Economic Analysis of Strategies to Combat HLB in Florida Citrus

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Introduction

Huanglongbing (HLB) is a bacterial disease that affects all varieties of citrus. It is commonly referred to as citrus greening. HLB is suspected to have been inadvertently smuggled into Florida, presumably from China via Miami. HLB was first discovered in Florida in 2005 and is now found in all counties where commercial citrus is produced. It is spread by a small leaf-feeding insect, the Asiatic citrus psyllid. The Asian citrus psyllid is noted for its short range maneuverability and long range drift by wind, implying simultaneous within and across spatiotemporal host plant spread. To appreciate the devastating impact of HLB on Florida citrus, it is said to be of far worst tree damage compared to citrus canker responsible for the destruction of over 4 million trees. HLB has already been implicated for loss in land acres allocated to citrus in the state since 2006, and soaring grower costs in terms of tree eradication, psyllid control, inspections, and replanting costs (TBO, 2008).

HLB acts to disrupt the phloem of the tree thereby limiting its ability to uptake nutrients. Initially this leads to yellowing of leaves, promotion of premature fruit drop, and production of small, misshapen fruit that contain bitter juice with no economic value. As the disease spreads through the tree, the amount of usable fruit produced diminishes until eventually the tree is of no economic value (Brlansky et al. 2011). At the present time, there are no known measures that effectively combat the disease. In this paper, an introduction to HLB and its likely impact on Florida citrus are presented. Strategies to combat the disease are identified. A model of disease spread is developed using a Gompertz function. This model is applied to hypothetical Florida citrus groves to assess the potential cost of the disease if growers choose a "do nothing" strategy. These results will be used as a baseline to estimate the benefits of alternative strategies.

HLB is a disease with two important characteristics. First, the rate of spread is strongly affected by tree age because the psyllids prefer new growth (Brlansky et al. 2008). Young trees, which are more vigorous as compared to mature trees, produce more flushes and thereby are more susceptible to psyllid feeding and disease transmission. In the case of mature trees, the disease spreads more slowly (Gottwald 2010). Consequently, an infected mature tree is capable of producing usable fruit for several years while at the same time serving as a source of infection for other healthy trees. Second, control through tree eradication is complicated by a latency period between the time a tree first becomes infected and when it expresses visual symptoms. Once a mature tree is infected, it may not begin to exhibit symptoms of the disease for up to two years. If the rate of infection in a particular grove is relatively high at the time the disease is first discovered, a policy of eradication of symptomatic trees may result in destruction of the entire grove.

HLB is the single most vicious and debilitating citrus disease responsible for the destruction of almost 100 million trees in major citrus growing areas of the world where the disease has been endemic (Aubert et al. 1985, Bové 1986). This is partly due to its elusiveness to various regionally specific management prescriptions. Early detection is the only remedy that may lead to complete eradication of HLB.

Control Strategies in Florida

At this time, there are three distinct strategies being employed to deal with greening. What we will call Strategy 1 is to do nothing, in other words, allow the disease to spread and take no measures to slow its spread or mitigate its impact. This strategy represents a baseline from which to estimate the net benefits of Strategies 2 and 3. Strategy 1 has no effect on per acre costs as management tactics are not modified. Per acre revenues, however, are gradually affected as the disease spreads and the number of healthy fruit that can be harvested and utilized gradually declines. At some point, per acre revenues will not cover per acre grove maintenance costs and at that point, the grove is no longer economically viable. The disease spreads faster in younger groves, so younger groves cease to be economically viable at a faster rate compared to an older grove with the same initial level of infection.

