Modeling the effectiveness of California's efforts to contain Huanglongbing

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Summary

One of the most complicated issues facing the Citrus Pest and Disease Prevention Committee (CPDPC) is how to quantify the effectiveness of the residential control program in protecting commercial groves from Huanglongbing, as it is difficult to establish what would have happened if the program had never been implemented (a counterfactual situation). Although there is no perfect way to discern the answers, the best option available is to use a model, with care, backed up with expert evaluation of the results. This is the approach we have used over the last year, refining an agent-based model (ABM) for Huanglongbing (HLB) spread. Preliminary work with a second spatially explicit model, the Cambridge model, has also been completed.

Results from the ABM indicate that a residential control program near commercial groves, structured like the one currently utilized in Southern California, significantly limits disease incursion into commercial groves from residential areas, especially when combined with an area-wide Asian Citrus Psyllid (ACP) management program in commercial citrus. Results from the Cambridge model also indicate that tree removal and ACP management limit HLB spread.

INTRODUCTION

The ABM, built by the epidemiology team at the USDA-ARS lab in Ft. Pierce, FL, has been applied to study two main groups of California landscapes: San Gabriel and Ventura County. Within Ventura, we have simulated the impacts of different configurations of the disease management program, in complement with a project funded by the Citrus Research Board which is evaluating the potential economic benefits of cooperation among growers.

Work on the Cambridge SEIR (Susceptible, Exposed, Infected, Removed) model is underway in collaboration with Dr. David Bartels (USDA-APHIS) and Prof. Christopher Gilligan (Cambridge University, UK) to give the program an additional set of projections for the development of HLB across a larger swath of California, using a model they developed and used for Texas. This additional work is being supported by a Plant Protection Act (Sec. 7721) award to UC Davis/Cambridge and APHIS.

Background

Agent-based model

Previous simulations with the agent-based model indicated that residential control programs consisting of HLB+ tree removal combined with insecticide applications limited disease spread in the city of San Gabriel. However, that work left unanswered questions about how limiting residential infections would ultimately affect commercial citrus production. To address this, we used the ABM to simulate the spread of HLB from residential infections into commercial groves in three areas of Ventura County: Las Posas, Ojai, and the Santa Clara Valley (Figure 1). Scenarios simulated a 20-year timeframe.

Three scenarios were completed with the ABM. Two used HLB/ACP control programs designed to mimic strategies currently utilized by CDFA and California growers as closely as possible within the inherent limitations of the model; one of these applied control in residential areas only, and the other in both residential and commercial areas. The third scenario implemented no control program. Each scenario was replicated 100 times, with the residential HLB introduction location randomized for each replication.

