The Potential Long-term Cost-effectiveness of Rogueing HLB-Infected Citrus Trees in California: Preliminary Results

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Issue

Citrus greening disease, or Huanglongbing (HLB), has inflicted significant damage on citrus production across Florida and Texas. This disease, caused by the phloem-organized bacterium *Candidatus* Liberibacter asiaticus (*C*Las) and vectored by the Asian citrus psyllid (ACP), leads to nutrient deficiency in infected trees with decreased fruit yield and quality. Upon HLB infection, the disease swiftly spreads throughout the tree (Farnsworth et al. 2014), producing unripened fruit before the trees die from the disease.

Florida's struggle with Huanglongbing serves as a stark example of the potential harm this disease poses to citrus growers who have not been affected yet. The spread of HLB in Florida incurred an estimated cost of $4.5 billion to the state's economy between 2007 and 2011 (Alvarez et al. 2016; Farnsworth et al. 2014; Hodges and Spreen 2012). Florida's citrus value in 2022 fell to around $585 million (USDA-NASS 2023b). Annual production decreased by 8 million tons between 2004 and 2020 (Simnett and Kramer 2020). As of the 2022-2023, Florida orange production was down to approximately 720,000 tons (CPDPP 2023).

In California, the incidence of residential *C*Las+ ACP and HLB+ trees have been escalating rapidly. ACP was initially detected in residential trees in San Diego County in 2008 and is established throughout southern California in both residential and commercial citrus groves (Byrne et al. 2018; Hoddle 2012). Counties in California with identified HLB+ infections include San Diego, Riverside, Los Angeles, San Bernardino, Orange, and most recently, Ventura. None of these infections have occurred in commercial groves. According to the CDFA, the number of identified HLB+ trees reached 7,701 as of April 15, 2024.[1] In July 2023, the number of infected trees was 5,708 (Johnston et al. 2023), a concerning rate of transmission among residential trees of nearly 35% in less than a year. These results

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[1]Source: https://maps.cdfa.ca.gov/WeeklyACPMaps/HLBWeb/HLB_Treatments.pdf

come on the heels of two *C*Las+ ACP being found in commercial groves in two different southern California counties (CPDPP 2020; CPDPP 2022). These events motivate our efforts to identify effective HLB management practices for California and elsewhere as there is still no known cure for HLB.

As noted, California has not yet experienced a HLB tree infection in a commercial grove. To prevent such infections, many growers spray insecticides to control the ACP populations. The California Department of Food and Agriculture conducts surveys and trapping to monitor for ACP as well as release taramixia (parasitic wasps) to control ACP populations, and outreach, among other practices, to help in the battle to control the spread of HLB. Another possible option is removing infected trees (rogueing) once a symptomatic tree is identified. The experience with HLB in Florida and Texas with implementing a three-pronged approach of tree removal (rogueing), insecticide spraying and re-planting with HLB-free trees may suggest otherwise (Graham et al. 2020). Moreover, Li et al. (2020) express that rogueing is not cost-effective in Florida. These negative outcomes may be due to production of processing oranges rather than fresh market fruit, which brings a much lower price, or as suggested by Yuan et al. (2021), the approach lacked region-wide implementation. It is worth noting that California primarily produces for the fresh fruit market (USDA-NASS 2023b) and thus may see different outcomes when rogueing.

In this research note, we consider rogueing (tree removal) of infected trees for a newly planted California Navel orange grove that sells to the fresh market over a 20 year lifespan, which is a sufficient time frame to evaluate the effects of HLB on the productive and profitable lifespan of the grove to see how cost-effective this practice is by itself relative to taking no action to control ACP or HLB. We consider ACP insecticide spraying and both rogueing and spraying approaches in other research notes, which can be found at `https://www.csus.edu/faculty/k/kaplanj/researchnotes/`. Utilizing a simulation model, we assessed the impact of different combinations of rogueing frequencies (ranging from 45 to 135) and thresholds (ranging from 0.1 to 0.4) on citrus production.

