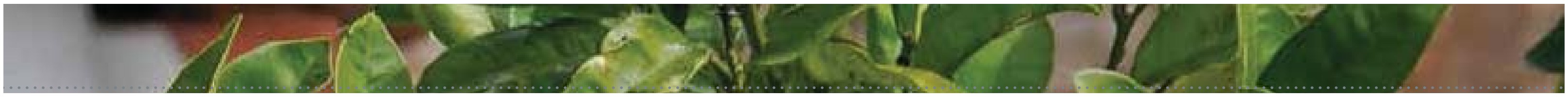


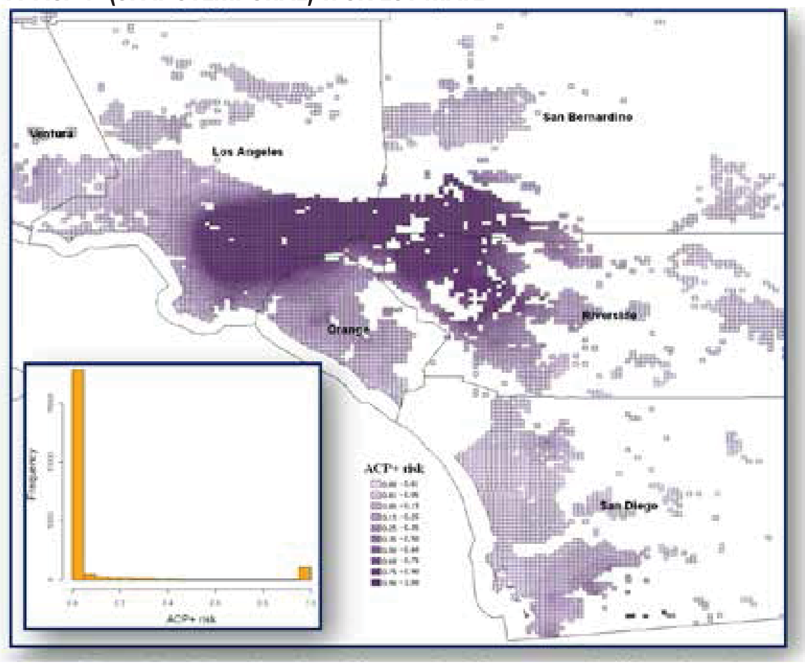
RISK-BASED RESIDENTIAL HLB/ACP SURVEY FOR CALIFORNIA, TEXAS AND ARIZONA

Tim Gottwald, Weiqi Luo, and Neil McRoberts

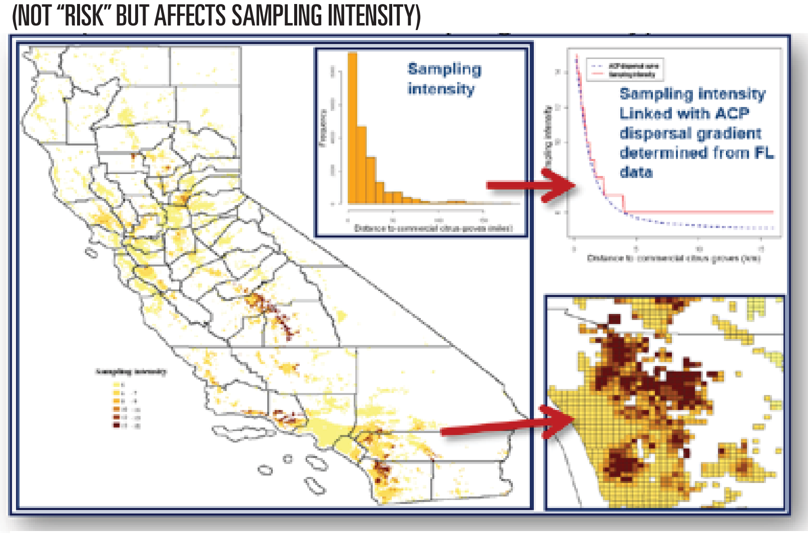
The recent discoveries of huanglongbing (HLB) in California's Los Angeles Basin and Texas' Rio Grande Valley and the continual increase in Asian citrus psyllid (ACP) populations, plus the vector of HLB in Arizona, underscore the imminent danger of HLB introduction and spread in these three states. The citrus industries are also at considerable risk due to their expansive shared borders with Mexico. HLB infections and the looming ACP populations in Mexico with close proximity to the U.S. border continually threaten additional immigration and establishment of these pests in the United States.

