrus x paradisi* (includes grapefruit)	6	6	5	5
Chile	*Citrus limon* and *Citrus aurantifolia*	908	882	856	831
Chile	*Mangifera indica, Garcinia mangostana, Psidium guajava*	0	0	0	0
Chile	*Citrus sinensis*	575	567	559	551
Chile	*Citrus reticulata, Citrus clementina, Citrus unshiu*	552	581	612	645
Paraguay	*Citrus x paradisi* (includes grapefruit)	46	46	47	48
Paraguay	*Citrus limon* and *Citrus aurantifolia*	24	24	24	25
Paraguay	*Mangifera indica, Garcinia mangostana, Psidium guajava*	0	0	0	0
Paraguay	*Citrus sinensis*	613	617	620	624
Paraguay	*Citrus reticulata, Citrus clementina, Citrus unshiu*	92	93	94	95
Peru	*Citrus x paradisi* (includes grapefruit)	10	10	11	11
Peru	*Citrus limon* and *Citrus aurantifolia*	962	963	963	964
Peru	*Mangifera indica, Garcinia mangostana, Psidium guajava*	436	432	427	423
Peru	*Citrus sinensis*	855	877	900	924
Peru	*Citrus reticulata, Citrus clementina, Citrus unshiu*	1.200	1.267	1.338	1.413
Uruguay	*Citrus x paradisi* (includes grapefruit)	5	5	4	4
Uruguay	*Citrus limon* and *Citrus aurantifolia*	285	278	271	265
Uruguay	*Mangifera indica, Garcinia mangostana, Psidium guajava*	0	0	0	0
Uruguay	*Citrus sinensis*	611	604	597	591
Uruguay	*Citrus reticulata, Citrus clementina, Citrus unshiu*	566	555	545	534

Table: Production Impacts: Evolution of production value (with the presence of the pest, with control)

Country	Fruit	Production Value 2017 (MM USD)	Production Value 2018 (MM USD)	Production Value 2019 (MM USD)	Production Value 2020 (MM USD)
Argentina	*Citrus x paradisi* (includes grapefruit)	129	118	108	99
Argentina	*Citrus limon* and *Citrus aurantifolia*	2.732	2.926	3.134	3.356
Argentina	*Mangifera indica, Garcinia mangostana, Psidium guajava*	3	3	3	3
Argentina	*Citrus sinensis*	995	1.000	1.005	1.010
Argentina	*Citrus reticulata, Citrus clementina, Citrus unshiu*	764	792	822	852
Bolivia	*Citrus x paradisi* (includes grapefruit)	5	5	4	4
Bolivia	*Citrus limon* and *Citrus aurantifolia*	102	111	120	130
Bolivia	*Mangifera indica, Garcinia mangostana, Psidium guajava*	52	56	60	64
Bolivia	*Citrus sinensis*	230	229	227	226
Bolivia	*Citrus reticulata, Citrus clementina, Citrus unshiu*	542	607	681	763
Brazil	*Citrus x paradisi* (includes grapefruit)	124	125	126	127
Brazil	*Citrus limon* and *Citrus aurantifolia*	2.410	2.454	2.498	2.543
Brazil	*Mangifera indica, Garcinia mangostana, Psidium guajava*	3.797	3.873	3.950	4.029
Brazil	*Citrus sinensis*	26.068	25.312	24.578	23.865
Brazil	*Citrus reticulata, Citrus clementina, Citrus unshiu*	2.311	2.254	2.197	2.142
Chile	*Citrus x paradisi* (includes grapefruit)	6	6	6	6
Chile	*Citrus limon* and *Citrus aurantifolia*	740	718	697	677
Chile	*Mangifera indica, Garcinia mangostana, Psidium guajava*	0	0	0	0
Chile	*Citrus sinensis*	629	621	612	603
Chile	*Citrus reticulata, Citrus clementina, Citrus unshiu*	607	639	673	709
Paraguay	*Citrus x paradisi* (includes grapefruit)	50	51	52	52
Paraguay	*Citrus limon* and *Citrus aurantifolia*	20	20	20	20
Paraguay	*Mangifera indica, Garcinia mangostana, Psidium guajava*	0	0	0	0
Paraguay	*Citrus sinensis*	671	675	679	683
Paraguay	*Citrus reticulata, Citrus clementina, Citrus unshiu*	102	102	103	104
Peru	*Citrus x paradisi* (includes grapefruit)	11	11	12	12
Peru	*Citrus limon* and *Citrus aurantifolia*	784	784	784	785
Peru	*Mangifera indica, Garcinia mangostana, Psidium guajava*	504	499	494	489
Peru	*Citrus sinensis*	936	961	986	1.011
Peru	*Citrus reticulata, Citrus clementina, Citrus unshiu*	1.320	1.394	1.472	1.554
Uruguay	*Citrus x paradisi* (includes grapefruit)	6	5	5	4
Uruguay	*Citrus limon* and *Citrus aurantifolia*	232	226	221	216
Uruguay	*Mangifera indica, Garcinia mangostana, Psidium guajava*	0	0	0	0
Uruguay	*Citrus sinensis*	669	661	654	647
Uruguay	*Citrus reticulata, Citrus clementina, Citrus unshiu*	623	611	599	588

Table: Health Impacts: Assumptions and Affected Population

Country	Area 2016	Dosis	Insecticides Use 2016 (lts)	Use Change (the same that area change)
Argentina	145.936	1,5	218.904	0,6%
Bolivia	56.557	1,5	84.836	3%
Brazil	838.912	1,5	1.258.368	0%
Chile	17.858	1,5	26.787	-1%
Paraguay	11.178	1,5	16.767	1%
Peru	95.118	1,5	142.677	2%
Uruguay	19.046	1,5	28.569	-3%

Country	Insecticides use 2017 (lts)	Insecticides use 2018 (lts)	Insecticides use 2019 (lts)	Insecticides use 2020 (lts)
Argentina	220.174	221.451	222.735	224.027
Bolivia	87.737	90.737	93.841	97.050
Brazil	1.256.355	1.254.344	1.252.337	1.250.334
Chile	26.621	26.456	26.292	26.129
Paraguay	16.891	17.016	17.142	17.269
Peru	145.774	148.938	152.171	155.474
Uruguay	27.786	27.025	26.284	25.564

Country	Desaease Rate	Affected Population 2017 (persons)	Affected Population 2018 (persons)	Affected Population 2019 (persons)	Affected Population 2020 (persons)
Argentina	5,15	1.134	1.140	1.147	1.154
Bolivia	5,15	452	467	483	500
Brazil	5,15	6.470	6.460	6.450	6.439
Chile	5,15	137	136	135	135
Paraguay	5,15	87	88	88	89
Peru	5,15	751	767	784	801
Uruguay	6,15	171	166	162	157