Under Strategy 2, an aggressive inspection program is initiated (four to twelve inspections per year) to identify symptomatic trees, and once found, are immediately eradicated (Brlansky et al. 2008). An aggressive psyllid control program is also put into place to suppress psyllid populations. Muraro (2010) has estimated that in Florida, Strategy 2 increased grove maintenance costs by about $450 per acre. The logic behind Strategy 2 is that by eradicating symptomatic trees, the level of inoculum in a particular citrus grove will be gradually reduced. Eventually the incidence of the disease will be reduced to a point where it can be economically tolerated. There are four problems associated with Strategy 2. First, the latency period of the disease implies that not all diseased trees will be removed, and these asymptomatic trees will serve as a reservoir of the disease inoculum. Second, if a grove is already at a high level of known infection and given that more trees are infected but not yet symptomatic, it may not be possible to rid a particular grove of the disease without eradicating the entire grove. The probability of this outcome is clearly related to the level of infection when the first positive find is made and the age of grove. Third, eradication or suppression of the disease to a tolerable level in one grove may not be possible if neighboring growers are not adequately suppressing the disease in their groves. Neighboring groves will serve as sources of the inoculum, and the disease may be continually re-introduced into the groves of the grower following Strategy 2. Fourth, plant pathologists have yet to characterize the key parameters that would significantly define the timeline by which to control HLB through eradication of symptomatic trees. These parameters include the feasible base level of HLB infection, the number of years it would take to achieve that base level, and the probability that young tree resets will survive to productive maturity.

Strategy 3 is an approach first developed in southwest Florida and is, in part, a response to the Achilles heel of Strategy 2, namely if Strategy 2 is initiated too late, the entire grove may be eradicated before the disease is suppressed. While a high rate of disease incidence is one possible reason for adoption of Strategy 3, it is also possible that under some conditions, Strategy 3 yields a higher net present value than Strategy 2 even though Strategy 2 could successfully reduce HLB inoculums to a manageable base level. Strategy 3 proposes to treat the visual symptoms of HLB through foliar application of micro and macro nutrients. The tree's defense response to HLB's damage of the phloem, the vascular system of the tree, is to produce compounds that block phloem vessels. This damages the root system and inhibits the ability of the tree to uptake nutrients from the ground. In the foliar feeding method, a portion of the nutritional needs of the tree is applied through foliar sprays including both macro and micro nutrients (Spann et al. 2010). Symptomatic trees are not removed and scouting for the disease is discontinued. As with Strategy 2, a strong psyllid control program is practiced. Roka, et al. (2010) have estimated that the per acre increase in grove maintenance costs associated with Strategy 3 ranges from $200 to $600 per acre depending on the type and amount of foliar nutritionals a grower decides to apply. The primary concern among plant pathologists with Strategy 3 is that HLB inoculum is left unchecked. The economic implications of Strategy 3 include whether it is feasible for young trees (ages 3-8) to reach their productive maturity, whether planting the next generation of citrus trees is economically viable, and whether the presence of a grove following Strategy 3 while other growers follow Strategy 2 will cause increased damage on the latter growers' fields. Spatial analysis of disease spread in south Florida suggests that spread between citrus blocks is a more significant portion of disease spread than the spread of the disease within a citrus block (Gottwald et al. 2008). This suggests that heterogeneous control methods may reduce the viability of Strategy 2.

HLB Disease Incidence

Disease incidence has been variously estimated using a variety of approaches. Gotwald (2010) determined disease incidence via a logistic spread rate per year calculated by linear regression of transformed disease incidence in Florida (1.37–2.37). HLB incidence in Florida has also been found in similar studies to increase within 10 months from 0.2 % to as much as 39 % (Gottwald et al. 2007b, 2008; Irey et al. 2008). Spatiotemporal spread models have also been used to characterize HLB in Florida where simultaneous within and across grove spread were common (Gottwald et al. 2008). Other studies have been conducted such as in Vietnam where HLB incidence is found to vary depending on the management strategy employed (Gatineau et al. (2006) or in Brazil where incidence have been shown to depend on proximity to HLB-infected citrus groves (Bassanezi et al. 2006; 2005).

