# ECONOMIC IMPACTS OF HUANGLONGBING DISEASE IN SÃO PAULO STATE

**Sílvia Helena Galvão de Miranda**
ESALQ-USP, Piracicaba – SP, Brazil
E-mail: shgdmira@usp.br

**Andréia Cristina de Oliveira Adami**
CEPEA/ESALQ-USP, Piracicaba – SP, Brazil
E-mail: adami@cepea.org.br

**Renato Beozzo Bassanezi**
Fundecitrus, Araraquara- SP, Brazil
E-mail: rbbassanezi@fundecitrus.com.br

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# ECONOMIC IMPACTS OF HUANGLONGBING DISEASE IN SÃO PAULO STATE[1]


## ABSTRACT

The main objective of this paper is to estimate the potential impacts of the increasing dissemination of the Huanglongbing (HLB) disease in citrus orchards in São Paulo State, Brazil, which is the largest world producer of orange juice and to discuss the importance of phytosanitary programs in order to control the disease's spreading in the territory. The methodology applied to evaluate the impacts and to discuss the importance of phytossanitary programs is the Cost-Benefit Analysis approach. A model has been used to project the orchard size and production along 20 years as well as to estimate the costs of production and disease control for the same period. Some assumptions have been made about the disease spread, prices and other variables for two basic scenarios: one considering the presence of an official phytosanitary program to eradicate and control the HLB, jointly implemented by Fundecitrus, which is a private institution; and the second one without the official program. The revenues for each scenario have been estimated and accumulated for 20 years, likewise the costs. The losses caused by the HLB considered to evaluate the avoided losses in the scenarios comprised basically those related to production reduction (yield) and reduction of the orchards' size. Cost-benefit ratios have been calculated for both scenarios. Regarding the CBA results for economic impacts, we found that for each Real invested by government and by Fundecitrus in the phytosanitary program, there is an avoided loss that amounts to R$ 57.3, which consists on a very high benefit-cost ratio for this kind of investment. When the additional costs imposed to farmers to manage the HLB is computed in the CBA analysis, the ratio falls to 4.6, however it is still higher than one, indicating that this phytosanitary "investment" is recommendable. Despite criticisms on this approach and the assumptions made, it provides elements to decision making, for both public and private actors and it allows having some approximation of impacts. Estimating those impacts is relevant to prove policy makers that phytosanitary policy has a high net benefit for society. It is worth-mentioning that other economic and social losses might be incorporated in the analysis.



**KEY-WORDS: Citrus, Benefit-Cost Analysis, phytosanitary program, Brazil**


## 1- INTRODUCTION

This paper aims to estimate the potential impacts of the increasing dissemination of the Huanglongbing (HLB) disease in citrus orchards in São Paulo State, Brazil, which is the largest world producer of orange juice. A second goal is to highlight the importance of phytosanitary programs in order to control the disease's spreading in the territory.

In December 2009 there was a drastic change in the implementation of phytosanitary controls in the State. Until this time, São Paulo State had a program to control and eradicate the

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HLB conducted jointly by the official state agency partnership with Fundecitrus – Fundo de Defesa da Citricultura, and supported also by the Ministry of Agriculture. Fundecitrus conducted the inspections in the citrus orchards and monitored the suppression of diseased plants until that month. Since this change, the role of inspecting and eradicating has been left only to the own producer, relying on the State and Federal regulation. Additionally, the State government committed to organize a specific commission to keep track of the disease's issue in replacement of the previous agreement.

Consequently, São Paulo State has faced an increase of HLB (or Greening) incidence and the sustainability of this sector has become a concern. In Brazil, the HLB was first reported in March 2004, in Araraquara, in the center region of São Paulo State. Later, in October 2004, the HLB infection reached in average 3.4 percent of blocks in the State. In 2010, Fundecitrus sampling pointed 38.8 percent of blocks with at least one symptomatic plant and 1.9 percent of infected trees in São Paulo. Finally, in the last survey, in August 2011, blocks and trees infected reached, respectively, 53.4 and 3.78 percent.

This paper was conducted by applying the Cost-Benefit Analysis (CBA) tool to evaluate the current and projected impacts of HLB. The base year is 2009 and scenarios last for 20 years, which is the life expectation of citrus orchards in the State. The CBA allows analyzing losses and benefits of a certain scenario and comparing different scenarios in terms of their benefit/cost ratios. Economic impacts are the focus of this analysis, although we know that social and environmental effects also are relevant regarding the disease dissemination and its control.

In order to analyze the impacts, the benefits are measured by avoided losses, similarly to Vo and Miller (1995)'s approach. It means that benefits are quantified according to the difference between the revenues of citrus sector in different scenarios: scenario of HLB free dissemination causing increasing damages and, alternatively, the scenario of disease´s control. In the other hand, the costs are measured by the expenses of government and Fundecitrus with the phytosanitary program to control and eradicate HLB, as well as by the private outgoings (particularly from producers) to follow the regulation to control and eradicate HLB.

This approach is useful to give support to policy makers and private agents' decisions because it allows comparing different scenarios in terms of costs and benefits (Miranda et al, 2009). In the United States (Spreen et al, 2007) and Mexico (Salcedo et al, 2011), there have been also studies regarding the HLB dissemination and its impacts.

The application of CBA to assess sanitary and phytosanitary policies has been used before, associated with other analytical tools in Economics. Áragon (2003) highlights that this approach can be used to determine social and economic impacts of a project and some studies may illustrate this use. Rautapaa (1984), apud Macleod (2006), examined the benefits and costs of keeping Finland free of *Liriomyza trifolii*, which attacks leaves of chrysanthemum; and Pemberton (1988) that studied benefits and costs of eradicating the bacterium *Clavibacter michiganensis* ssp. *sependonicus*, responsible to transmit the Ring spot in potatoes.