To avoid the devastation this disease has demonstrated in Florida and other areas around the world, we must find initial infections of HLB quickly and at very low incidence. Such initial introductions often take place in residential areas where citrus is grown in dooryards. There is an urgent need for highly-sensitive statewide survey methods of residential areas combined with rapid intervention to contain and eliminate further spread. How we accomplish such extensive surveys, essentially to find HLB and ACP prior to their extensive spread, presents considerable logistical challenges.

A. ACP+ (SPATIOTEMPORAL) RISK ESTIMATE



B. DISTANCE TO COMMERCIAL CITRUS GROVES
(NOT "RISK" BUT AFFECTS SAMPLING INTENSITY)



C. TOTAL RISK (INCLUDING ALL VARIABLES AND FILTERING)

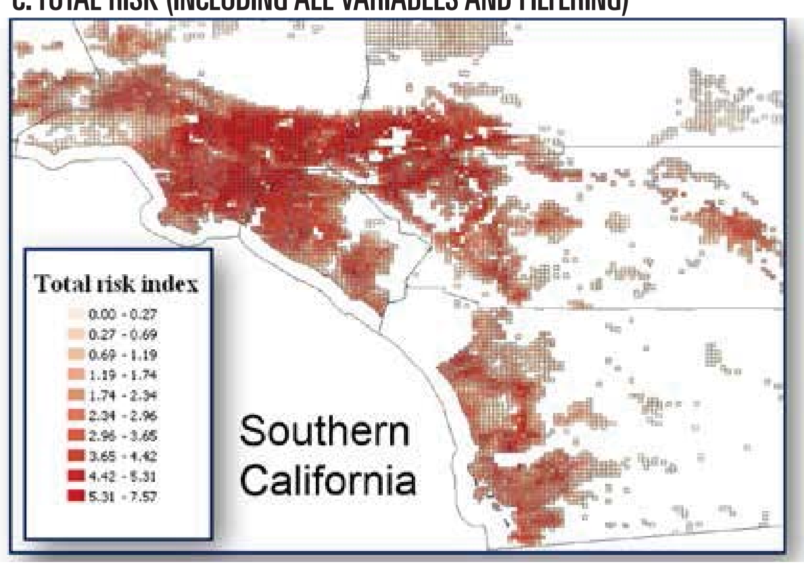


Figure 1. A) ACP+ (Spatiotemporal) risk in Southern California. B) Inverse distance-based function from commercial citrus used to adjust sampling intensity. C) Total risk estimate presented on a square mile grid. Risk for each "stratum" as indicated by color intensity.

These issues were further exacerbated by the 2008 economic downturn that continues to result in dwindling fiscal resources for many regulatory agencies, including those tasked with conducting the survey for HLB. The effects of the recent severe cold in California may further constrain financial resources, increasing the need for a cost-effective preventive action survey.

Therefore, sampling efforts need to be deployed based on potential risk of introduction and threat to commercial citrus to optimize early detection and management. This article introduces and briefly describes a risk-based residential survey that has been constructed and deployed in Southern California, the Rio Grande Valley of Texas and Southern Arizona. Detailed explanation has been published as a webcast and can be viewed at:
http://www.plantmanagementnetwork.org/edcenter/seminars/Outreach/Citrus/HLB/

FILTERING OF THE SURVEY AREA

First, we needed to determine where citrus exists in the expansive residential areas of these states. Residential areas to be surveyed were determined by a human population density map generated from the 2010 U.S. Census data. This map was then filtered to remove areas where residential citrus would not exist or only contain rare or minimal numbers of trees. Such areas include:

A. Water bodies such as major lakes, ponds, rivers and reservoirs.

B. Recreation areas including municipal, state and national parks and forests, community centers, golf courses, zoos, amusement parks and convention centers.