The Economic Model

A citrus grove is an asset. We propose to estimate the economic impact of HLB through its effect on the value of a particular citrus grove. There are a variety of approaches in asset valuation, but the most appropriate approach in this application is the income method. In the income method, future costs and revenues are estimated to give per annum net revenue. Future net revenue is discounted to the present to give net present value (NPV) using the formula

$$NPV = \sum_{t=1}^{T} \frac{(P_t Q_t - C_t(Q_t))}{(1+r)^{t-1}}$$

where P_t is price in time period *t*, Q_t is yield in time period *t*, C_t are costs in time period *t*, and *r* is the discount rate. HLB affects the NPV of an infected grove by decreasing future fruit production , thereby reducing revenue. Since the rate of spread depends upon age of first infection, it will be necessary to compute NPV as a function of the age of first detection as well as the level of infection at first detection.

The Biological Model

Bassanezi and Bassanezi have proposed the use of a Gompertz function to depict the spread of HLB. This function specifies that the disease incidence, *y*, at time *t* is:

$$y_t = e^{\ln(y_0)e^{-\beta t}}$$

where y_0 is the disease incidence at first detection and β is the annual rate of spread of the disease. In their 2008 paper, they identified four values for β based upon four ranges of age of first infection: 0-2, 3-5, 6-10, and over 10 years of age. As age at first infection increases, the rate of spread decreases. These four parameter values give rise to a family of four disease spread curves which depict the proportion of infected trees in a particular grove. These curves are interacted with Florida fruit yield functions to generate expected yield per acre with and without the disease. Using an average of on-tree prices over the past four seasons, expected revenue is calculated. These figures are compared to annual grove maintenance cost; when costs exceed revenues, the grove is no longer economically viable. This baseline analysis will allow for a comparison of the net benefits and the length of economic viability of the grove under other strategies relative to the “do nothing” strategy.

Empirical Estimation

We create disease spread curves using β values of 1.300, 0.650, 0.325 and 0.244 for each of the 0-2, 3-5, 6-10, and over 10 years old age groups, respectively (Bassanezi et al., 2006; Catling and Atkinson, 1974; Gatineau et al. 2006; Gotwald et al. 1991, 2007a/b). The Gompertz incidence curves (figure 1) shows that the disease incidence reaches the asymptotic level (100 % incidence) in young groves as early as 5 years from disease detection, compared to groves older than 10 years which take over 20 years to reach this level.

Given data on estimated boxes of fruit per tree by age group for both Valencia and non-valencia oranges from the Florida agricultural statistics service (Florida citrus statistics 2008-2009), the Gompertz curves are interacted with the investment or NPV model as specified above to estimate HLB impact on grower earnings based on tree age. Citrus prices are expressed in $/pound solids

($1.25/pound solid) with pound solid per box values dependent on tree age. The estimates are made on a per acre basis for a grower with 150 trees per acre and 100% original tree acreage remaining and 150 reset/solid set density. We use a 10% discount rate for calculation of net present values. Operating and production costs for a mature grove include herbicide, pesticide, and fertilizer applications, irrigation, and pruning, but do not include HLB foliar nutritional sprays or pesticide applications for the baseline calculations. Since we assume no resetting, the adjusted reset grove costs by tree age are set to zero, as well as the establishment costs/acre for new solid set, the cost of tree removal and planting reset-replacement trees, reset frequency, and reset yield adjustments. Yield loss due to freeze or disease is set to zero to avoid duplication.

We calculate net present value using a 15 year time horizon. Beyond 15 years, the net present value per year goes towards zero. We calculate the net present value for groves with an initial average age ranging from 0 to 17. Beyond 17 years of age, tree yields no longer increase, so calculations for groves of this age represent our net present value upper bound.

Results

Under a do nothing strategy, with an initial disease incidence of only 0.1%, groves with an average tree age of 6 year or less will yield a negative net present value. Groves that contain younger trees at first detection have a lower net present value due to the faster disease spread of the disease in younger groves. As we increase the initial rate of disease incidence, the average age for which the net present value is negative increases. With a disease incidence rate of 3.1% at first detection, all groves will yield a negative net present value. Table 1 reports the net present values for groves with rates of disease incidence varying from 0.1% to 3.1% and for average initial grove ages of 0, 3, 6, 10, 14, and 17 years. Figure 2 plots the net present values as a function of disease incidence and average age at first detection. It also contains contour lines, with the orange line marking the ages and disease rates at which the net present value is $0.00.