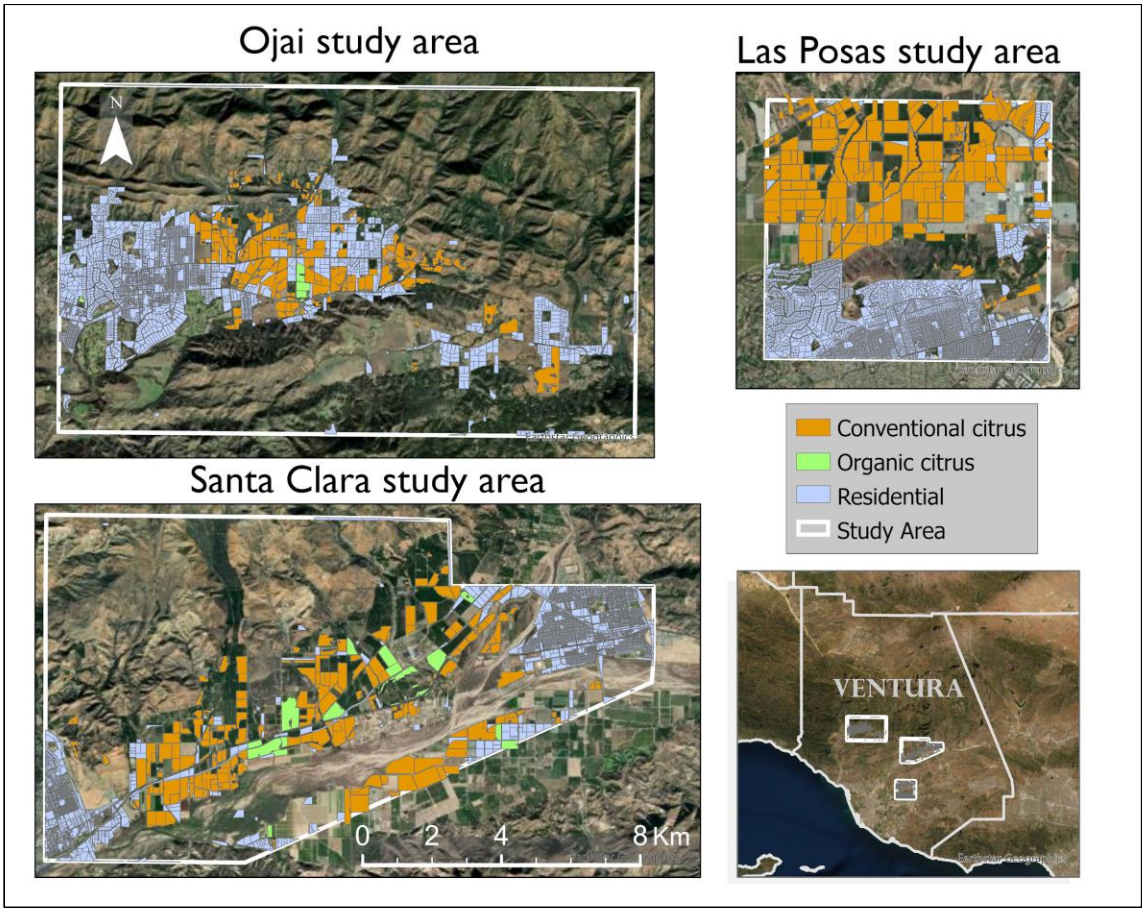

Figure 1. The three study areas in Ventura county used in the agent-based model. Orange polygons indicate the location of conventional citrus groves, green indicates organic groves, and purple are residential locations.

Residential

Under the "Residential" control program, a risk-based survey is implemented four times per year, surveying 25% of residential properties, with a 50% sampling density per property. Huanglongbing confirmations occur two weeks after the survey. Within seven days of confirmation, an insecticide spray with 90% efficacy is applied in a 50 m radius around any detected HLB+ trees, and a 250 m survey around the detection is implemented. Any subsequent HLB+ trees detected are removed, but no additional insecticide applications are made, regardless of additional detections.

Residential & Commercial

Scenarios implementing both residential and commercial control utilized the same control strategies detailed above, with the addition of commercial insecticide sprays. These sprays mimicked the current area-wide strategy in Ventura, with an insecticide applied once each during Jan-Feb, Jul-Aug, and Sep-Oct. All groves were treated within 21 days. The insecticide was assigned a 50% efficacy level as a compromise between high efficacy achieved by some growers and the low level of control obtained in other cases.

Cambridge model

The Cambridge model simulated HLB spread in Southern California (Figure 2) over 6 years, from 2015 - 2021. Two scenarios are presented here: HLB+ tree removal with ACP management, or no control. A 400 m treatment radius around HLB+ trees was assumed in these simulations. Treatments are assumed to reduce HLB transmissibility by 80%.

Figure 2. The Southern California study area used in the Cambridge model.

Results

Agent-based model

The percent of commercial trees infected with HLB over time is shown in Figure 3, and in residential trees in Figure 4. There are contrasting results for commercial production in Ojai compared with the other two areas studied with the ABM; in the scenario where only residential controls are implemented, HLB is predicted to reach more than 50% of trees in Ojai after 20 years. In Las Posas and the Santa Clara valley, HLB incidence in commercial citrus is predicted to be approximately 2% and 3%, respectively, after 20 years (Table 1). Although these simulations assume initial infections were always in residential areas, the results reveal that the effect of landscape and the spatial mixing of residential and commercial citrus may have a stronger impact on the rate of disease spread than was previously appreciated. Disease spread is predicted to be comparatively rapid in Ojai because of the extent to which commercial and residential citrus are intermingled (Figure 1). Note, however, that even in Ojai, effective vector control in commercial citrus is predicted to keep disease incidence to <2% of trees after 20 years.