Study Methods

We use a budget approach to estimate the effects of HLB on Navel orange production and profits for a representative newly planted California Navel orange grove using alternative rogueing strategies to reduce HLB effects. Data from University of California Cooperative Extension cost and returns studies (O'Connell et al. 2015; Kallsen et al. 2021) and California County Agricultural Commissioner Reports (USDA-NASS 2023a) are used to derive costs, prices, and yield conditions for Navel orange production for a representative newly planted grove in southern California. Table 1 lists the costs for producing California Navel oranges. Table 2 provides the prices per box and maximum boxes per acre used in the analysis and were derived from California County Agricultural Commissioner Reports (USDA-NASS 2023a).

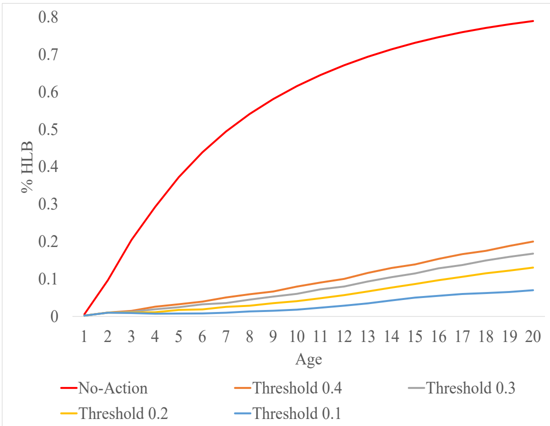
Cultural cost year 1	$7,756.43/acre
Cultural cost year 2	$1,789.04/acre
Cultural cost year 3	$2,066.17/acre
Cultural cost year 4	$3,198.23/acre
Cultural cost year 5	$4,590.30/acre
Cultural cost year 6+	$7,859.15/acre
Monitoring cost	$6/acre/survey
Tree removal cost	$3/tree

Table 1: Cultural costs and rogueing costs used to analyze rogueing tree to manage HLB

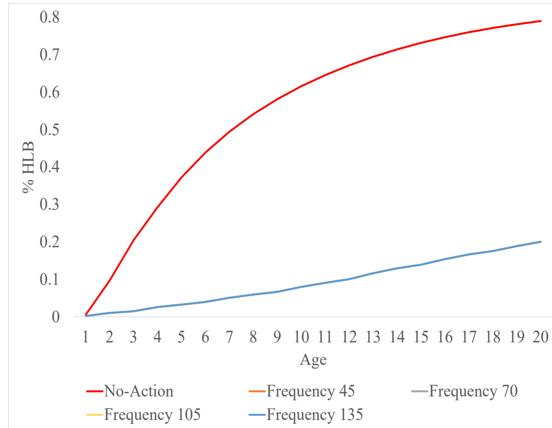
	$/Box	Boxes/acre
Low	6	541
Average	13.5	836
High	21	1,176

Table 2: Price per box and Maximum boxes per acre of Navel oranges used in the analysis of tree rogueing to manage HLB

An agent-based model adapted from Lee et al. (2015) and Haynes et al. (2021) simulates citrus flushes, ACP, and HLB spread in a newly planted Navel orange grove. Simulated data are required given field trials to measure HLB spread or treatment effectiveness are not possible. The simulation model generated HLB severity across various rogueing scenarios involving a range of monitoring frequencies to survey for infected trees and HLB severity thresholds for removing infected trees. Figure 1 shows the average annual HLB severity for the different HLB severity thresholds and grove surveying frequencies over a 20-year time frame. Figure 1a illustrate HLB severity varies by threshold with the lowest HLB severity when the HLB severity is greater than or equal to 40% of a tree is infected as the fewest trees are taken out of production annually under this scenario 2a. Figure 1b shows that the HLB severity does not vary across surveying frequencies for a given HLB severity threshold as the



(a) HLB severity by grove age for no action and HLB severity tree removal thresholds of 10%, 20%, 30% and 40% (labeled as Threshold 0.1, Threshold 0.2, Threshold 0.3, and Threshold 0.4, respectively).