We also identify the year at which operating costs exceed revenue as a function of disease incidence and average tree age at first detection (Figure 3). For groves with an average age of 4 years or less, revenue never exceeds operating costs. For these young groves, production is small or none and the disease spreads quickly, preventing the grove from having a positive net revenue. For the oldest groves, revenues exceed costs for the first 6 to 8 years, depending on initial disease incidence. However, even for mature groves, the disease spreads to a point where revenues no longer exceed costs.

Conclusion

The do nothing strategy is not a viable long term-strategy for any grove. Mature groves will be able to survive for longer than younger groves, but all groves will eventually experience net losses as a result of HLB.

Additionally, the disease incidences at which net present value is negative are rather low. No grove maintains a positive net present value once initial disease incidence reaches 3.1%. This highlights the need for an active HLB management strategy undertaken by all growers.

Literature Cited:

Aubert, B., M. Garnier, D. Guillaumin, B. Herbagyandodo, L. Setiobudi, and F. Nurhadi. 1985. “Greening, a serious disease threat for the citrus production of the Indonesian archipelago.” *Future prospects of integrated control. Fruits* 40:549-563.

Bassanezi, R. B., and R. C. Bassanezi. “An Approach to Model the Impact of Huanglongbing on Citrus Yield”. International Research Conference On Huanglongbing (IRCHLB) Proceedings, Orlando, Florida Dec. 2008.

Bassanezi, R.B., and R. C. Bassanezi. “An Approach to Model the Impact of Huanglongbing on Citrus Yield”. International Research Conference On Huanglongbing (IRCHLB) Proceedings, Orlando, Florida Dec. 2008.

Bassanezi R. B., A. Bergamin Filho, L. Amorim, and T. R. Gottwald. 2006. “ Epidemiology of huanglongbing in São Paulo.” *Proceedings of Huanglongbing Greening International Workshop*, Ribeirão Preto. p.37.

Bassanezi R. B., Busato L. A., Bergamin-Filho A., Amorim L, Gottwald T. R. 2005. Preliminary spatial pattern analysis of Huanglongbing in S˜ao Paulo, Brazil. *Proc. 16th Conf. Intern. Org. Citrus Virol.*, pp. 341–55. IOCV, Univ. Calif., Riverside, CA.

Bové, J.M. “Huanglongbing: A Destructive, Newly Emerging Century-old Disease of Citrus.” *Journal of Plant Pathology* 88(2006): 7-37.

Bové, J. M. 1986. “Greening in Arab Peninsula: Towards new techniques for its detection and control.” *FAO Plant Prot. Bull*. 34:7-14.

Brlansky, R. H., M. M. Dewdney, and M. E. Rogers. 2011. 2011 Florida Citrus Pest Management Guide: Huanglongbing (Citrus Greening). Publication #PP-225. Gainesville: Institute of Food and Agricultural Sciences, University of Florida. Available online at http://edis.ifas.ufl.edu/cg086

Gatineau, F., T. H. Loc, N. D. Tuyen, T. M. Tuan, N. T. Hien, and N. T. N. Truc. 2006. “Effects of two insecticide practices on population dynamics of Diaphorina citri and huanglongbing incidence in south Vietnam.” *Proceedings of Huanglongbing–Greening International Workshop*, Ribeirão Preto, Brazil. p.110.

Gottwald, T. R. 2010. Current Epidemiological Understanding of Citrus Huanglongbing. *Annual Review of Phytopathology.* 48:119-39.

Gottwald T, Irey M, Gast T, Bergamin-Filho A, Bassanezi R, Gilligan CA. 2008. A stochastic spatiotemporal analysis of the contribution of primary versus secondary spread of HLB. *Proc. Int. Res. Conf. Huanglongbing*, pp. 285–90.

Gottwald TR, Irey M, Gast T, Parnell S, Taylor E, Hilf M. 2007b. Spatio-temporal analysis of an HLB epidemic in Florida and implications for future spread. In: Proc.17th Conf. IOCV, Riverside, CA (*submmited*).