In the United States, the CBA has been applied to support government decisions on sanitary policy. Vo and Muller (1995) applied the CBA to evaluate the potentiality of dissemination and impacts of fruit-fly (*Bactrocera carambolae*) in the United States and in Central America. Another interesting example is the study of the United States Department of Agriculture (USDA) to estimate effects of Japanese requirements to import apples over the USA and Japan bilateral trade, which also counted on the use of more sophisticated economic models as well (Calvin e Krissoff, 1998). More recently, Jetter et al (2000) applied the benefit-cost analysis to evaluate the Citrus Canker in California.

In Brazil, the first literature register in using CBA to sanitary issues is provided by a research report (Miranda et al, 2010), which calculated the cost/benefit ratio of federal sanitary programs for three important cases: the Program of Control and Eradication for *Bactrocera carambolae* for fruits; the Program of Prevention for Avian Influenza; and the Program to Control and Eradicate HLB in São Paulo.

According to Spreen et al. (2007), the HLB has important consequences for orange production and for prices of juice in the international market. This disease reduces yield, jeopardizes the reforming of orchards and increases costs of production because it increases defensive applications. Besides those direct effects, some indirect impacts can be forecast, such as environmental and health problems (because of intensive use of chemicals and contamination risks), social impacts due to changes in the production system and due to replacement of orchards by other crops that are not necessarily labor-intensive as fruits production.

Currently, HLB is present in São Paulo State and in South of Minas Gerais State and North and Northeastern of Paraná State. The Ministry of Agriculture defined some rules to eliminate symptomatic plants, infected by HLB through regulations (*Instrução Normativa* of Ministry of Agriculture nº 10/2005 and *Instrução Normativa* nº 32/2006) and later, in 2008, the one that is still valid, *Instrução Normativa* nº 53/2008 (IN53), promoting a quicker inspection and elimination of infected plants, and establishing a semester report about the HLB status in the farms required to all citrus producers (RUIZ ET AL, 2010).

However, one caveat to control HLB´s dissemination is that the recommended management should be adopted in a co-joint action by all producers. Despite the law and the technical recommendation, only a share of citrus growers has been taking the recommendations on eradication of symptomatic plants, and this situation is compromising the control of HLB dissemination and the sustainability of this fruit production, particularly in São Paulo. Consequently, there is a risk that this economic activity may move to other regions that are still free from the disease and a drastic social change might result from such a migration.

Therefore, studies that identify and quantify these potential impacts may put more light on the necessity of fostering urgent measures to prevent negative effects, both economic and social. And this is especially important because no short-term or medium-term solution has been identified to control HLB so far, although there are several efforts in developing research in the fields of genetics and detection techniques. So, Morris and Muraro (2008) affirm that it is necessary to establish an efficient management program, which guarantees the highest possible profitability until new controls are developed.

## 2 – METHODOLOGY AND DATABASE

The CBA model implies the identification of benefits and costs related to policies or actions or projects that are being evaluated and compared. This study has delimitated the analysis to the most relevant economic benefits and costs for each scenario selected. The scenarios proposed project the evolution of HLB in São Paulo State and consequently, the evolution of orchard size, yield losses and citrus production. Once established the projections, the present value of benefits (avoided losses) and costs were calculated and summed up in order to allow comparing scenarios.

To conduct this kind of study, it is important to join as much technical and scientific information about the pest and the crop analyzed, because they are essential to establish good scenarios in terms of the disease dispersion and impacts.

### 2.1. Epidemiological model

In order to trace the disease development in São Paulo State and project its damages along the timeline, an epidemiological model proposed by Bassanezi and Bassanezi (2008) was applied. These authors estimated the incidence of symptomatic trees (*y*) and the severity of HLB in each symptomatic tree (*S*), for each year, considering the absence of disease controls. The equation below calculates the proportion of symptomatic plants in the blocks depending on years after the occurrence of the first symptomatic tree:

$$y = e^{(-(-\ln y_0).e^{-r_G * t})} \tag{1}$$

Where $y$ is the proportion of symptomatic trees in $t$ (year), $y_0$ is the proportion of symptomatic trees when the first occurrence is registered and $r_G$ is the annual growth rate of the disease's incidence.

Authors took a different value of $r_G$ for each category of plants age when the first symptoms are verified. In younger blocks in the orchards, the HLB progress is faster than in older blocks. Values for $r_G$ to categories of 0-2 years old, 3-5 years old, 6-10 years old and plants older than 10 years are respectively, 1.30, 0.65, 0.325 and 0.244 (Bassanezi and Bassanezi, 2008).

To evaluate the total severity of HLB in blocks, *i.e.*, the proportion of the tree's canopy taken by the disease symptoms along 20 years, and taking into consideration the plants' age, the authors above-mentioned proposed also a logistic model (equation 2):

$$S = \frac{S_0}{S_0 + (1 - S_0)^{e^{-rS*t}}} \tag{2}$$

Where $S$ is the proportion of symptoms in the leaves of a tree depending on the years after the occurrence of symptoms; $S_0$, initial severity or the proportion of symptoms in the crown when they first appear; and $t$ is the age of tree when the disease is first registered. Also the values of severity rate $r_S$ vary according to plants' age: 3.68 for 0-2 years old plants; 1.84 for 3-5 years old plants; 0.92 for plants 6-10 years old and 0.69 for trees older than 10 years (Bassanezi and Bassanezi, 2008).

Once the severity data is calculate according to plant's age and for 20 years, it is possible to estimate the yield loss of infected plants in relation to yield of healthy plants. Equation 3 relates production to disease severity, which is represented by an exponential negative model (Bassanezi and Bassanezi, 2008):

$$x = e^{-1,85*S} \quad (3)$$

Where $x$ represents the proportion of the infected orchard production in relation to a healthy orchard; $S$ indicates the total severity, or the proportion of the crown with symptoms and -1.85 is a parameter found in literature for the most common sweet orange varieties grown in São Paulo State (Bassanezi et al., 2011a).

