

Inferential and geostatistical analysis to optimize sampling, monitoring, and decision making in the management of *Diaphorina citri* (Hemiptera: Liviidae) in Mexico.



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The National Institute for Forestry, Agriculture and Livestock Research (INIFAP) is part of the ministry of Agriculture (SAGARPA).

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8 Regional Research Centers, 38 Experimental Stations
 1100 researchers

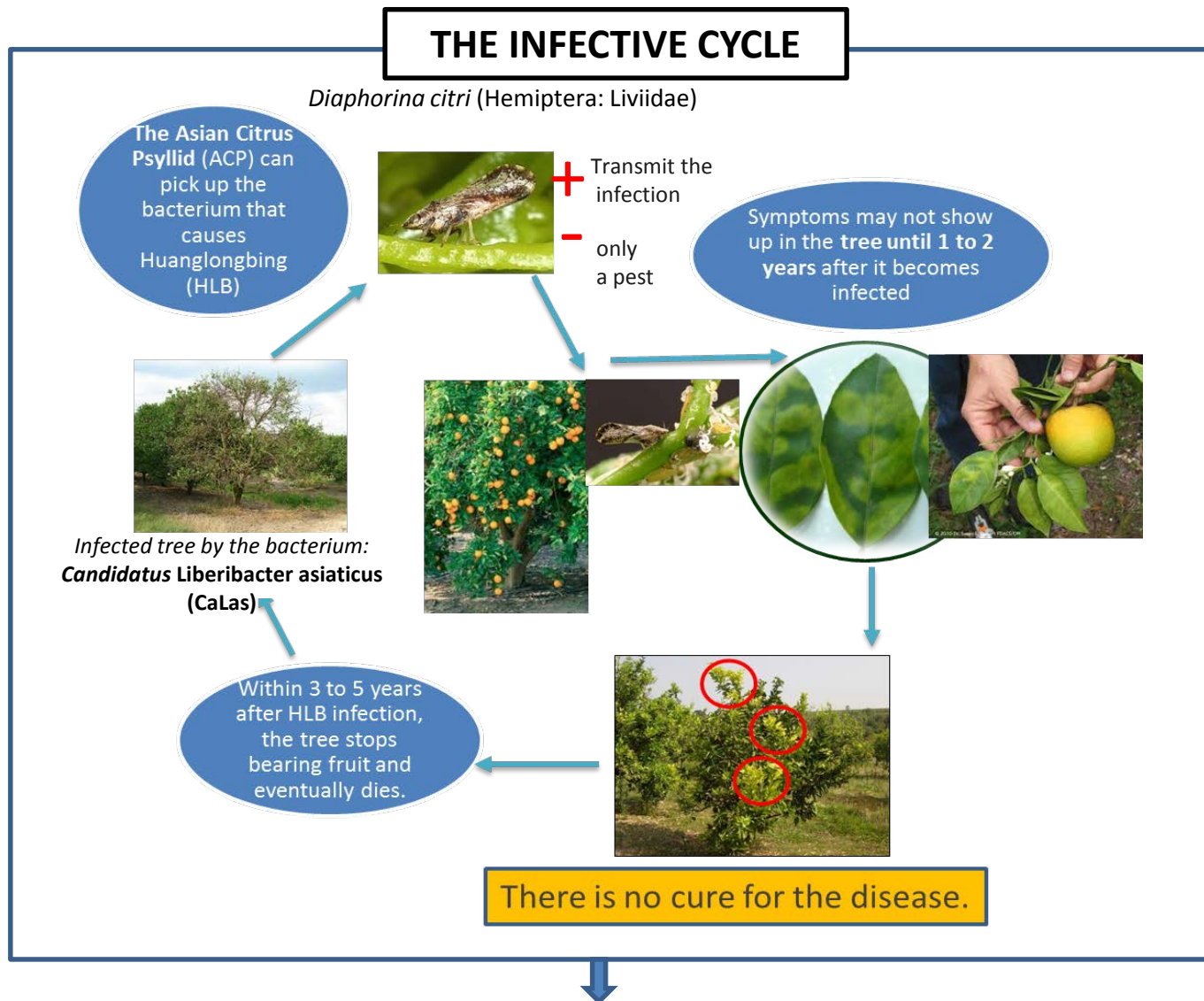
Where are we?

-Cotaxtla Experimental Station
 in the State of Veracruz

Program of Modeling and
 Agrometeorology

The Asian Citrus Psyllid (ACP) and the Citrus Disease Huanglongbing (HLB)

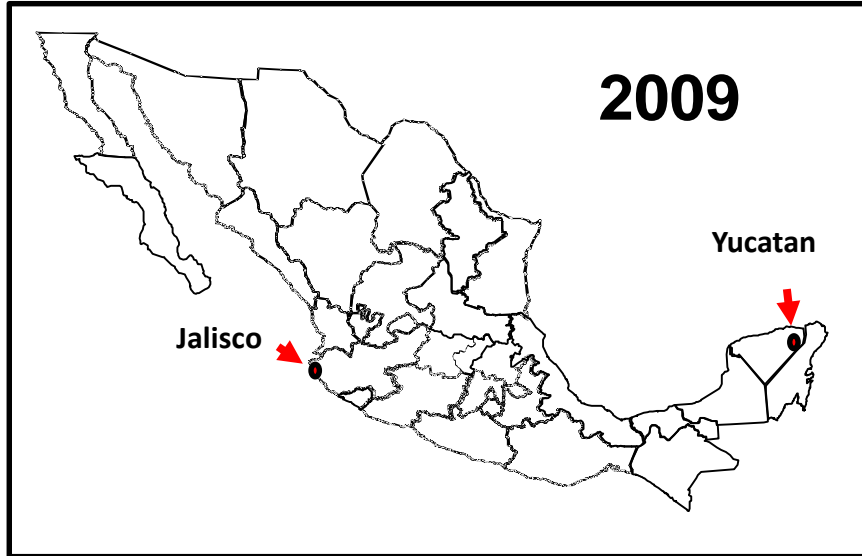
The Situation: is one of the most destructive diseases of citrus worldwide.



