# New Economic Returns to Coordinated Actions to Control HLB

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*Year 2 of 2 (100% Complete)*

## Objectives

1. Define appropriate/useful measures of the net benefits of coordinated action against ACP and HLB
2. Estimate the current net benefits of coordinated ACP and HLB control efforts
3. Estimate the dynamic path of net benefits under alternative degrees of coordination levels to determine when coordination is no longer cost effective
4. Study fairness issues regarding fees collected and subsequent control of ACP and HLB that may hinder willingness to undertake coordinate action

## Problem and Significance

The primary action taken by Southern California citrus growers to prevent the emergence of huanglongbing (HLB) in commercial groves is coordinated area-wide insecticide treatments against the disease vector, the Asian citrus psyllid (ACP). The coordination aspect of area-wide treatment involves growers applying insecticides within an agreed-upon time window. The guiding theory behind coordination is that treating an entire area within a treatment window improves the efficacy of treatment because ACP cannot avoid treatment by moving to an untreated orchard. However, growers have not achieved 100% coordination of sprays. Estimation of the reduction in treatment efficacy from incomplete coordination provides data needed to better understand the magnitude of benefits that could accrue from better coordination.

## Benefit to Industry

Estimates of the incremental gains from greater coordination of area wide ACP treatments will allow the California citrus industry to better target limited resources available to prevent spread of HLB to commercial groves. The industry has options for controlling HLB. Directing resources towards options that achieve the largest net benefits maximizes the probability that HLB is kept out of commercial groves.

## Progress Summary

The effects of greater coordination in area-wide treatment were estimated by using an agent-based model developed specifically to better understand how ACP/HLB evolve over time. The model was constructed primarily by Drew Posny and Weiqi Luo who work for USDA's Agricultural Research Service in Fort Pierce, Florida. CRB project 5300-212 provided financial support for model construction. Agent-based models are "bottom-up" models that mimic individual interactions between agents in the system and between the agents and their environment over time. The total effect of these interactions are then used to estimate landscape-level impacts. The agents interact according to set of rules specified by mathematical equations. The agents in the model we used are citrus trees, the ACP population, and the HLB disease. Weather conditions and ACP/HLB control measures impact how ACP populations and disease spread evolve over time. The model attempts to represent reality by accounting for many factors including ACP lifespan, ACP net reproduction rate and dispersal distance, citrus host type, planting density, and flush availability. The model runs over actual landscape that include the location of both citrus orchards and residential citrus trees. Our simulations were run on the three Ventura County landscapes shown in Figure 1. Results from these simulations are not readily transferable to other regions because of the importance of climate in determining ACP growth rates.

The model is designed to allow the analyst great flexibility in setting up the model to account for differences in geography, climate, and ACP population dynamics. We needed to specify 55 separate parameter values before running the model. This flexibility however comes at a cost. Data to guide parameter values were often not available. And too-often when we found studies and data on which to base parameter values the resulting model runs resulted in simulated ACP populations and associated disease spread that bore little resemblance to the reality of low ACP populations and no official detections of HLB in Ventura County orchards. In selecting model parameters we were cognizant of the need to parameterize the model so that results generally agreed with on-ground reality even when selected parameters may not have been supported by data.

To simulate the effect of increased coordination of treatments on ACP populations requires selection of meaningful scenarios to run with the model. Two natural scenarios are to simulate ACP populations, and any resulting spread of HLB, assuming first that growers in an area all made treatments in a 21-day window, and then assuming that all treatments were made in a 60-day window. We anticipated that ACP populations would be more impacted when area-wide treatments were all completed within 21 days than within 60 days. We also wanted to make sure that the model behaved as we thought it should and included a no-control scenario where no treatments targeted at ACP were made. For each of these three coordination scenarios we altered the efficacy of insecticide application to account for differences across the common insecticides used to control ACP. At the low end we assumed that 50% of treated ACP were killed by treatment. At the high end we assumed that 80% died. These efficacy levels reflect ACP sampling data before and after treatments in Ventura County.