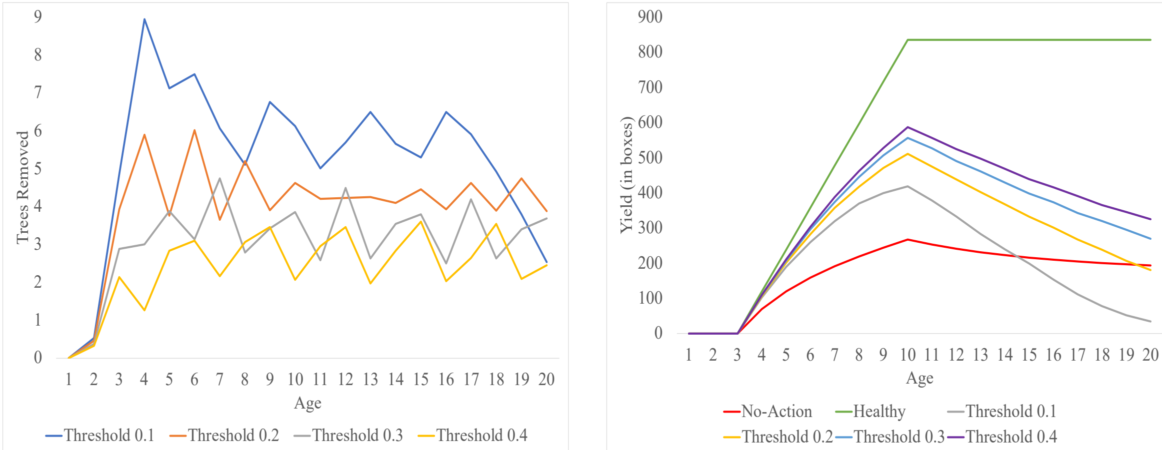
(b) HLB severity by grove age for no action and HLB survey frequencies of 45, 70, 105, and 135 days (labeled as Frequency 45, Frequency 70, Frequency 105, and Frequency 135, respectively) for the 40% HLB severity tree removal threshold.

Figure 1: HLB severity for a representative Navel orange grove in California when taking no action and for varying HLB severity threshold and grove monitoring survey frequencies.

same number of infected trees are removed annually regardless of how often one surveys throughout the year. As such, the yield per acre for different ages of a grove do not vary for different HLB monitoring survey frequencies but do for the different tree removal thresholds. Figure 2 provides the trees removed each year and the corresponding yield in 37.5 lbs boxes per acre per year over the 20-year simulation time frame. As seen in Figure 2a, fewer trees are removed each year the higher the threshold and as such Figure 2b yields increase with increases in the threshold.

To estimate healthy (uninfected) yield in each year for each scenario, We use a weighted-average of the yield per acre for data from the California County Agricultural Commissioner Reports (USDA-NASS 2023a) as the average maximum yield per acre[2] shown in Table 2 and the age-yield profile reported in the UCCE cost and returns studies (O'Connell et al. 2015; Kallsen et al. 2021). For the infected grove over the timeframe, a yield factor, estimated by Bassanezi et al. (2011) is multiplied by the healthy yield in a given year and then applied to the remaining trees in the infected grove in that year and then across the different grove ages. We similarly, use a weighted-average of Navel orange prices from the California County Agricultural Commissioner Reports (USDA-NASS 2023a) to derive the average price per 37.5 lb box. We also use the lower and upper bounds for the 95% confidence levels for the low and high price scenarios, respectively. For the simulated citrus grove, we assume there are 110 trees per acre. We use the estimated age-yield profiles in Figure 2b to calculate profits for the healthy groves, infected groves where no action is taken to control HLB, and infected groves where rogueing scenarios are adopted over a 20-year lifespan as this is sufficient time to observe the effects of HLB spread and effectiveness of rogueing scenarios on yields and grove profits . We evaluate cumulative profits across the different scenarios, and highlight when the grove turns a positive cumulative profit and how long the grove remains profitable as HLB spreads and rogueing reduces the number of trees per acre.