### 2.2 Cost-Benefit Analysis

In this paper, the benefits of controlling HLB were estimated indirectly by valuating losses that could be avoided by a phytosanitary governmental program to prevent, control and eradicate the HLB, maintained hypothetically for 20 years, in similar conditions to that one prevailing in São Paulo State until December 2009, *i.e.*, basically having the inspections and eradications implemented by Fundecitrus through a cooperation agreement with Ministry of Agriculture and with the State Secretary of Agriculture. On the other hand, costs were calculated based upon the government expenses (federal and state) with this phytosanitary program, along 20 years, added by the expenses of Fundecitrus in providing technical support, including inspections and elimination of infected trees. A second step was taken to compute the private costs of controlling HLB, which comprised the estimation of the additional costs faced by producers to control the psyllid *Diaphorina citri*, the vector that is responsible to spread the pathogen of HLB. These costs were also calculated for a 20 years period.

The equation below shows how to calculate the benefit/cost ratio of the projected monetary flows, converted to present values. The timeline is given by $j$ (20 years) and the discount rate is defined by $i$:

$$B/C = \sum_{j=0}^{n} R_j/(1+i)^j \Big/ \sum_{j=0}^{n} C_j/(1+i)^j \quad (4)$$

*Where* $Rj$ = Benefits of adopting the phytosanitary program to HLB in year $j$; $Cj$ = Costs of the program in $j$. Two discount rates were tested in the CBA for HLB, the SELIC official rate (that represents the basic reference for interest rate in Brazil), valued in 11.17% and the TJLP (long-term interest rate determined by government to its investments), valued at 7.1%, in real currency of December 2009. According to Berger (1980), when B/C is larger than 1, the benefits overcome costs and the action or policy proposed should be implemented. Otherwise, it should be abandoned.

The application of the epidemiological model was conducted to simulate the avoided losses in production. A time series of projected prices for orange was necessary to monetize the production and losses caused by HLB along the 20 years. So to obtain these time series, prices were projected through a simulation based on a historical time series, from 1995 to 2010. A year average was calculated for each of those 16 years, considering only producer prices for the season period (July to December). This method assumes that the cyclical movements in the market will be kept during the following 20 years. Monthly prices from 1995 to 2010 were collected from Cepea (www.cepea.esalq.usp.br ).

Production costs were based on calculations provided by Figueiredo (2008) for 2006, when these costs were already reflecting effects of HLB occurrence and consequently producers had to afford with additional expenses to control the disease. Production costs for 2004 were also taken from the same source, in order to have a reference of costs to an *ex-ante* situation for HLB occurrence. These data were used in real Dollars in order to project production costs along the timeline and then converted to real values of Brazilian currency of December 2009.

### 2.3 Scenarios

We define two scenarios to analyze the impacts of HLB in São Paulo citrus production. First scenario A assumes that the disease will disseminate faster in the state territory, as there is no official phytosanitary program conducted by the government in cooperation with Fundecitrus. In this case, the assumption is that only 30 percent of producers would adopt the legal mandatory procedures in reporting and the technical recommendations to inspect and eliminate infected plants. In this scenario, the size of orchards will decrease because of HLB dissemination. The alternative scenario B assumes that there is an official phytosanitary program in which Fundecitrus maintains cooperation with Ministry of Agriculture and State government, giving support to inspect and monitor elimination of trees. In this case, producers will face higher costs of production, although we assume that they will succeed in keeping the number of citrus trees in São Paulo state, along 20 years, by reducing the disease growth rate.

Therefore, scenario A does not consider the government expenses and neither does Fundecitrus´s budget on inspections and surveillance. Otherwise, scenario B takes into consideration those budget expenses of federal government and Fundecitrus to hold the phytosanitary program. Additionally, scenario B considers private costs, calculated by producer´s additional expenses to control HLB dispersion, according to legal recommendations.

Knowledge about HLB allows affirming that impacts of HLB in the orchards vary according to plants age, varieties and the initial incidence of disease in the blocks. These are the basic variables considered to project the evolution of HLB in the State. On the other hand, the productivity of contaminated plants will decrease according to incidence and severity of HLB. The incidence of HLB in São Paulo varies according to plant age and different regions, which can be observed by data presented in Table 1 and 2.

## 3 – RESULTS AND DISCUSSION

Fundecitrus surveys have been collecting information on citrus orchards in São Paulo State as well as monitoring the evolution of some diseases, including the HLB. Table 1 contains the number of trees distributed by age in the State, referring to 2009, when the total number of plants reached more than 214 million. These categories were used to project the orchards behavior along the timeline, according to plants age and HLB incidence. Table 1 also provides the results of sampling for HLB incidence in orchards, collected in April 2009, which were used to simulate the advance of disease along the years.

Another information to feed the epidemiological model refers to initial incidence in each region of the State, considering that Fundecitrus surveys divides the State in five regions and these regions present different levels of HLB. Table 2 also contains results of Fundecitrus´s sampling to HLB for each region. Base-year is 2009.

In order to estimate the losses in yield and production of an infected plant in relation to a healthy plant, the average yield for citrus trees were taken from Fundecitrus, by age, and measured in boxes of 40.8kg. Data is available in Table 3.

Table 1 – Survey on HLB incidence conducted by Fundecitrus: distribution of trees and percentage of infected plants by age. São Paulo State. April 2009

| Plant Age (years) | Number of trees | Percentage of trees/age | Percentage of trees with HLB |
|---|---|---|---|
| 0-2 | 17,452,128 | 8.15 | 0.1499 |
| 3-5 | 40,663,482 | 18.98 | 0.7053 |
| 6-10 | 45,878,755 | 21.42 | 1.3759 |
| >10 | 11,200,445 | 51.45 | 0.8302 |
| Total | 214,194,808 | 100 | 0.8680 |

Source: Barbosa et al (2009).