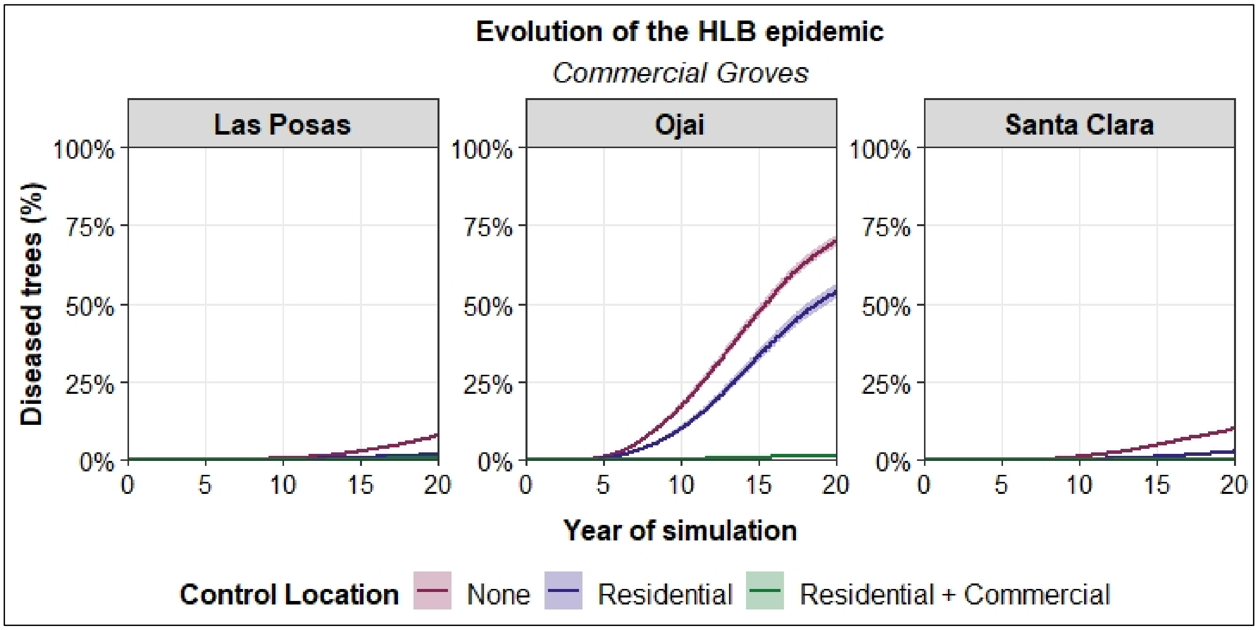

Figure 3. The percent of diseased trees in commercial groves in three study areas of Ventura county over 20 years under three different huanglongbing/ Asian citrus psyllid control programs.