Simulations of HLB epidemics within the three study areas in Ventura County were run for a period of 20 years randomizing the initial location of cryptically infected citrus trees (infectious, but not symptomatic) over 100 replicate simulations for each treatment. Infected trees were initially located in either commercial groves, residential properties, or both. To estimate the benefits of coordination, we examined the effect of different coordination levels on ACP population dynamics, on the progression of HLB, and on the cumulative impact of the disease on commercial citrus groves.

Figure 2 shows per-tree ACP populations (vertical axes) over time (horizontal axes) in the Ojai Valley study area. The first notable result is that psyllids spread to every commercial grove and residential property within the first year of simulation across every scenario. Average ACP prevalence reaches maximum carrying capacities in most of the scenarios within the first six months.

Simulation results demonstrate that grove size is important in determining whether ACP can be controlled in an orchard. Small groves have a larger proportion of borders which implies more points of infestation than larger groves. The level of coordination corresponding to the 60-day window offers little ACP control unless efficacy is 80% larger groves. Treatments coordinated within a 21-day window with 50% efficacy can keep ACP populations at low levels only in bigger groves over a 20-year period. As the efficacy of insecticide treatments increases, the level of ACP control improves. For example, insecticide treatments coordinated within a 21-day window with 80% efficacy can keep ACP populations under control. These results show that high levels of both insecticide efficacy and coordination are needed to effectively manage ACP populations in Ventura County.

In terms of HLB dynamics, Figure 3 results show that three treatments per year within a 21-day window can delay the onset of HLB and keep the proportion of diseased trees after 20 years under 50% across all study areas. With 65% efficacy, the 21-day window can keep disease incidence at 25% for 10 years in many scenarios. By contrast, treatments with 50% efficacy are not effective in delaying disease spread. Landscape structure also impacts ACP and HLB dynamics. In Ojai disease incidence in commercial groves reaches its maximum under no control after seven years, even when the initial inoculum comes exclusively from residential properties. This suggests that areas with high intermixing of commercial and residential properties may face a significant challenge trying to reduce HLB spread if no control measures are applied. Fortunately, the results suggest that coordinated insecticide treatments with high efficacy are most effective in this landscape. In Las Posas and Santa Clara, where the commercial groves are larger and more isolated, the disease spreads more slowly under no control.

To examine the impact of the HLB epidemic on commercial citrus groves after 20 years, we calculated the area under the disease progress curve (AUDPC) from Figure 3. We tested the effect of the initial location of HLB-positive trees, the coordination scenario and the level of efficacy on the AUDPC through an analysis of variance (ANOVA). The results are shown in Figure 4. When the three landscapes are considered together, the landscape accounts for the majority of the variance in AUDPC, followed by the coordination scenario, the level of efficacy and the initial location of infected trees.

## Conclusions

California citrus growers have supported area-wide ACP treatment programs as the primary means of controlling ACP and preventing spread of HLB. Our simulation results indicate that this support is well-placed if growers in an area coordinate their treatments so that they occur within a 21-day window and if effective insecticides are used. If either of these conditions are not met then our results indicate that it will be quite difficult to control the spread of HLB in Ventura County after infection enters commercial groves.

## CRB Project # 5300-192

## Publications and Presentations

Garcia-Figuera, S., Deniston-Sheets, H, Grafton-Cardwell, E.E., Babcock, B.A., Lubell, M., and McRoberts, N. 2021. “Perceived Vulnerability and Propensity to Adopt Best Management Practices for Huanglongbing Disease of Citrus in California.” *Phytopathology*. https://doi.org/10.1094/PHYTO-12-20-0544-R.

Garcia-Figuera, S., Grafton-Cardwell, E.E., Babcock, B.A., Lubell, M., and McRoberts, N. 2021. “Institutional Approaches for Plant Health Provision as a Collective Action Problem.” *Food Security* https://doi.org/10.1007/s12571-020-01133-9.

