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Authors
Gottwald, T.
Luo, W.
McRoberts, N.

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Risk-based residential HLB/ACP survey for California, Texas and Arizona

Gottwald, T.[1], Luo, W.[1,2], and McRoberts, N.[3]

[1]USDA, ARS, US Horticultural Research Laboratory, Fort Pierce, Florida, USA
[2]CIPM, NC State University, Raleigh, North Carolina, USA
[3]University of California, Davis, California, USA

The recent discoveries of HLB in the Los Angeles Basin and the Rio Grande Valley of Texas underscore the imminent danger of HLB spread in these two States and the urgent need for highly sensitive survey methods for early detection of new residential infections of HLB combined with rapid intervention to contain and eliminate further spread. The Arizona citrus industry is also at considerable risk due to the proximity to the Mexican border and continued immigration of ACP from Mexico. The 2008 economic downturn has led to dwindling fiscal resources for many regulatory agencies including those tasked with conducting the survey for HLB. Therefore, sampling efforts need to be deployed based on potential risk introduction and threat to commercial citrus to optimize early detection. A risk-based residential survey has recently been constructed and deployed in Southern California and the Rio Grande Valley of Texas, and is being designed for Southern Arizona.

Filtering of the survey area

Residential areas surveyed were determined by a human population density map generated from 2000 and 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; including:

h. Water bodies, such as major lakes, ponds, rivers, and reservoirs.
i. Park and recreation areas including national parks and forests, community centers, golf courses, zoos, amusement parks, and convention centers.
j. Transportation areas such as airports, airfields, train and bus stations, and parking lots.
k. Living areas that would not support citrus such as hotels and resorts, hospitals and care centers, nursing and retirement facilities, Tyumen oil institutions, jails and prisons.
l. Commercial workplaces such as shopping and retail centers, industrial areas, office spaces, vineyards, and non-citrus agricultural areas.
m. Community areas such as colleges, schools, churches, and cemeteries.
n. Areas higher than 700 m (2300 feet) which is the reported elevation above which ACP cannot survive due to either temperature or atmospheric pressure (Albert 1883).
o. Areas where yearly minimum temperatures (based on 10-year temperature averages) fall below the tolerance threshold, (temperature and duration) for survival of ACP.
p. Military installations, Indian reservations, and other places that cannot be surveyed due to lack of access. However, these areas will be used in the risk calculation that follows (see below).

The result is a fully filtered residential population map which includes only residential areas that are presumed to be able to sustain residential citrus.

Calculation of Risk

The overall risk algorithm is constructed considering several major components of risk. Initially, each of these components will be simply given equal weighting, 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 data is collected during subsequent survey cycles, we reassess the various contributions of each individual risk factor and then apply appropriate weightings 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.

a. *Estimation of residential citrus populations:* Based on data provided by CDFA, in the LA basin 60% of the households have residential dooryard citrus and of these households the average is approximately 2 trees per household. Initially for Texas and Arizona similar population structures were used to estimate the population density of residential citrus statewide. However, residential citrus population density is not a direct linear relationship with human population but rather varies nonlinearly with human population density. The nonlinear relationship was estimated for the state of Florida and the same mathematical function applied initially to California, Texas and Arizona until such time as more data are collected directly from each state and the function corrected specifically to reflect their individual situations. Using the human population we can then map all or part of each state as a function of residential citrus population density.