Besides the average productivity of a healthy citrus tree, it was necessary to calculate the yield reduction or the relation between healthy plants productivity and infected plants productivity. Figure 1 illustrates the evolution of yield in healthy and infected orchards. Each curve identifies the orchard yield trend according to age at initial time, *i.e.*, when the first symptomatic tree appears. So, the highest curve represents a healthy orchard. For instance, the green curve, just below the healthy plant curve represents an 18 year-old orchard facing the outbreak of HLB. This graph was built using Araraquara´s data on HLB incidence.

Table 2 – Distribution of citrus plants in São Paulo State regions and HLB incidence, according to Fundecitrus surveys. 2009 and 2010

| Citrus Regions São Paulo State | 2010 | 2009 | | |
|---|---|---|---|---|
| | % of infected plants by HLB | Number of Plants | Percentage of trees | Percentage of plants infected |
| Northwest | 0.0530 | 18,950,278 | 8.85 | 0.0008 |
| North | 0.3905 | 45,184,964 | 21.10 | 0.0376 |
| Centre | 3.5103 | 71,161,424 | 33.22 | 1.3594 |
| West | 0.3400 | 8,248,289 | 3.85 | 0.0636 |
| South | 2.0007 | 70,649,853 | 32.98 | 1.2303 |
| Total | 1.8700 | 214,194,808 | 100 | 0.8680 |

Source: Fundecitrus surveys.

Based on Tables 1, 2 and 3 and applying the epidemiological model proposed by Bassanezi and Bassanezi (2008), the number of trees was calculated for each one of the 20 years projected, by age. The calculations were conducted by region and then summed up for the State. This procedure allowed evaluating the losses in terms of number of citrus trees in the State by comparing the size of orchards in scenario A and in scenario B. A software written in excel by Bassanezi (*unpublished*) was used to project the number of trees and orange production along 20 years. Figure 2 presents the evolution of orchards in São Paulo State for both scenarios and it highlights the loss in orchards production, which is the correspondent difference between the two curves. Note that the production fell more than 300 million citrus boxes by the $15^{th}$ year comparing the scenarios with and without the phytosanitary program, illustrating the importance of HLB impacts if the disease is not controlled.

Table 3 – Average yield for healthy citrus plants, in orange boxes (40.8kg), per tree, by age category. São Paulo State. 2009

| Plant Age | Citrus boxes/tree | Plant Age | Citrus boxes/tree |
|---|---|---|---|
| 0 | 0 | 11 | 2.16 |
| 1 | 0 | 12 | 2.24 |
| 2 | 0.74 | 13 | 2.30 |
| 3 | 0.99 | 14 | 2.33 |
| 4 | 1.23 | 15 | 2.35 |
| 5 | 1.44 | 16 | 2.34 |
| 6 | 1.63 | 17 | 2.30 |
| 7 | 1.80 | 18 | 2.25 |
| 8 | 1.94 | 19 | 2.17 |
| 9 | 2.06 | 20 | 2.07 |

Source: Fundecitrus.

Regarding scenario B, it was considered that the management of HLB provided conditions to maintain the stand of citrus trees practically at the same level of 2009, by taking a rate for orchard reform enough to keep the stand of trees. On the other hand, for scenario A, it was necessary to make assumptions about the loss in orchards size, as producers will not control for HLB and therefore it will become increasingly difficult to keep citrus trees producing for long. So, it is assumed that there will be a reduction in orchards in the State, and this loss in annual replant rate varies accordingly to the initial incidence of HLB in the municipalities that are comprised by the five regions.

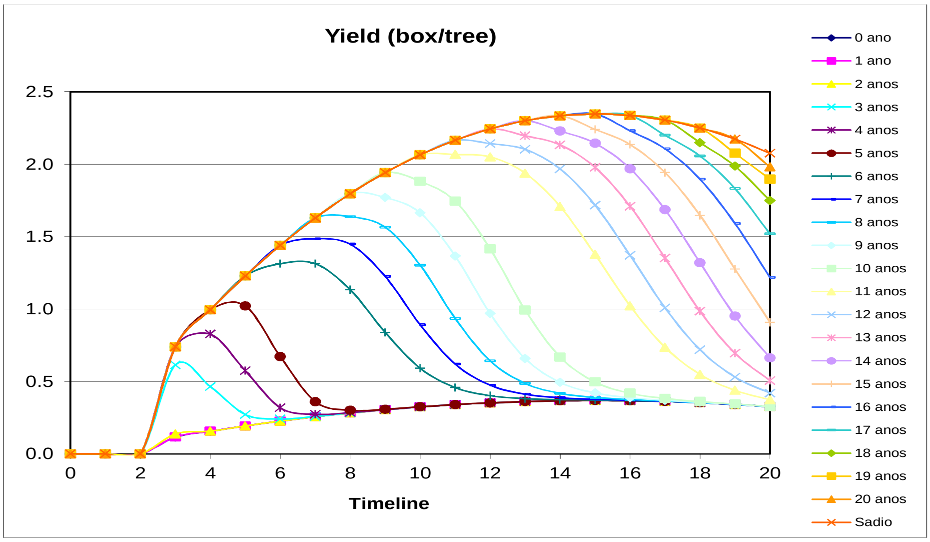


Figure 1 – Yield evolution in orchards, by age, along 20 years, according to age of first HLB-symptomatic tree appearance. Model for Araraquara region – São Paulo State. Source: calculated by Bassanezi (2010). Note: "anos" means years and "sadio" is healthy.