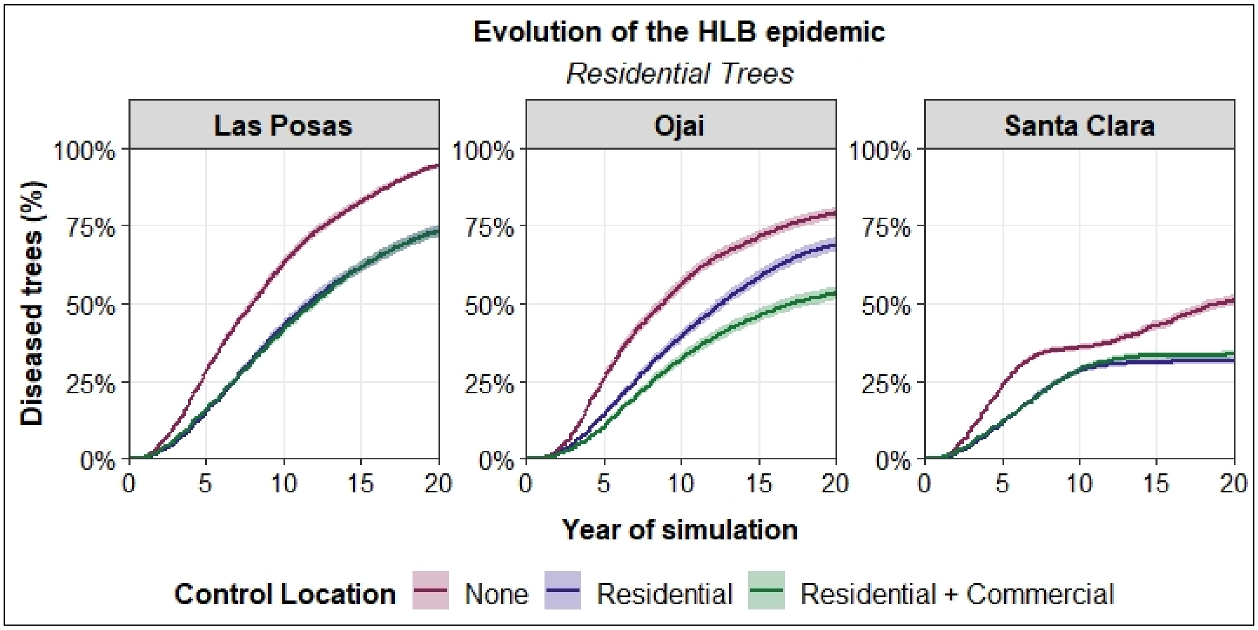

Figure 4 The percent of diseased trees in residential areas in three study areas of Ventura county over 20 years under three different huanglongbing/ Asian citrus psyllid control programs.

Table 1. Huanglongbing progress over five-year intervals from the simulated epidemics in Ventura County.

	Las Posas Diseased Trees (%)					
	--------------------- Commercial ---------------------			--------------------- Residential ---------------------		
Year	No Control	Residential	Residential + Commercial	No Control	Residential	Residential + Commercial
5	0.09	0.04	0.02	28.25	15.01	15.70
10	0.63	0.29	0.17	62.90	42.77	41.38
15	2.80	0.86	0.37	82.77	61.65	61.65
20	7.85	1.87	0.70	94.34	73.24	72.98

	Ojai Diseased Trees (%)					
	--------------------- Commercial ---------------------			--------------------- Residential ---------------------		
Year	No Control	Residential	Residential + Commercial	No Control	Residential	Residential + Commercial
5	1.07	0.56	0.04	26.06	14.40	10.42
10	17.35	10.20	0.31	56.41	39.48	32.18
15	47.32	33.47	0.90	71.37	58.38	45.95
20	69.83	53.77	1.48	78.96	68.80	53.22

	Santa Clara Diseased Trees (%)					
	--------------------- Commercial ---------------------			--------------------- Residential ---------------------		
Year	No Control	Residential	Residential + Commercial	No Control	Residential	Residential + Commercial
5	0.07	0.04	0.01	23.45%	11.51	11.85
10	1.15	0.27	0.06	35.77	28.26	28.52
15	4.87	1.1	0.10	42.94	31.15	33.21
20	10.0	2.7	0.16	50.97	31.70	33.54

Cambridge model

Figure 5, below, shows the probability of infection on a logarithmic scale (blue = 0.001, red = approaching 1) in different stages of HLB progress for the LA basin and Riverside.