[2]This underestimates the yield when a grove is established since the data captures yields for all ages.



(a) Average trees removed per acre by grove age for HLB severity tree removal thresholds of 10%, 20%, 30% and 40% (labeled as Threshold 0.1,Threshold 0.2, Threshold 0.3, Threshold 0.4, respectively).

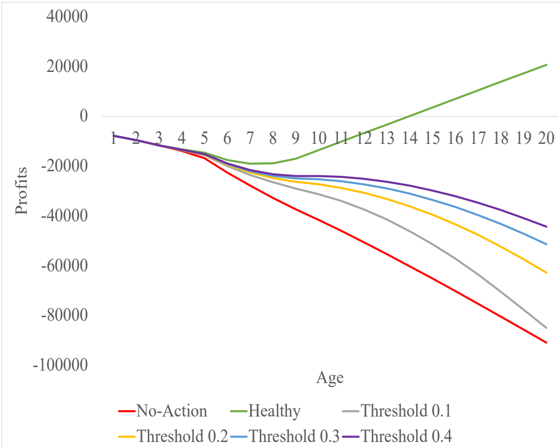
(b) Yield per acre by grove age for HLB severity tree removal thresholds of 10%, 20%, 30% and 40% (labeled as Threshold 0.1,Threshold 0.2, Threshold 0.3, Threshold 0.4, respectively) for mature yield of 836 boxes/acre/year.

Figure 2: Trees removed by year and yield (boxes/acre/year) for a representative California Navel orange grove and for varying HLB severity thresholds.

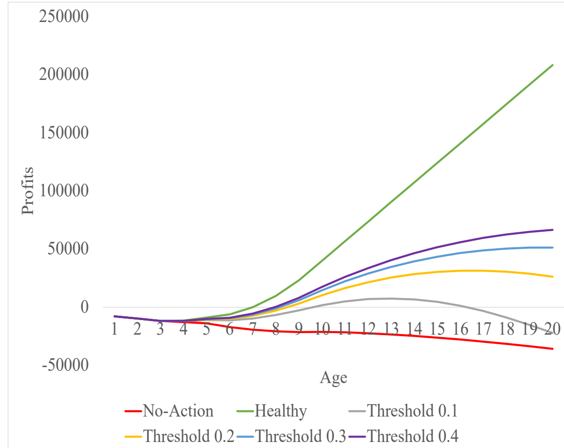
Findings

The results from the analysis reveal that taking no action to mitigate the spread of HLB show negative profits every year throughout the 20-year timeframe. When selecting rogueing strategy, it appears that positive profits are possible when prices are well-above average and yield is at or above average (see Table 3). Also, the threshold level for removing a tree affected HLB spread, trees removed, and ultimately the profitability of the grove, whereas the frequency of surveying the grove did not (Figures 3a through 3b).

The most profitable rogueing practice was observed at a frequency of 135 days and a HLB tree removal threshold of 40%. No profits were generated for HLB groves using rogueing at prices of $6 or $13.5 or with a yield of 541 boxes. Profits were only realized at year 12 for a threshold of 0.4 and year 13 for a threshold of 0.3 when the high price of $21 and a yield of 836 boxes were considered (see Table 3). Profits were consistently generated for each frequency and threshold combination with the high price of $21 and high yield of 1176 boxes (Table 3).