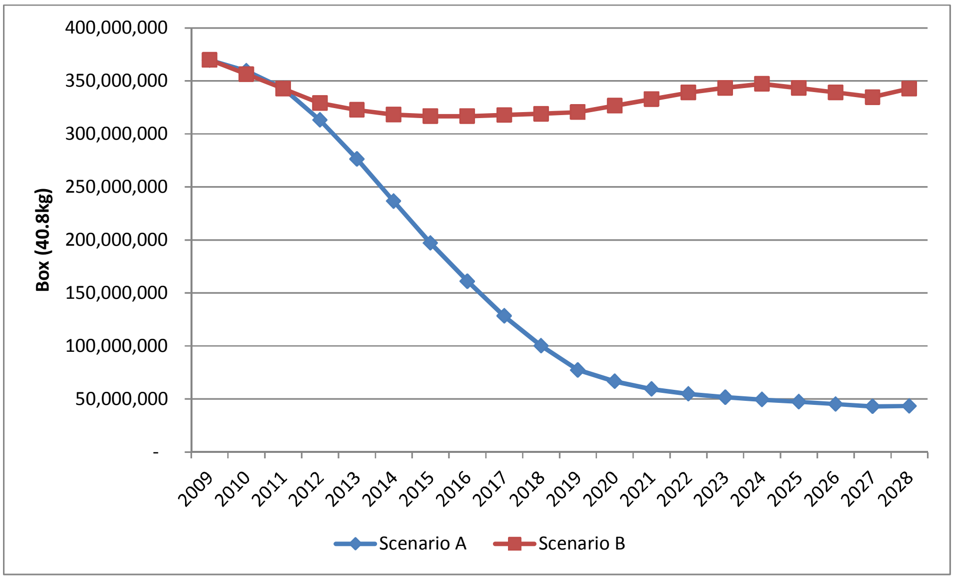


Figure 2 – Projection of citrus production in scenarios A (without phytosanitary program) and B (with the program) for São Paulo State (Orange boxes, 40.8kg/box). Projections for 2009-2028.

Table 4 shows the classification of municipalities in relation to the HLB incidence found by Fundecitrus in its survey of April 2009. These municipalities were divided in four categories with each one having a different loss rate in the yearly renew (orchard reform). This implies reduction of stand in the State along the 20 years period projected.

Table 4 – Classification of citrus municipalities/regions in São Paulo State proposed according to HLB severity ratio. Application to scenario A´s simulations

| Severity and incidence categories for HLB | Municipalities/Regions | Annual renewal rate of orchards[1] |
|---|---|---|
| High | Araraquara, Araras and Itápolis | Loss of 10% per year in the renewal rate[1] (initial rate is 100%) |
| Medium-High | Guarantã, Bebedouro and Faixa 1 | Loss of 5% per year in the renewal rate |
| Medium | José Bonifácio, Olímpia and Faixa 2 | The renewal rate is maintained in 100% for the first 5 years and afterwards this rates becomes to be reduced by 2% points per year until the 20th year |
| Low | Jales, Frutal, Mirandópolis, Votuporanga, Buri and Icem | In the first 3 years the renewal rate rises to 110%, because there is expansion of citrus orchards; in the following 5 years, the rate maintains 100% and then it starts reducing by 1% points per year |

Note: [1] The renewal rate of orchards should be 100% in a successful planting. Therefore, reduction in this rate indicates failure in renewing orchards. This abatement in renewal rate was applied only to 70% of orchards in scenario A, assuming that 30% of orchards are following the legal and technical recommendations to control HLB. This seems to be a strong assumption that should be loosened in further simulations.

As explained in the Methodology section, to valuate citrus production along the 20 years, producer prices for citrus were projected through a simulation based upon a historical time series, from 1995 to 2010. These simulated prices can be observed in Figure 3.

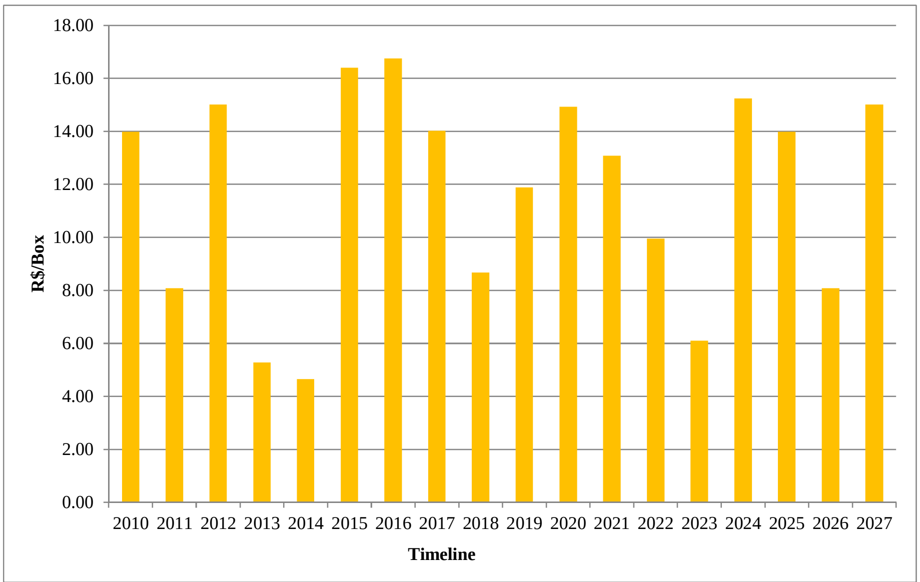


Figure 3 – Producer prices for citrus simulated to 2010-2028 in São Paulo State. Real values (Base year = 2009) R$/box. Source: based on CEPEA´s data for 1995-2010.

To compute the costs of implementing the IN53 in São Paulo State, an amount estimated by Fundecitrus has been taken.This institution estimates that the total expenses to follow and implement the IN53 has reached about R$99 million in 2009 (in real values). From this amount, a roughly one-third would be accounted by Fundecitrus and the governmental transferences, while about R$66 million should be afforded by own producers to face costs with inspection and elimination of plants. The R$33 million, in real values for 2009, were considered to be kept constant along the timeline.