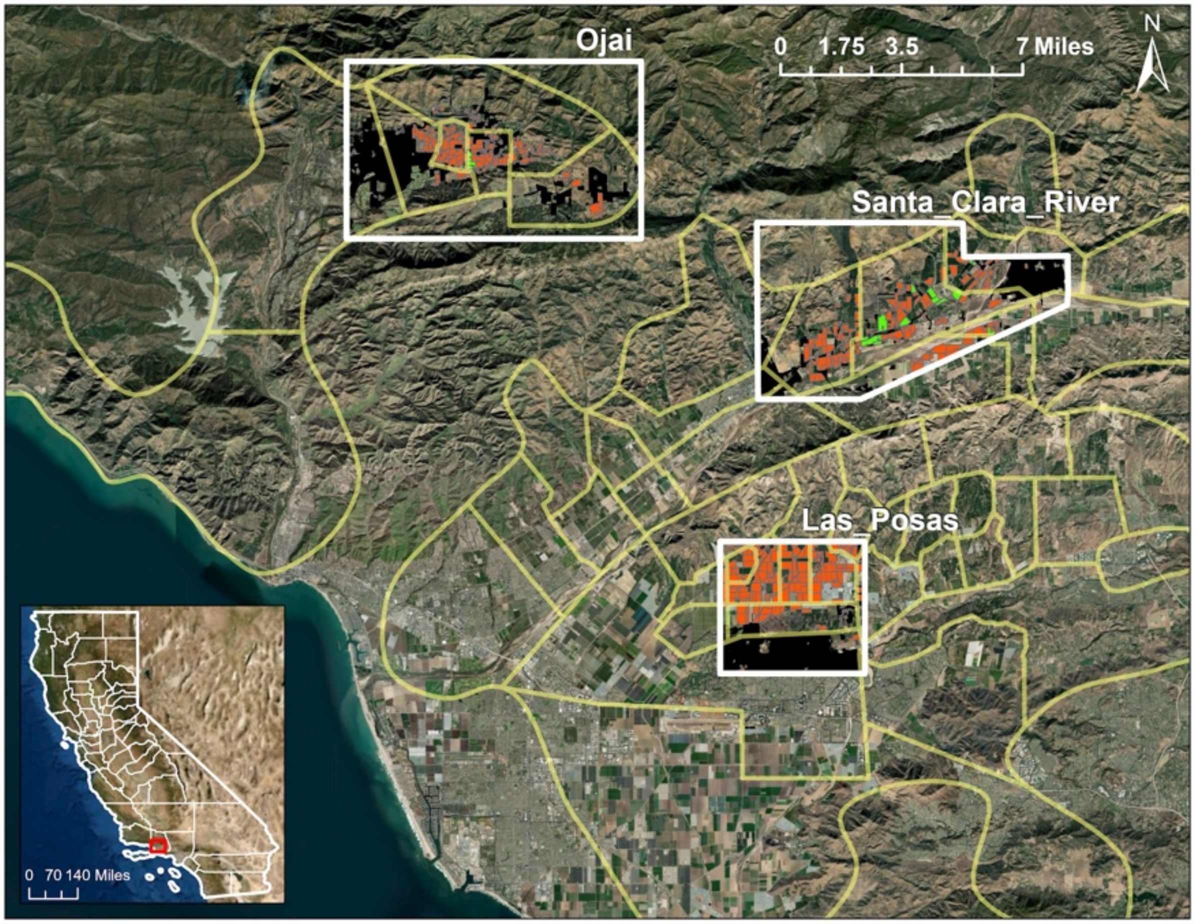


*Figure 1: Map of the three study areas in Ventura County. The boundaries of the three study areas are shown in white and the boundaries of the Psyllid Management Areas (PMAs) are shown in yellow. Within each study area, conventional citrus groves are shown in orange, organic citrus groves are shown in green and residential properties are shown in black. The map on the lower left corner shows the location of the study areas in the state of California.*