C. Transportation areas such as roads, highways, airports, airfields, train and bus stations and parking lots.

D. Living areas that would not support citrus such as hotels and resorts, hospitals and care centers, nursing and retirement facilities, oil fields and refineries, various institutions, jails and prisons.

E. Commercial workplaces such as shopping and retail centers, industrial areas, office spaces, vineyards and non-citrus agricultural areas.

F. Community areas such as colleges, schools, churches and cemeteries.

G. Areas higher than 700 meters (about 2,300 feet – the reported elevation above which ACP cannot survive due to either temperature or atmospheric pressure).

H. Areas where yearly minimum temperatures (based on 10-year temperature averages) fall below the tolerance threshold, (temperature and duration either -5 or -9 C°) for survival of ACP.

Military installations, Native American reservations and other places that cannot be surveyed due to lack of access were also considered. However, these areas will be used in the risk calculation that follows (see below).

The result is a fully filtered residential population map that includes only residential areas presumed to be able to sustain residential citrus, the disease and its vector.

CALCULATION OF CITRUS DENSITY AND RISK FACTORS

How do we identify where to start looking, and how do we prioritize this massive area we need to examine? To accomplish this seemingly enormous task, we need to develop a method to estimate the associated "risk" of introduction of HLB for each area we need to survey and then prioritize our search based on this risk.

The overall risk algorithm or model (mathematical method to determine risk) is constructed considering several major components of risk. Initially, each of these components is given equal weight, because it is difficult to quantify the relative influence of each risk factor compared to the others without substantial data. The risk model is dynamic and can be easily changed over time as necessary. As data is collected during subsequent survey cycles, we reassess the various contributions of each individual risk factor and then apply appropriate weighting (estimates of the relative risk of each factor) accordingly. This will allow us to dynamically change and enhance the survey model through time, thus making it more accurate and robust relative to mapping and prediction.

But first, we need to build a map that estimates the *residential citrus populations*. Let's use the Los Angeles area as an example. Based on data provided by the California Department of Food and Agriculture (CDFA), in the LA Basin, 60 percent of the households have residential dooryard citrus. Of these, the average is approximately two citrus trees per household.

However, residential citrus population density is not a direct linear relationship with human population, but rather varies with human population density. This *nonlinear* relationship was estimated for each state, i.e., California, Texas and Arizona, based on human population. By this method, we can then map residential citrus density for all or part of each state as a function of human population density.

Consider the various risk factors. For a more complete explanation, see the webcast indicated on page 54.

A. **Estimation of risk due to potential ACP spread:** Risk was evaluated due to potential ACP spread from commercial nurseries, home centers, packinghouses, other citrus production or commercial vendors (e.g., big box stores or flea markets) and green waste facilities. In addition, risk was evaluated for military installations and Native American reservations, both of which will be excluded from the survey due to lack of access. Neither of these are subject to customs and/or import/export regulation, which suggests that they could act as unknown sources for introduction of HLB and ACP. From prior data collected in Florida, we know that ACP risk decreases with distance from the source out to about 9.6 miles (16 km). Thus, risk is estimated as a function of distance from commercial citrus production and sales centers. However, not all of these areas are given the same risk weighting. Obviously, nurseries that produce citrus have a high risk as do retail centers with high volume of citrus sales; whereas, small retail nurseries and incidental retail vendors would have much lower risk.

B. **Estimation of risk due to known ACP population prevalence and dynamics:** From 2010 to 2012, data from ACP trapping in Southern California, Texas and Arizona were considered. The locations (spatial positions) of prior ACP populations and their duration (how long they had existed in each location) were combined in an overall mathematical model (known as a spatiotemporal disease dispersal model). Thus, it is not only the presence of ACP, but its duration (temporal function) that ascribes risk to a particular location. An overall map of ACP risk was created for each state. This is used both for residential and commercial citrus surveys dynamically. Data collected in future surveys will be incorporated into the risk calculation; and as a result, the ACP risk maps will change continually over time.