Regarding the costs faced by producers to manage HLB along life-time of orchards, a basic level of costs has been collected to show costs before HLB entrance in São Paulo and then, afterwards, the additional costs to control and manage orchards with this disease. Thus, the basic production cost was taken from Figueiredo (2008), relatively to 2004 (before HLB's introduction) and for 2006 (beginning of HLB dissemination in the State). These costs were corrected to real values of 2009 and were used to compare with more recent information on costs of HLB controls, which were based on Belasque et al (2010b). Belasque´s paper presents several different measures and methods to inspect and to eliminate infected plants, identified according considering to case studies in farms located in São Paulo. Authors considered three different management methods, named Management Programs I, II and III, which increases in complexity of technology and expenses in that order. Data are displayed in Table 5.

The cost to manage HLB in Management I was used to calculate producer's expenses in the scenarios A (30 percent of farmers, simplified by 30 percent of trees) and B (for 100 percent of farmers, e.g., 100 percent of trees), for those regions where the initial incidence of HLB was very low. In the other bound, the third method of managing HLB (Management III), the most expensive and sophisticated, was assumed to be applied in those regions where the disease showed more disseminated and severe. For intermediate regions, the Management II was used to simulate producers' expenses to controlling HLB. Those costs were then projected for 20 years, according with other additional assumptions on the disease behavior. Afterwards, costs time series was discounted by interest rates (to have present values in 2009) and summed up to compare scenarios.

Table 5 – Citrus production costs by age category and costs to control HLB in São Paulo State, in US$ per tree

| Orchard Age (years) | Production Costs - Orchard without HLB (2004) (US$/tree) | Production costs Orchard in 2006 (US/tree) | Management Program I[1] (US$/tree) | Managemen t Program II (US$/tree) | Management Program III (US$/tree) |
|---|---|---|---|---|---|
| 0 | 3.205 | 5.511 | 6.085 | 6.859 | 8.016 |
| 1 | 1.349 | 2.424 | 2.998 | 3.772 | 4.930 |
| 2 | 1.363 | 2.426 | 3.000 | 3.774 | 4.932 |
| 3 | 2.061 | 3.348 | 3.922 | 4.697 | 5.854 |
| ≥ 4 | 2.897 | 4.005 | 4.579 | 5.353 | 6.511 |

Source: elaborated with data from Figueiredo (2008) and Belasque et al. (2010b). Note 1: Management Programs I, II and III refer to production costs in 2006 added by expenses to control HLB in three different programs/technologies.

Once the entire database for 20 years of production and plants elimination was built up, for both scenarios, the analysis of benefits and costs and the discussion about the HLB impacts in São Paulo State is possible. First results are presented in Figure 4, which repeats the information of Figure 2, but now also discriminates the losses relating to eradication of plants and reduction of orchards in scenario A, which can be compared to outcomes for scenario B.

According to assumptions and the modeling, and taking 2009 as base-year, assuming that the stand of citrus orchard will maintain in the State, the expected production would reach about 6.7 billion boxes of 40.8kg after 20 years in Scenario B (if the disease was absent in the State, this production would be of 6.9 billion boxes). Differently, scenario A shows a drastic drop in citrus production, generating only 3 billion boxes after 20 years, which corresponds roughly to a 45.3 percent reduction in citrus production compared to the alternative scenario.

When the three losses – yield reduction, orchards reduction and losses in revenue due to plants eradication - are calculated, discounted by the SELIC rate and summed up for scenario A, it amounts to R$13.1 billion (in real values of 2009); if the long-term interest rate (TJLP) is applied, outcome amounts to R$19.8. The TJLP choice is more convenient if the social aspects of investments in phytosanitary policies by government and private sectors are going to be considered in the analysis, as emphasized by Miranda et al (2011).

Along the timeline, it is noteworthy that according to the incidence of disease at the initial period, in scenario B, losses could be very significant because of infected plants elimination and the security margin of plants eliminated at the beginning of the projection time. On the other hand, as time goes by, the recovery of orchards health and the drop in the dissemination growth rate, attenuate losses. Under the same analysis, but regarding scenario A, there will be a gradual but drastic decrease in number of trees and in yield. This comparison can be done using curves presented in Figure 1 and 2.

Several alternative scenarios could be tried to address differences through regions and levels of disease severity. One interesting exercise could simulate that regions with lower severity (for instance, in Jales municipality) will attract investments in citrus orchards, as HLB severity increases in other medium and high infected regions from São Paulo State (like Araraquara, e.g.), where it will be expected a reduction of citrus cultivated area and probably a replacement by other crops, particularly by sugarcane in the last few years.

A second kind of economic and social impact estimated relates to effects on labor market, especially through a cut in positions inside citrus sector, mainly in farming level. The 45.3 percent fall in production along timeline were assumed to cause a proportional reduction in jobs. First, the differential between the average salary paid to citrus employees and average salary paid to other fruits employees was calculated using CAGED/RAIS (MTE, 2010) database for 2009. This differential amounted roughly to R$61.6/worker/month. Then, this differential was multiplied by the total number of employees in citrus production segment in São Paulo State and afterwards, multiplied by the 45.3 percent reduction.

This assumption on jobs losses could be easily replaced by other alternatives of analyzing the effects over labor market. However, there are scarce studies and databases for citrus labor market and it seems that the method applied achieves minimum requisites on approaching a conservative shock and outcome.

The impacts on production costs caused by HLB dissemination were found very significant and economically they underline that there will be a time when farmers will have to ponder if it is financially feasible or not to keep in the citrus business. In scenario A, the additional cost of production costs was computed only for 30 percent of citrus trees in the State. For 70 percent of orchards in São Paulo, costs of production was assumed to be that one proposed by Figueiredo (2008) for 2006, converted to 2009 values. It means that this cost already includes some tools to manage HLB in São Paulo orchards, although it is not including too significant additional costs.