Halbert, S. E., and K. L. Manjunath. 2004. "Asian citrus psyllids (Sternorrhyncha: Psyllidae) and greening disease in citrus: a literature review and assessment of risk in Florida." *Fla. Entomol.* 87:330-354.

Irey M, Gottwald TR, Stewart M, Chamberlain H. 2008. Is it possible to replant young groves in an area with endemic HLB: a hierarchical sampling approach to determine infection? *Proc. Int. Res. Conf. Huanglongbing*, pp. 116–17.

Muraro, R.P. 2010. Costs of Managing HLB and Citrus Black Spot. Presented at 2010 Citrus Expo. Ft. Meyers, FL. May 19, 2010.

Tampa Bay Online (TBO). 2008. "Citrus Greening." Tampa Bay Online, a Media General Company. Available at http://www2.tbo.com/content/2008/dec/21/bz-citrus-greening/news-money/ (February 2011).

Roka, F. R. Muraro, A. Morris. 2010. Economics of HLB Management: Pull Trees or Spray Nutritionals. International Citrus Economics Conference, Orlando, FL. Oct. 2010.

Spann, T.M., R.A. Atwood, M.M. Dewdney, R.C. Ebel, R. Ehsani, G. England, S.H. Futch, T. Gaver, T. Hurner, C. Oswalt, M.E. Rogers, F.M. Roka, M.A. Ritenour, M. Zekri, B.J. Boman, K. Chung, M.D. Danyluk, R. Goodrich-Schneider, K.T. Morgan, R.A. Morris, R.P. Muraro, P. Roberts, R.E. Rouse, A.W. Schumann, P.A. Stansly, and L.L. Stelinski. 2010. IFAS Guidance for Huanglongbing (Greening) Management. Publication #HS1165. Gainesville: Institute of Food and Agricultural Sciences, University of Florida. Available online at http://edis.ifas.ufl.edu/hs1165.