C. **Transportation corridors:** The primary and secondary roads and expressway system used for commercial citrus production, i.e. fruit movement, is considered as the transportation corridor. Based on analyses of this system in Florida, a mathematical equation was used to estimate risk over distance to transportation corridors of concern for each state.

D. **Climatological effects:** From Hall's previously published data, we can extrapolate minimum temperature thresholds below which the ACP vector cannot survive. Thus, residential and commercial survey maps were adjusted by minimum temperature thresholds to represent the likelihood of ACP development and spread.

E. **Population demographics** are especially important. From prior data in a number of locations in various countries, we know that residents with Asian heritage have ties and connections to Asian countries that have HLB, and thereby pose a higher threat of introduction (unintentional and often unknowingly). Therefore, higher sampling intensity and risk calculations are ascribed to those areas where Asian populations are prevalent. The initial HLB find in the Los Angeles Basin was within one such high-risk Asian population area.

F. **Risk of HLB-positive trees and ACP** vectors that are carrying the HLB pathogen are added as they occur. To date, there is one HLB-positive location in California, four (two commercial groves and two residential) in Texas, and none in Arizona. However, this is likely to change through time as the epidemic evolves.

G. Based on analyses of Florida data, a **more intensive sampling effort is conducted in areas surrounding known HLB infections.**

H. **An adjustment for sampling intensity** was also developed based on proximity to commercial citrus plantings. A higher sampling intensity is conducted near commercial citrus areas ***(Figure 1 on page 54)***.

DISTRIBUTION TO STAKEHOLDERS: HOW CAN STAKEHOLDERS USE THIS SURVEY METHOD?

A. **Overall mapping of cumulative total risk** was calculated for each of the regions of concern for each state ***(Figure 1–C)***.