(a) Cumulative profits for a healthy grove, an HLB infected grove, and rogueing scenarios when monitoring every 135 days for varying HLB thresholds (10%, 20%, 30%, 40%) over a 20-year lifespan with a price of $13.5/box and a mature yield of 836 boxes per acre. No rogueing scenario was able to produce positive profits in any year.



(b) Cumulative profits for a healthy grove, an HLB infected grove, and rogueing scenarios when monitoring every 135 days for varying HLB thresholds (10%, 20%, 30%, 40%) over a 20-year lifespan with a price of $21/box and a mature yield of 1176 boxes per acre. All thresholds generated profit for this scenario, with 40% being the most successful.

Figure 3: Cumulative profits for a healthy grove, an HLB infected grove, and rogueing scenarios by HLB severity tree removal threshold over the 20-year simulated time frame for the average price and yield simulation and the high price and yield simulation.

	$21/box, 836 boxes/acre		$21/box, 1176 boxes/acre	
	First Profitable Year	**Last Profitable Year**	**First Profitable Year**	**Last Profitable Year**
Healthy	year 9	year 20	year 7	year 20
No-Action	-	-	-	-
Rogue (135, 0.4)	year 12	year 17	year 8	year 20
Rogue (135, 0.3)	year 13	year 15	year 9	year 20
Rogue (135, 0.2)	-	-	year 9	year 17
Rogue (135, 0.1)	-	-	year 10	year 13
Rogue (105, 0.4)	year 12	year 17	year 8	year 20
Rogue (105, 0.3)	year 13	year 15	year 9	year 20
Rogue (105, 0.2)	-	-	year 9	year 16
Rogue (105, 0.1)	-	-	year 10	year 13
Rogue (70, 0.4)	year 12	year 17	year 8	year 20
Rogue (70, 0.3)	year 13	year 16	year 9	year 20
Rogue (70, 0.2)	-	-	year 9	year 15
Rogue (70, 0.1)	-	-	year 10	year 13
Rogue (45, 0.4)	year 12	year 17	year 8	year 20
Rogue (45, 0.3)	year 13	year 17	year 9	year 20
Rogue (45, 0.2)	-	-	year 9	year 16
Rogue (45, 0.1)	-	-	year 10	year 13

Table 3: Grove age when cumulative profits are greater than zero for the first time and the last year annual profits are greater than zero for a healthy grove, an HLB infected grove, and select rogueing scenarios that resulted in positive cumulative profits at some time during the 20-year simulated time frame. Scenarios not shown did not generated positive profits at any age except for the excluded healthy grove scenarios which were profitable but are not listed to highlight the positive rogueing scenarios.

Key Insights

- Rogueing trees to control HLB in Navel orange groves in California is not a sustainable option unless prices are well above average and yields are at or above average. Moreover, cumulative profits for rogueing strategies lag far behind those for a healthy grove and signal Navel orange production may not be a viable land use choice once HLB spreads to commercial groves.
- The positive results seen above rely on an assumption that all the available fruit can be sold as fresh fruit. Since HLB leads to bitter fruit that cannot be sold as fresh fruit, these results cast further doubt that rogueing is a viable option for California commercial groves.

Acknowledgements

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References

Alvarez, S., E. Rohrig, D. Solís, and M. H. Thomas (2016). Citrus Greening disease (huanglongbing) in Florida: economic impact, management and the potential for biological control. *Agricultural Research 5*, 109–118.

Bassanezi, R. B., L. H. Montesino, M. C. G. Gasparoto, A. Bergamin Filho, and L. Amorim (2011). Yield loss caused by huanglongbing in different sweet orange cultivars in São Paulo, Brazil. *130*(4), 577–586.

Byrne, F. J., E. E. Grafton-Cardwell, J. G. Morse, A. E. Olguin, A. R. Zeilinger, C. Wilen, J. Bethke, and M. P. Daugherty (2018). Assessing the risk of containerized citrus contributing to Asian citrus psyllid (Diaphorina citri) spread in California: Residence times and insecticide residues at retail nursery outlets. *Crop Protection 109*, 33–41.