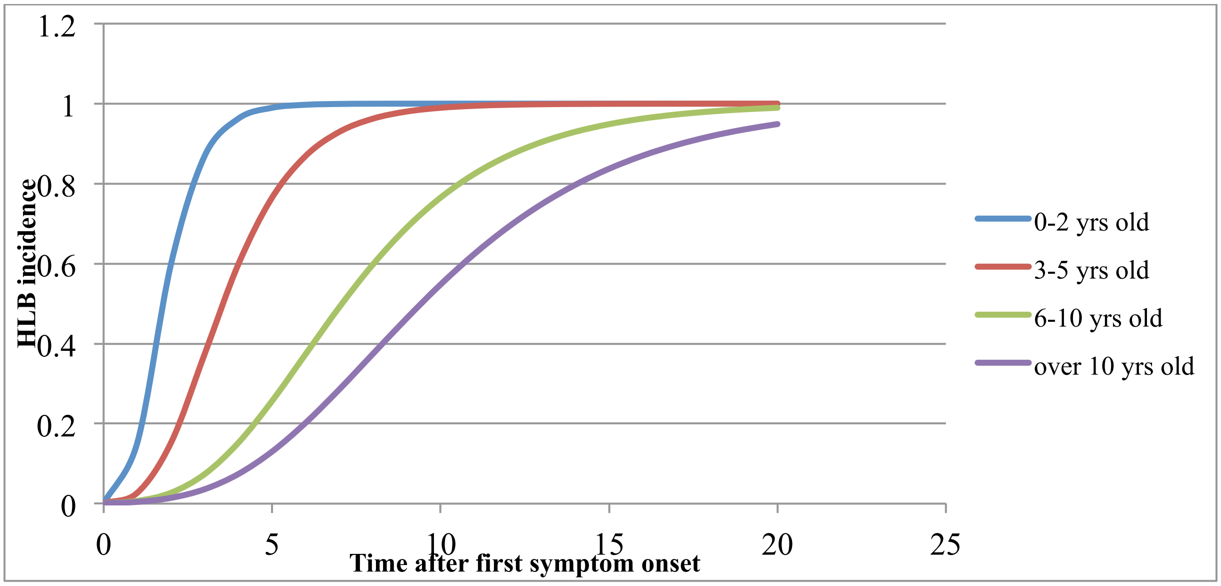

Figure 1: Disease Incidence Using a Gompertz Disease Spread Function

Table 1. Net Present Value for the Do Nothing Strategy

Disease Incidence at First Detection	Average Age of Trees at First Detection					
	0	3	6	10	14	17
0.001	-7252.14	-5722.45	-338.50	1396.89	2731.28	3199.71
0.003	-7263.03	-5960.10	-939.64	694.29	1974.89	2435.31
0.005	-7268.15	-6083.46	-1263.78	312.03	1560.53	2015.28
0.007	-7271.54	-6170.01	-1496.33	36.31	1260.49	1710.57
0.009	-7274.08	-6237.70	-1681.19	-183.76	1020.34	1466.31
0.011	-7276.12	-6293.77	-1836.35	-369.06	817.70	1259.96
0.013	-7277.82	-6341.90	-1971.01	-530.33	641.01	1079.84
0.015	-7279.28	-6384.24	-2090.61	-673.90	483.48	919.11
0.017	-7280.56	-6422.15	-2198.60	-803.81	340.74	773.35
0.019	-7281.70	-6456.54	-2297.36	-922.83	209.81	639.54
0.021	-7282.73	-6488.09	-2388.56	-1032.95	88.55	515.54
0.023	-7283.66	-6517.27	-2473.47	-1135.62	-24.63	399.74
0.025	-7284.52	-6544.45	-2553.02	-1231.97	-130.92	290.90
0.027	-7285.31	-6569.92	-2627.98	-1322.87	-231.30	188.08
0.029	-7286.05	-6593.90	-2698.93	-1409.03	-326.50	90.50
0.031	-7286.74	-6616.58	-2766.36	-1491.00	-417.15	-2.45