b. *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 Indian reservations, both of which will be excluded from survey due to lack of access. Neither of which
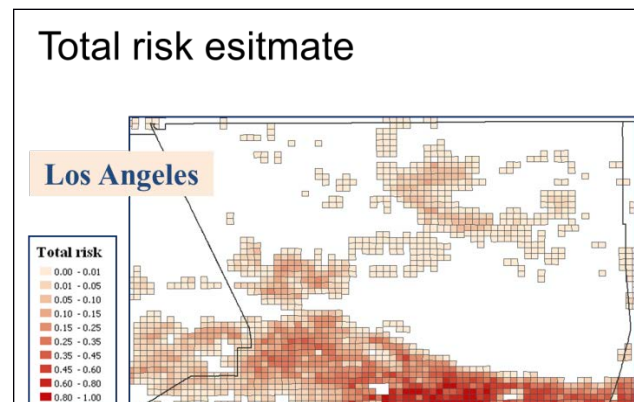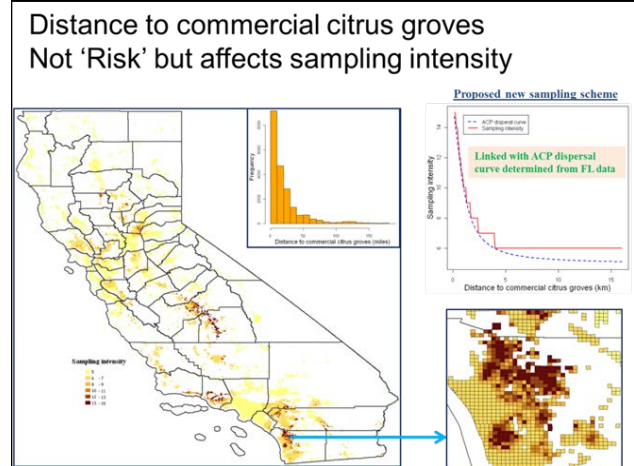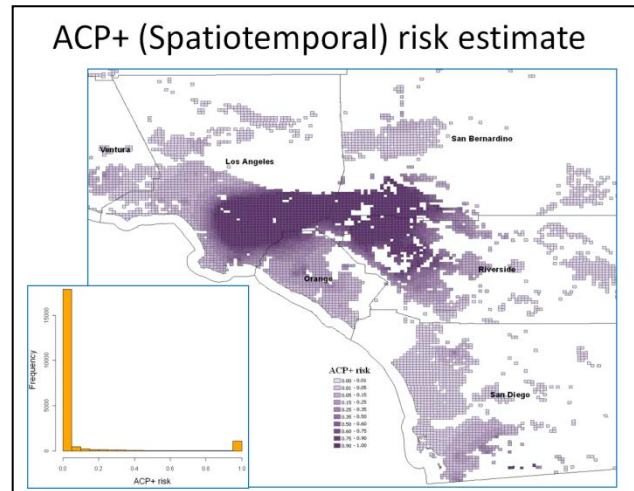
Figure 1. Top) ACP+ risk in Southern California. Middle) Inverse distance-based function from commercial citrus used to adjust sampling intensity. Bottom) Total risk estimate presented on a1-mi^2 grid.

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 following an adjusted power law function up to approximate 16 km. This function is applied to estimate and weight risk 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 traffic of citrus sales, whereas, small retail nurseries and incidental retail vendors would have much lower risk.

c. *Estimation of risk due to known ACP population prevalence and dynamics*: From 2010 to 2012, data from ACP traps in Southern California and ACP incidence in Texas and Arizona were considered. The spatial positions of prior ACP populations and their duration were combined in an overall 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 layer 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 in risk calculation and as a result the ACP risk maps will change over time. Risk from ACP spread is considered an inverse power law function over distance (Fig. 1 Top).

d. *Transportation corridors*: The primary and secondary roads and expressway system used for commercial citrus production movement is considered the transportation corridor. Based on analyses of this system in Florida, a negative exponential function (extents to be determined) was used to estimate risk over distance perpendicular to transportation corridors of concern for each state.

e. *Climatological effects* were accounted for where appropriate. From previously published data (Hall et al., 2011) we can extrapolate minimum temperature thresholds below which ACP cannot survive. Residential and commercial survey maps will be adjusted by minimum temperature thresholds to represent the likelihood of ACP development and spread.

f. *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 resulted from areas where Asian populations are prevalent. The initial HLB find in Los Angeles Basin was within one such high risk Asian population area.

g. *Risk of HLB positive find(s) and Las positive ACP* are added as they occur. To date there is one in California, four (two commercial and two residential) in Texas, and none in Arizona, but more will likely occur over time. A distribution function was calculated based on data in Florida that provides a description of risk of HLB as a function of distance from HLB positive detections via an inverse power law function. More sampling effort will be emphasized on each area and surrounding areas with HLB infection.

h. *An adjustment for sampling intensity* was also developed based on proximity to commercial citrus plantings. An inverse distance weighted function from commercial citrus was used provide a higher sampling intensity near commercial citrus areas (Fig. 1 Middle).