CPDPP (2020). *CLas-positive Asian Citrus Psyllid Found in Riverside Commercial Grove*. CPDPP. https://citrusinsider.org/.

CPDPP (2022). *CLas-positive Asian Citrus Psyllid Found in San Diego Commercial Grove*. CPDPP. https://citrusinsider.org/.

CPDPP (2023). *Florida Production Numbers Serve as California's Warning Signal*. CPDPP. https://citrusinsider.org/.

Farnsworth, D., K. A. Grogan, A. H. van Bruggen, and C. B. Moss (2014). The potential economic cost and response to greening in Florida citrus. *Choices 29*(3), 1–6.

Graham, J., T. Gottwald, and M. Setamou (2020). Status of huanglongbing (hlb) outbreaks in florida, california and texas. *Tropical Plant Pathology 45*, 265–278.

Haynes, S., A. Singh, and J. D. Kaplan (2021). An agent based model of acp/hlb in california citrus-preliminary results on the effects of insecticide and coordination on the spread of hlb. *California State University, Department of Economics Research Note 2021-2*.

Hoddle, M. (2012). Huanglongbing detected in Hacienda Heights, Los Angeles County. *Center for Invasive Species Research. Accessed December 5*, 2021.

Hodges, A. W. and T. H. Spreen (2012). Economic impacts of Citrus Greening (HLB) in Florida, 2006/07–2010/11: Fe903/fe903, 1/2012. *EDIS 2012*(1), 1–6.

Johnston, E., J. Kaplan, and A. Singh (2023). Potential economic consequences from huanglongbing (aka citrus greening disease) in california commercial citrus: Results for valencia orange production. *California State University, Department of Economics, Research Note 2023-4*.

Kallsen, C. E., G. W. Douhan, K. Jetter, D. Stewart, and D. A. Sumner (2021). *Sample Costs to Establish an Orchard and Produce Oranges*. UC Davis Department of Agricultural and Resource Economics. https://coststudyfiles.ucdavis.edu/uploads/pub/2021/08/12/2021orangessjvsouth.pdf.

Lee, J. A., S. E. Halbert, W. O. Dawson, C. J. Robertson, J. E. Keesling, and B. H. Singer (2015). Asymptomatic spread of huanglongbing and implications for disease control. *Proceedings of the National Academy of Sciences 112*(24), 7605–7610.

Li, S., F. Wu, Y. Duan, A. Singerman, and Z. Guan (2020). Citrus greening: Management strategies and their economic impact. *HortScience 55*(5), 604–612.

O'Connell, N. V., C. E. Kallsen, K. Klonsky, and K. P. Tumber (2015). *Sample Costs to Establish an Orchard and Produce Oranges*. UC Davis Department of Agricultural and Resource Economics. https://coststudyfiles.ucdavis.edu/uploads/cs_public/19/d4/19d4f1bb-408a-443e-a759-36fd53a2948f/oranges_vs_2015.pdf.

Simnett, S. and J. Kramer (2020). Citrus Greening disease caused falling production in Florida, but production is forecast to stabilize in 2019/20. *Economic Research Service, United States Department of Agriculture. Accessed December 5*, 2021.

USDA-NASS (2023a). *County Agricultural Commissioner Annual Report*. USDA-NASS. https://www.nass.usda.gov/Statistics_by_State/California/Publications/AgComm/index.php/.

USDA-NASS (2023b). *QuickStats*. USDA-NASS. https://quickstats.nass.usda.gov/.

Yuan, X., C. Chen, R. B. Bassanezi, F. Wu, Z. Feng, D. Shi, J. Li, Y. Du, L. Zhong, B. Zhong, et al. (2021). Region-wide comprehensive implementation of roguing infected trees, tree replacement, and insecticide applications successfully controls citrus huanglongbing. *Phytopathology® 111*(8), 1361–1368.