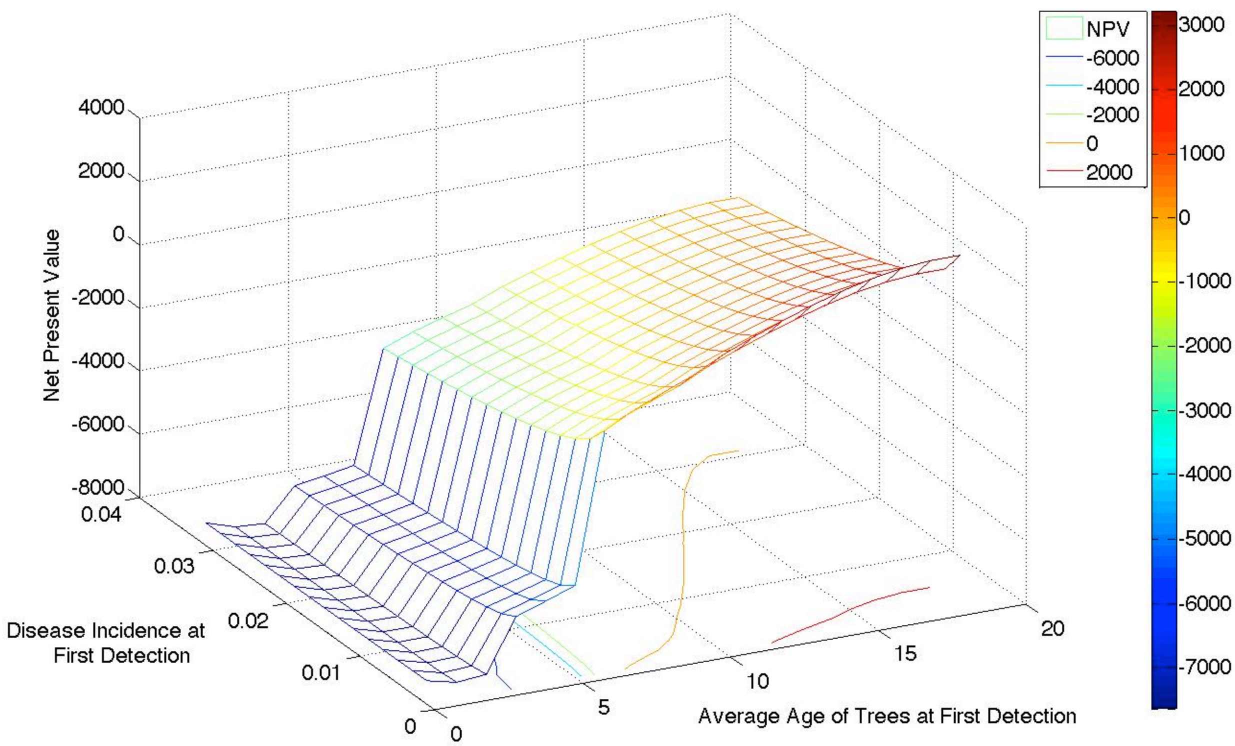

Figure 2. Net Present Value per Acre as a Function of Disease Incidence and Average Tree Age at First Detection with Contour Lines

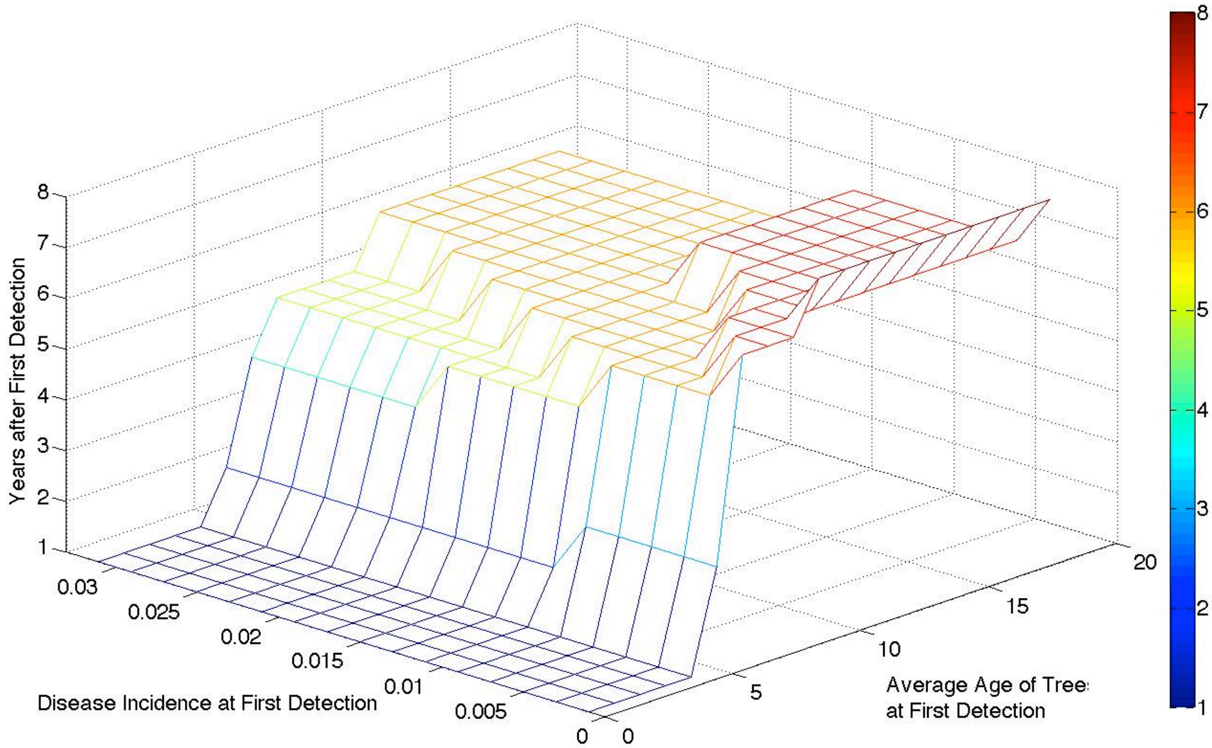

Figure 3. Year at which Operating Costs Exceed Revenues as a Function of Disease Incidence and Average Tree Age at First Detection