In the case of scenario B, 100 percent of orchards are assumed to be managed and so they face significant additional costs to control and eradicate HLB following guidelines mandated in IN53. So, this scenario assumes that farmers accept to afford with huge expenses in order to keep their orchard´s stand and productivity, in all regions. For each State region, the additional cost varies (Program I, II or III) depending on the initial HLB severity level, which is available through surveys collected by Fundecitrus.

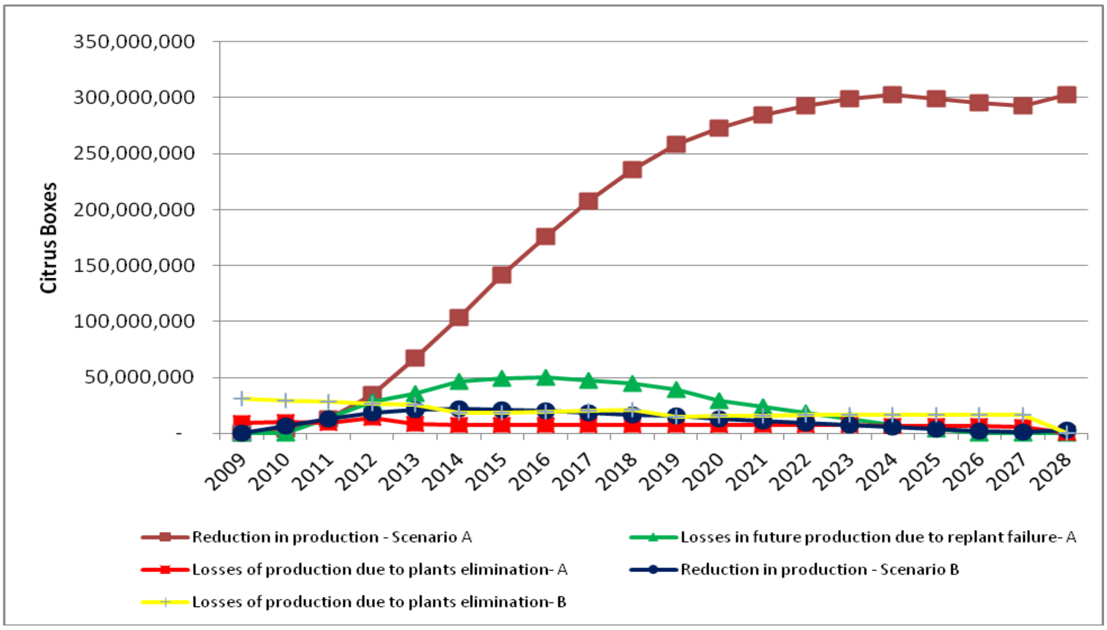


Figure 4 –Losses calculated for scenarios A and B: reduction in yields, reduction of orchards size and decrease in revenues due to plants elimination. São Paulo State. (Citrus box of 40.8kg). 2009-2028.

The magnitude and importance of these private costs for decision makers is determinant as for scenario B they were calculated around R$17 billion (accumulated for 20 years and discounted to present values by SELIC rate), which might be compared to only R$13.7 in scenario A, where there is no phytosanitary program to control the disease and therefore, only 30 percent of farmers afford with additional expenses to control HLB dissemination. It means that enforcing the IN53 along the 20 years-period requires additional R$ 4.25 billion in farmers' expenses with chemicals and inspections, mainly. These plus costs have to be subtracted from the benefits obtained in production gains in scenario B compared to scenario A and it shows that farmers who want to keep free of HLB or controlling its dispersion, despite gains in production, will face higher costs of production.

Besides private costs of implementing IN53, it is also important to take into consideration the expenditures of agencies to maintain an official phytosanitary program to HLB. As mentioned before, the estimated budget for government and Fundecitrus was about R$33 million (real values), necessary to keep the program in 2009. If ones accumulate such a budget along timeline (20 years) and then discount to present values, the final amount to implement the phytosanitary program ranges from R$288.9 (using SELIC interest rate) to R$371.5 million (using TJLP).

The benefits, measured by avoided losses in production and eradication, and the costs of a scenario with the phytosanitary program are then used to calculate the Benefit-Cost ratio. Final results can be seen in Table 6, where the net costs and benefits are calculated, as well as the benefit-cost ratio, for two comparable situations. For 20 years of projections, according to assumptions made, scenario A results in a total of R$25.4 billion economic losses due to HLB dissemination; while in scenario B, these losses amount roughly to R$4.2 billion. These results generate a net benefit of R$21.3 billion in favor of scenario B, i.e., in favor of having a phytosanitary program for HLB.

It is noteworthy that results above-mentioned derive only from evaluating direct economic effects from a supply side (trees and yield reductions and jobs losses). So, we conclude that there are net production benefits in managing the disease for São Paulo state, but there are still several other impacts that were not considered in the calculation.

On the other hand, when costs of the phytosanitary program are included in the evaluation, one can notice that government expenses are not so significant when compared to avoided losses of controlling HLB. The government expenditures projected for the whole period 20 years summed up R$ 371.5 million in scenario B. This amount compared to the net benefit in production side gives a benefit-cost ratio of 57.3 to government program. This means that for each R$ 1.00 allocated to the HLB phytosanitary program by the government and Fundecitrus, there is an income of R$57.30 that is avoided to be lost. From this result, one may conclude that the phytosanitary program consists on a very recommendable investment to make. These figures were estimated using the TJLP discount rate.