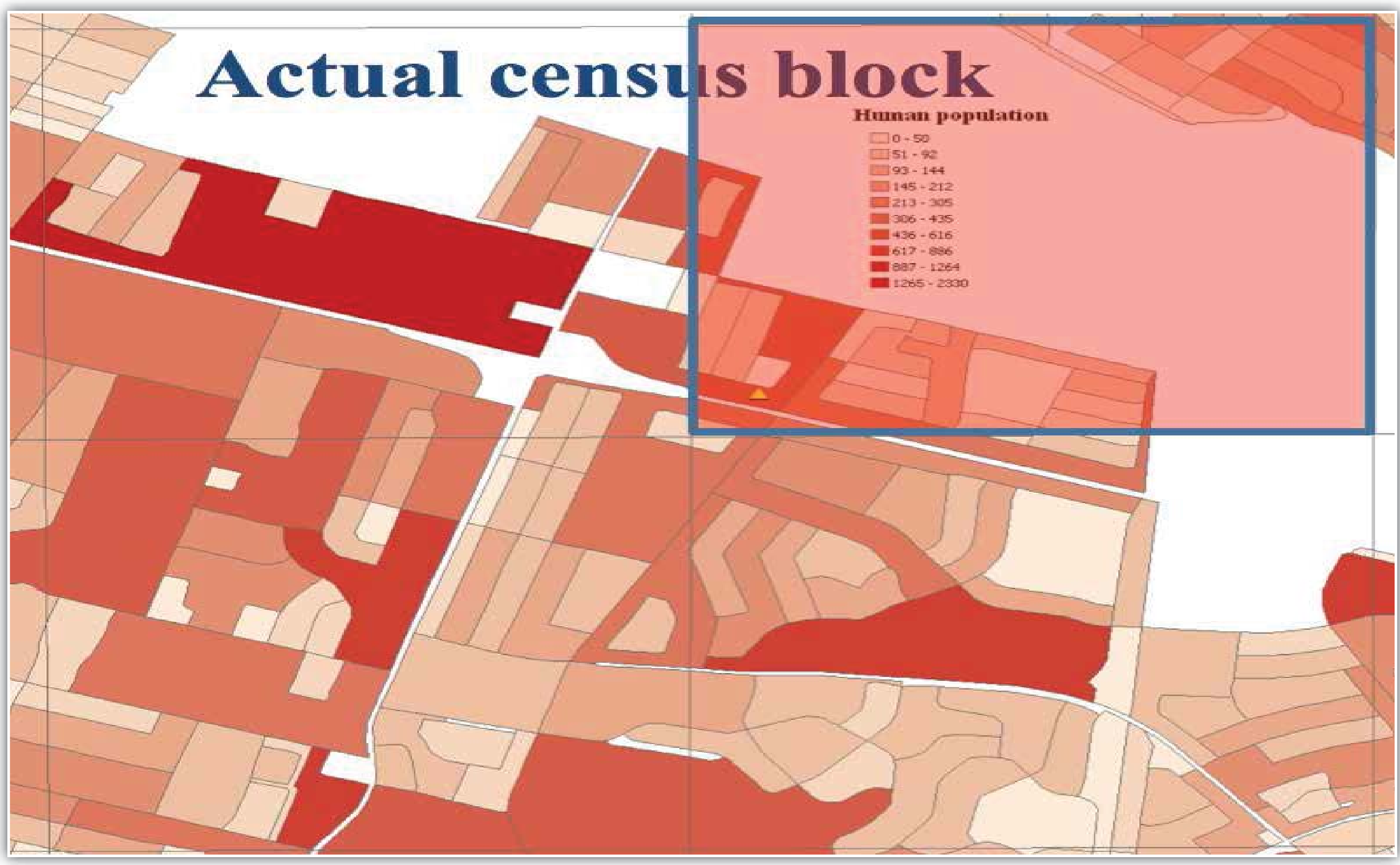
B. **Survey protocol:** Risk maps are provided to each state/agency based on STR (1 mile^2 areas described by Section–Township–Range [STR]). The calculated risk impacts the probability of an individual STR selection for residential survey; i.e., the higher the risk, the higher chance such STR will be selected. Therefore, "hot" disease and ACP population STR areas are the areas predominately covered, and extra assurance is provided via a stochastic (random) selection of a small proportion of STRs in low-risk areas. An output data set in Excel is also provided to the Agency conducting the survey that lists each STR and its estimated total risk. This can then be used to direct survey teams as a protocol to perform a systematic risk-based survey. If more fiscal and manpower reserves can be dedicated to survey, then regulatory agencies can simply select more STRs from the prioritized output list and include lower-risk areas.

C. **Multiple interactive maps** that can link to Google Earth are also provided so the regulatory agencies can target survey teams more precisely via visual representations of risk. ***Figure 2*** shows a satellite view of a four-mile^2 area of residential Los Angeles and a corresponding census block map for the same area. Note that manufacturing and nonresidential sub-areas have been filtered out.

GLOBAL PEST AND DESEASE MODELING

The survey models described above could also provide a modeling framework for the development of surveys for other citrus-producing areas and industries such as areas in Central and South America and the Caribbean. A similar framework can be easily transferred to apply to survey for other non-indigenous diseases when required. In the global sense, surveys that can predict and detect introductions before or while in low incidence will afford improved chances of disease suppression/management prior to areawide or regional spread that can eventually act as sources for future introductions into the US.

Figure 2. It is possible to pinpoint population and race in each individual residential area (ex. residential block), making it easier for regulatory agencies and surveyors to pinpoint survey locations and to map results. Mapping is done for each square mile grid by section, township and range.