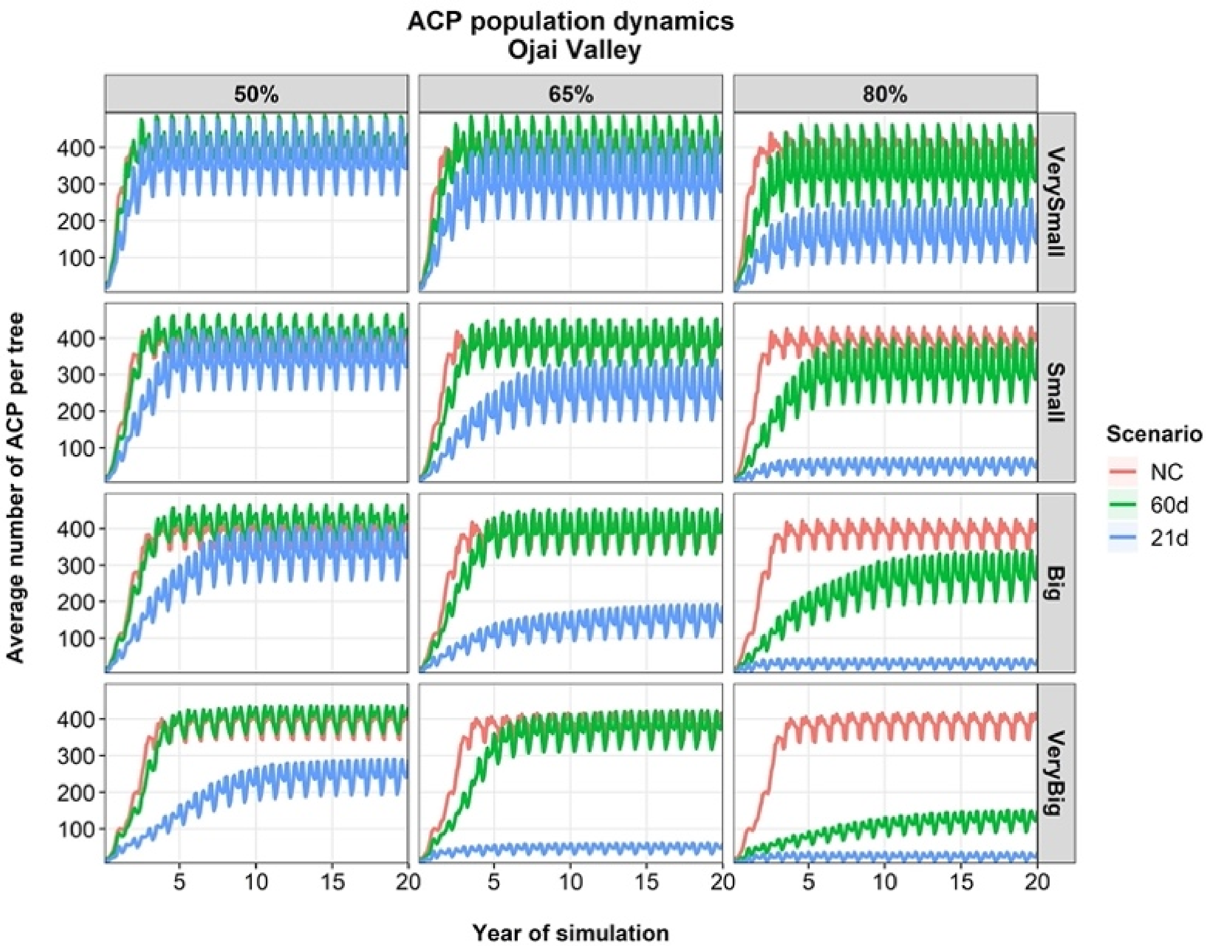


*Figure 2: Estimated ACP dynamics in Ojai Valley. The y axis represents the ACP per tree over 20 years of simulation. Columns correspond to the efficacy of the insecticide treatments against ACP. Rows correspond to the size of citrus groves. Colors correspond to three different coordination levels for the insecticide treatments: no control (red), insecticide treatments three times per year within a 60-day period (green) and within a 21-day period (blue).*