However, if the producers expenses with additional costs of production to control and eradicate HLB are incorporated to CBA, the benefit-cost ratio falls drastically, and using TJLP it equals to 4.6, meaning that for each R$1.00 invested by government, Fundecitrus and farmers to control HLB dissemination, there is an economic return of R$4.60. If SELIC discount rate is applied, this result changes to 3.9. Both ratios found indicate that it is still economically profitable to invest in citrus phytosanitary program, even if the private costs are so high. This is so because the productivity losses are really significant if the disease is not kept controlled in the State.

Regarding the process of HLB expansion and increasing impacts it is likely to have a differentiated effect among small-scale and large-scale producers. This point is one of the most important aspects emphasized by the Organization for Cooperation and Economic Development – OCDE (Miranda et al, 2009) as a social impact, in examining regulatory impact analysis (RIA) reports. HLB will probably cause supply shifts more significantly to smaller producers than large ones. Bassanezi et al. (2011b) experimentally proved that adopting the controls in larger areas is fundamental to guarantee the feasibility of renewing orchards. This paper and the field observations allowed implementing the concept of wide-area management for HLB in São Paulo as well as in Florida and supports the statement that small scale producers will be comparatively more affected than others.

Table 6 – Results for Cost-Benefit Analysis applied to evaluation of a HLB phytosanitary program for citrus in São Paulo State. Timeline: 2009 a 2028 (Discount rate: TJLP)

| **Base year= 2009** | **VPL( R$ 1000)- discount rate= TJLP (20 years of projection)** | |
|---|---|---|
| | **Scenario A (with disease and without phytosanitary program)** | **Scenario B (with disease and phyto- sanitary program)** |
| **Benefits** | | |
| Production value | 22,682,216.3 | 40,899,872.5 |
| Production loss | 23,979,243 | 4,157,128 |
| Job reduction | 1,451,886.05 | |
| **Total losses (avoided losses)** | **25,431,129.1** | **4,157,128.2** |
| Benefits = avoided losses in scenario B | 21,274,000.9 | |
| **Costs** | | |
| Government + Fundecitrus expenditures in the program | 0 | 371,531.7 |
| Producers (additional costs of production) | 17,251,886.4 | 21,502,919.4 |
| **Total costs** | **17,251,886.4** | **21,874,451.1** |
| Net costs | | 4,622,564.7 |
| Avoided net losses (avoided – costs) | | 16,651,436.2 |
| **Benefit-cost ratio (includes government+Fundecitrus+ producer costs)** | | **4.6** |
| **Benefit –cost ratio (only government + Fundecitrus costs)** | | **57.3** |

Source: calculated by authors.

Other relevant social and economic impacts might be estimated, if data are available for further studies. One example is to estimate how much the State and municipalities might lose in tax revenues because of HLB outbreak and expansion. According to Neves et al (2010), the citrus agribusiness account for about US$ 6.5 billion in Brazilian GDP and São Paulo State accounts for about 51 percent of the world orange juice in 2009. So, these are very impressive figures that certainly account for a significant share in government´s revenues, particularly in São Paulo State.

Another important issue is that allowing for HLB dissemination in São Paulo State consists on a risky situation for other producers in Brazil, like in the Northeastern states. It is a matter of time, according to experts, that this disease will disseminate to other regions. Some useful lessons can derive from experiences in Florida and São Paulo, in order to prevent or to mitigate negative impacts in other regions, if policy makers may have enough information to decide on *ex-ante* policies.

## 4 – FINAL COMMENTS

Despite the complexity and variety of scenarios that could be simulated for HLB development in Brazil, we can affirm that this disease has drastic economic impacts for citrus agribusiness in Brazil likewise it does in other countries, as literature has already shown. This study provides an illustration of calculations to approach the magnitude of major economic impacts, using the Cost-Benefit Analysis tool. Moreover, even though the social and environmental impacts were not estimated in this paper, we have literature evidences and experts´ knowledge that confirm they may become very significant as well.

Regarding the CBA results for economic impacts, we found that for each Real invested by government and by Fundecitrus in the phytosanitary program to control and eradicate HLB in São Paulo State, there is a avoided loss that amounts to R$ 57.3, which consists on a very high benefit-cost ratio for this kind of investment. When the additional costs imposed to farmers to manage the HLB is computed in the CBA analysis, the ratio falls to 4.6, however it is still higher than one, indicating that this phytosanitary “investment” is recommendable.

Although this analytical tool is simple to apply, it provides elements to decision making, for both public and private actors and it allows having some approximation of impacts. Estimating those impacts is relevant to prove policy makers that phytosanitary policy has a high net benefit for society. Of course, results presented in this paper still underestimates the net benefits, as social and environmental impacts were not considered in the analysis. And, moreover, one could say that economic analysis could be enhanced by more sophisticated tools, as Monte Carlo simulation and use of elasticities in fruits and orange juice markets to evaluate other shocks along the citrus agribusiness chain, having a broader overview of this sector. The disease affects also segments like retailers and processors, most probably through potential reductions in orange supply and over market prices, including international markets, and also for chemical markets that need to plan their investments in technology.

For State, federal and municipalities policy makers, there is also an important concern regarding the potential impacts of HLB dissemination over taxes revenues, mainly in regional levels. It is well known that this sector has a significant share in Agribusiness GPD and particularly in São Paulo State, there are several regions that are economically highly dependent on citrus production.

In regards of using CBA to evaluate phytosanitary and sanitary issues, there have been some efforts found in literature, mostly from developed countries, which points that this field of research seems promising for Brazilian agricultural economists. This is so also because Brazil faces several challenges in trade related to sanitary restrictions and there is a consensus that public policy in this area needs support from academia to develop analytical tools that might be easily applied by policy makers.

An specific challenge in this field refers to access epidemiological models that can supply the necessary data on pests and their dissemination pattern in order to guarantee good quality of projections.

For further studies we intend to evolve in estimating the above-mentioned economic effects not addressed by this paper, as well as the environmental impacts due to a significant increase in chemicals use, and the social impacts beyond shocks on jobs positions.

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