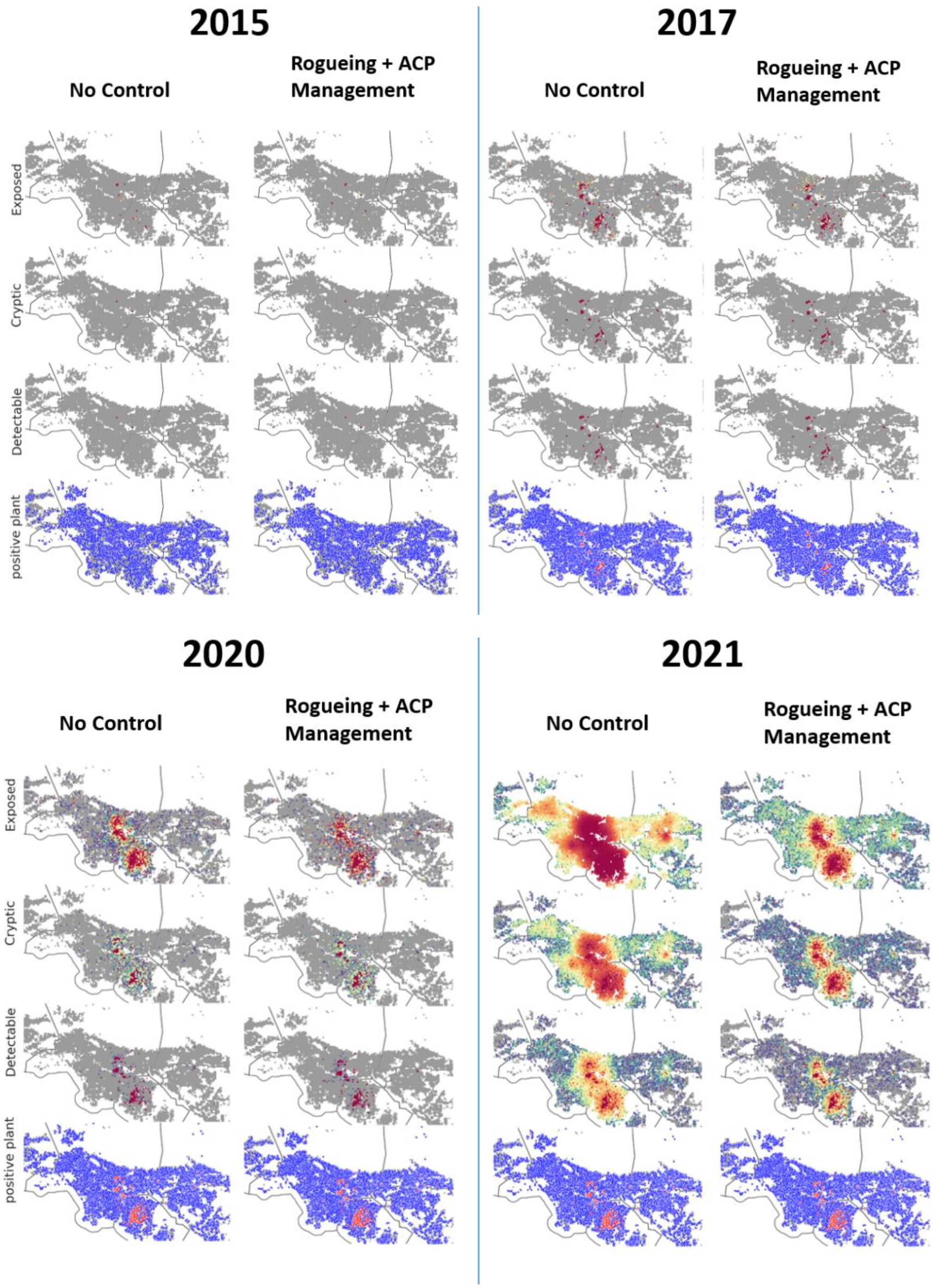

Figure 5. The probability of infection in different stages of HLB progress for the LA basin and Riverside. Probabilities are on a logarithmic scale (blue = 0.001, red = approaching 1). Figure provided courtesy of Cambridge University (Prof Chris Gilligan, Drs Viet Nguyen & Renata Retkute) and USDA-APHIS (Dr David Bartels).

Conclusions and future work

The purpose of this briefing is to provide an indication of the types of results that are being generated by the modeling studies. The results reported here indicate that ACP control around infected trees, with removal of known infected trees in residential areas, and in conjunction with ACP control in commercial citrus can significantly slow the rate of HLB spread into commercial citrus from residential sources.

The Cambridge model, which operates at a much larger spatial scale than the ABM but has less capacity for fine-tuning, is producing results that concur with observed experience and also with the annual risk-based survey risk calculation. We plan to get the two models running in tandem using a common set of parameters to simulate the effect of control activities with the aim of providing a more comprehensive analysis of the impact of the disease management program on the rate of spread of HLB.

While the results are encouraging, and further work will better match the structure of the simulated residential program to the set of activities used in reality, we stress that because the real program has evolved over time, simulations are always only an approximation of what is done in practice. We caution against hoping for nuanced answers about the effectiveness of fine details of program components; at a fine scale, the program may have to be evaluated simply on its merits.

Overall, we are encouraged by progress made, particularly over the last six months, and feel confident that the simulation modeling activities will be able to support the on-going deliberations about program cost-effectiveness by the Science Sub-Committee in 2021.