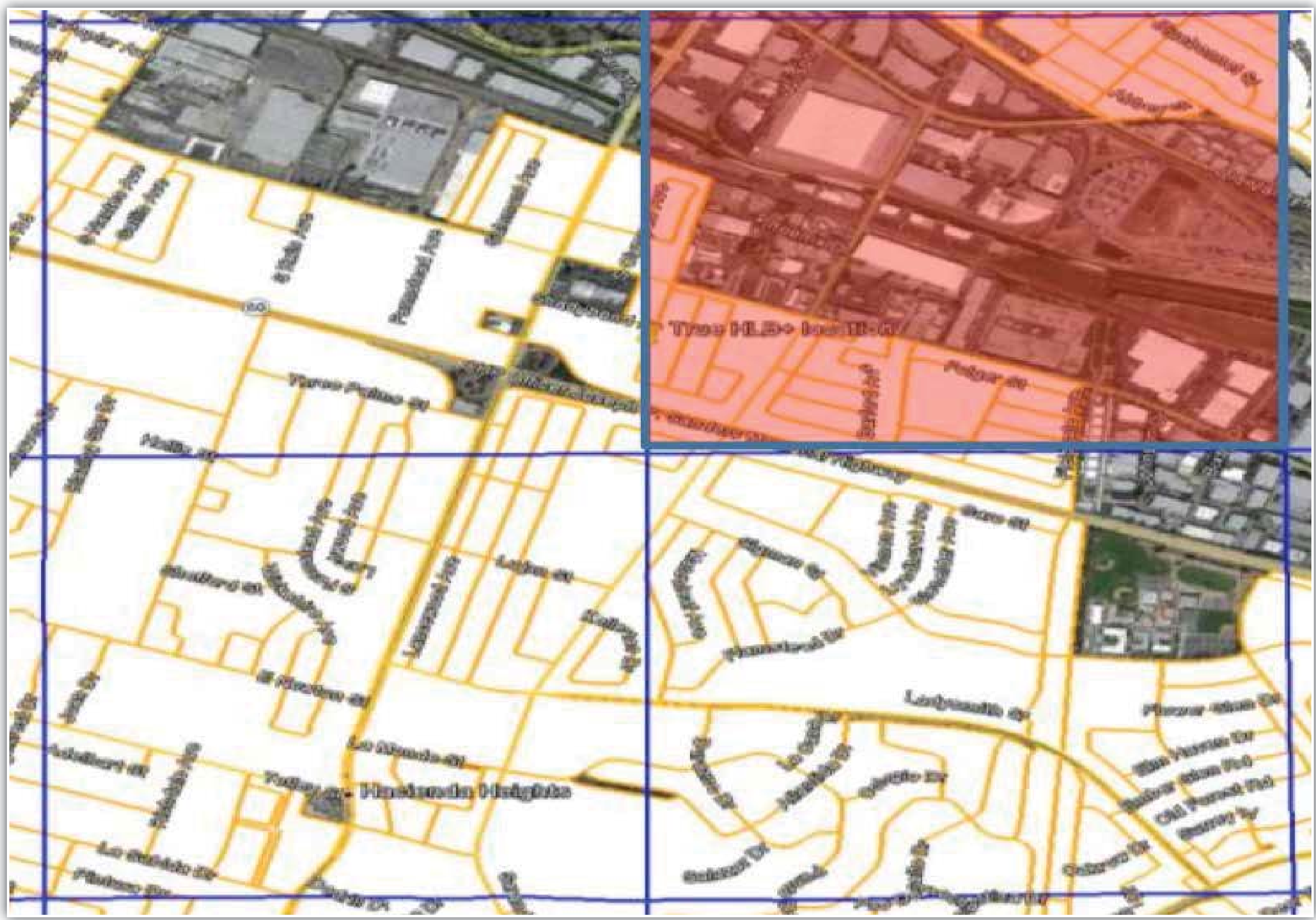


Figure 2, continued. It is possible to pinpoint population and race in each individual residential area (ex. residential block), making it easier for regulatory agencies and surveyors to pinpoint survey locations and to map results. Mapping is done for each square mile grid by section, township and range. This mapping version displays street names that regulators can use in tracking ACP and HLB.

Surveys that can predict and/or detect a pest introduction while its incidence is still low will increase the chances for early disease detection. If a pest introduction can be eliminated or controlled soon after its introduction, the epidemic can be stopped or slowed so that the pest can be more efficiently managed.

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