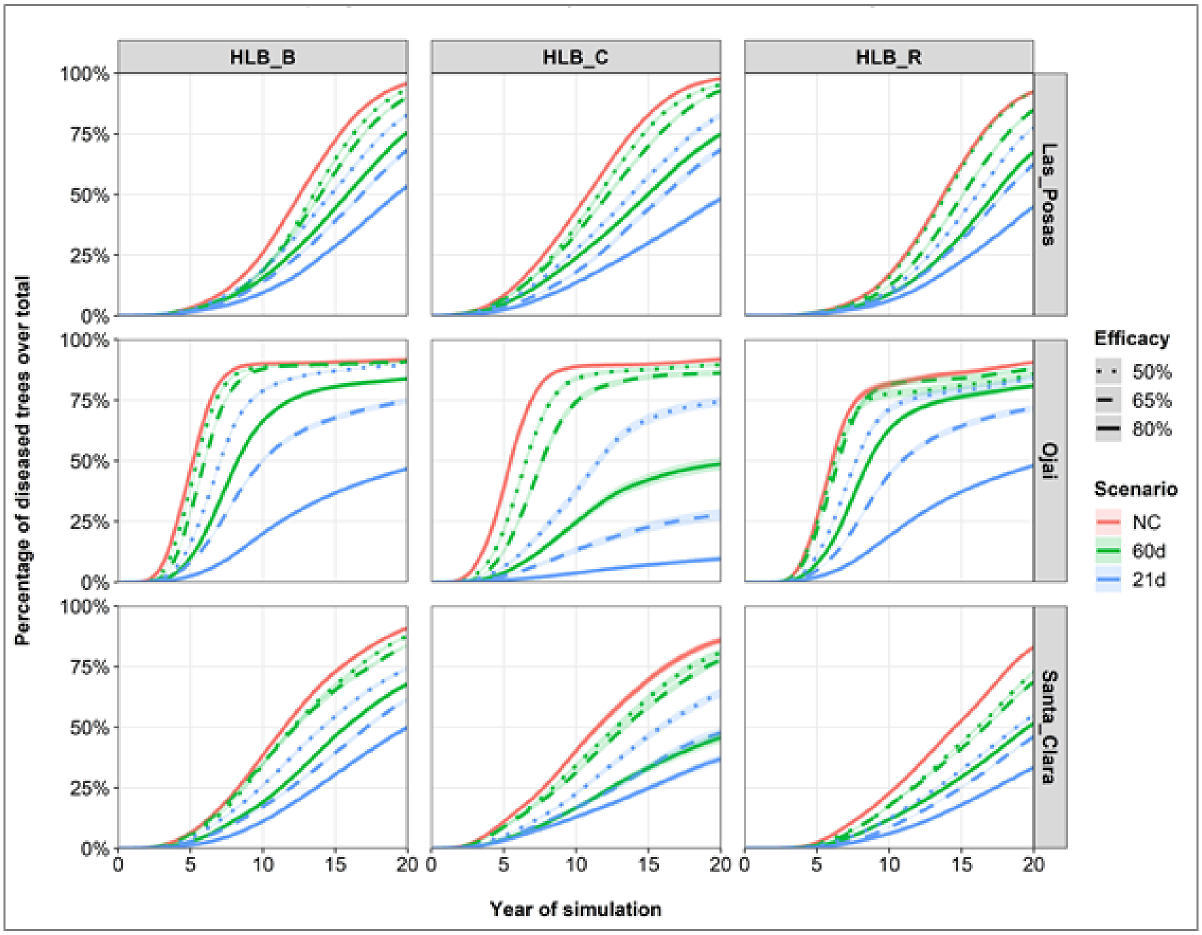


*Figure 3: Estimated evolution of the HLB epidemic in commercial groves in three landscapes in Ventura County over 20 years. The curves show the average percentage of diseased trees (exposed, cryptically infected or symptomatic) across 100 simulations. The line types correspond to three different efficacy levels of the insecticide treatments against ACP: 50% (short dash), 65% (long dash) and 80% (solid). The colors correspond to three different coordination levels: no control (red), insecticide treatments 3 times a year within a 60-day period (green) and within a 21-day period (blue). These scenarios were evaluated under three different initial conditions: HLB-infected trees in both commercial and residential properties (HLB_B), only in commercial (HLB_C) or only in residential (HLB_R).*