Distribution to stakeholders:

a. *Overall mapping of cumulative total risk* were calculated for each of the regions of concern

for each state (Fig. 1 Bottom).

b. *Survey protocol:* Risk maps were provided to each state/agency based on STR (1 mi.² areas described by section – township – range). The calculated risk impacts the probability of STR selection for residential survey, i.e., the higher the risk, the higher chance such STR will be selected. Therefore 'hot' disease STR areas are the areas predominately covered and extra assurance is provided via a stochastic selection of a small proportion of STRs in low risk areas. An output data set in Excel is also provided that lists each STR and its estimated total risk. This can then be used by 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 and include lower risk areas.

c. *Multiple interactive maps* that can link to Google Earth were also provided so the regulatory agencies could target survey teams more precisely via visual representations of risk. Figure 2 shows a satellite view of a 4 mi² area of residential Los Angeles and a corresponding residential risk map for the same area. Note manufacturing and nonresidential subareas have been filtered out.
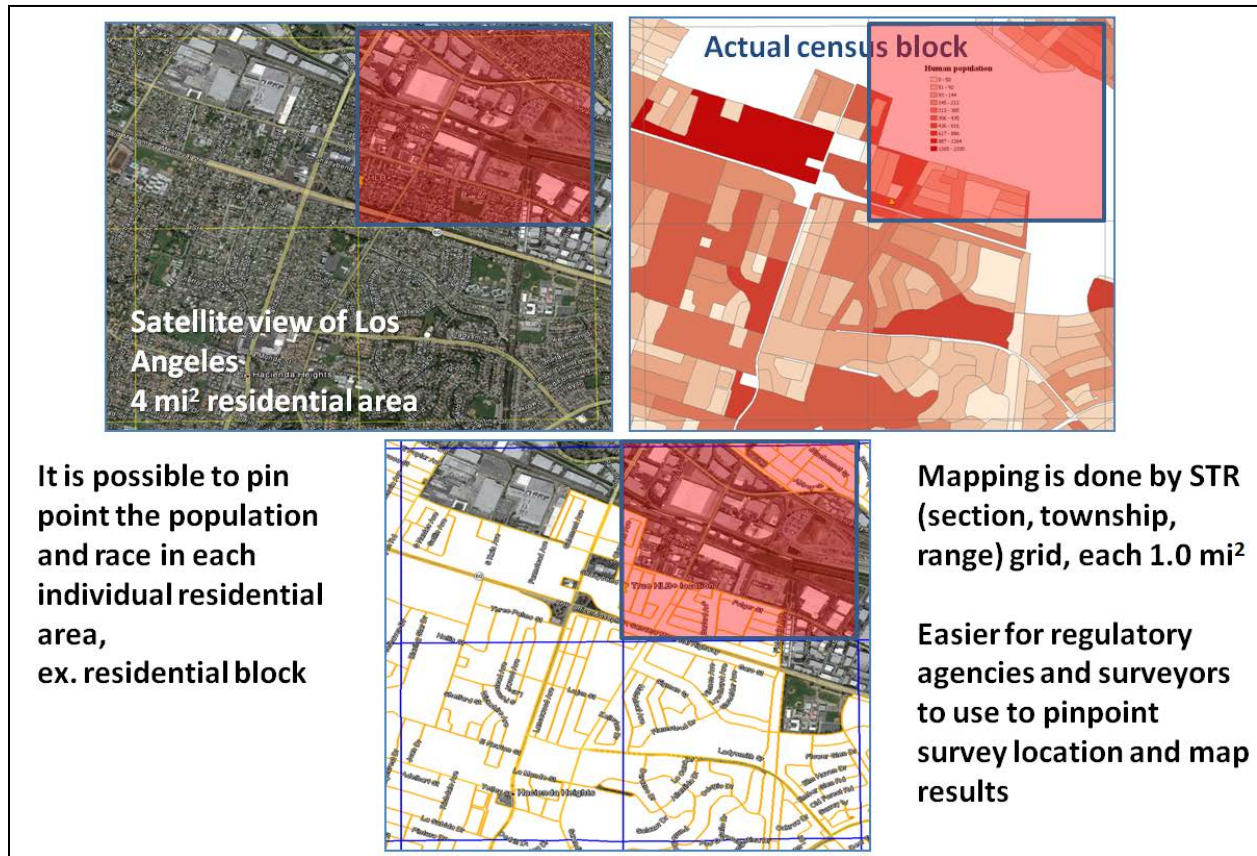

Figure 2. Multiple interactive mapping

The survey models described above provide a modeling framework for 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 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.

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