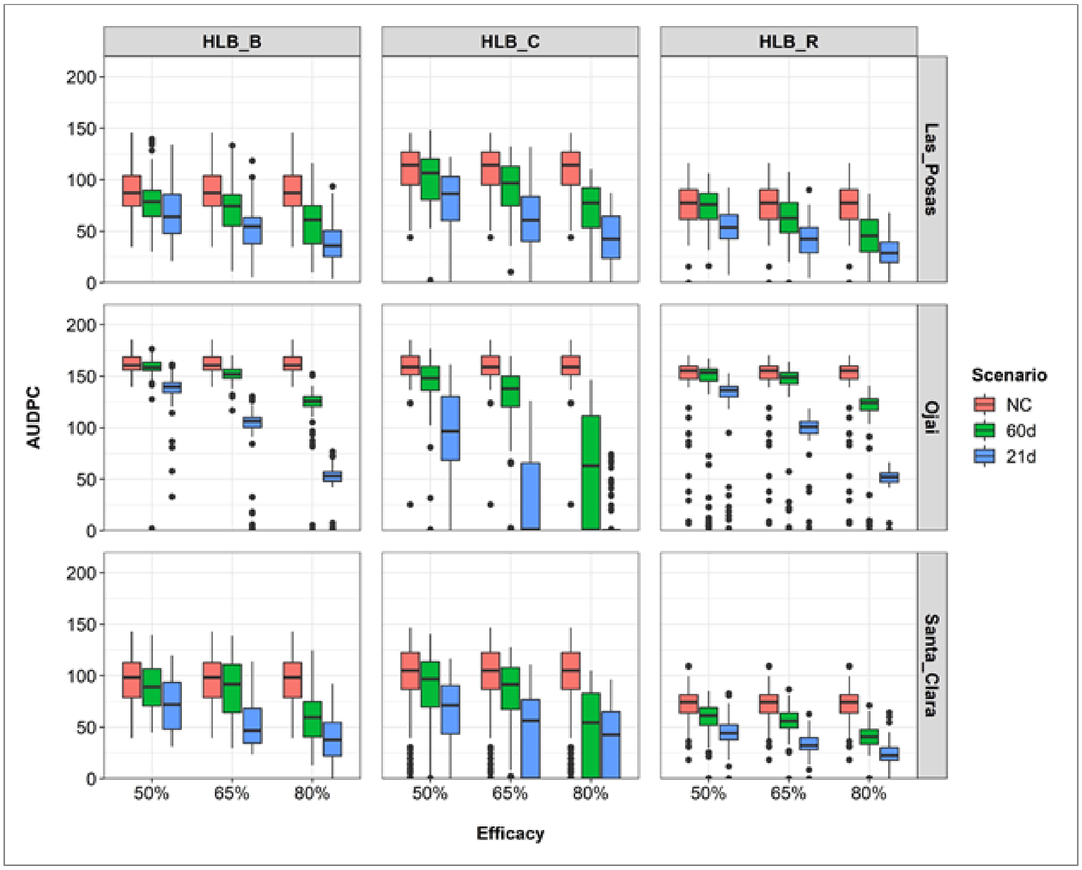


*Figure 4: Estimated impact of the HLB epidemic in commercial groves in three landscapes in Ventura County over 20 years. The boxplots show the area under the disease progress curve (AUDPC), with the first quartile, median and third quartile of the AUDPC values over 100 replicates for each treatment. The x axis on each plot shows three different efficacy levels of the insecticide treatments against ACP: 50%, 65% and 80%. The colors correspond to three different coordination levels: no control (red), insecticide treatments 3 times a year within a 60-day period (green) and within a 21-day period (blue). The columns correspond to three different initial conditions: HLB-infected trees in both commercial and residential properties (HLB_B), only in commercial (HLB_C) or only in residential (HLB_R). The rows correspond to the three study areas in Ventura County.*