The monitoring and control of the vector is a very expensive and important government action

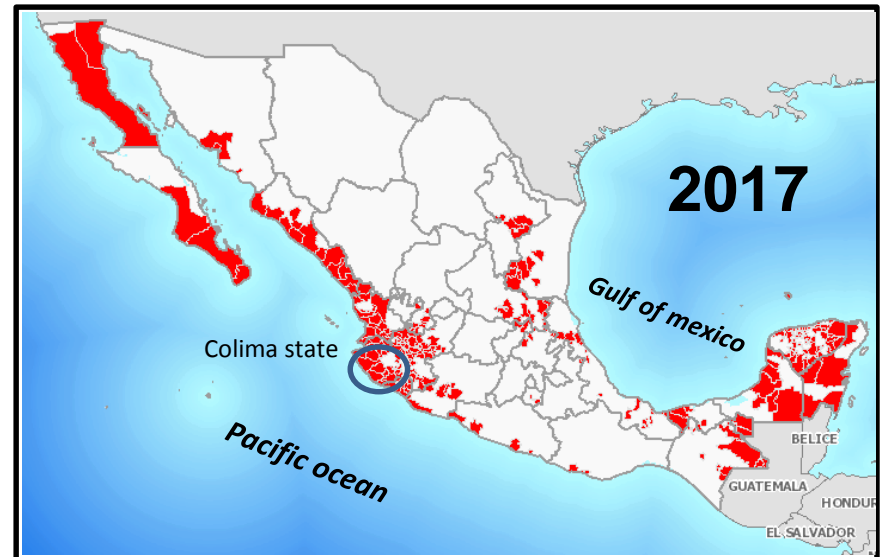
Status of the HLB in Mexico

Firsts outbreaks reported in Mexico



The insect vector (*Diaphorina citri*) is widely disseminated.

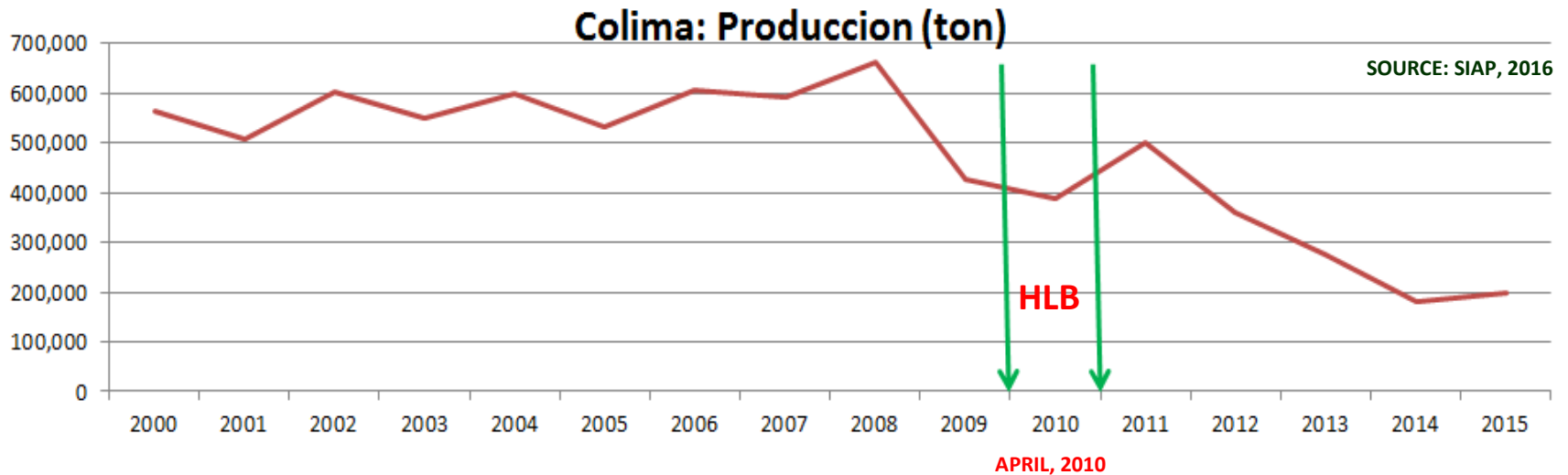
Dissemination of HLB in Mexico – July 2017



the lemon plant has frequent shoots (bud break) due to frequent pruning, and most of them it is irrigates

So far, 15% of the commercial area has been infected with HLB

Negative impact of HLB



The greatest damage is found in Colima state which is the main Mexican lemon producer.

The production has decreased in nearly 50% of the annual harvest



The National Campaign for the management, Monitoring and control against the HLB and its vector was established in 2010. (SENASICA, 2010)

Based on the oficial protocol of monitoring - 2015

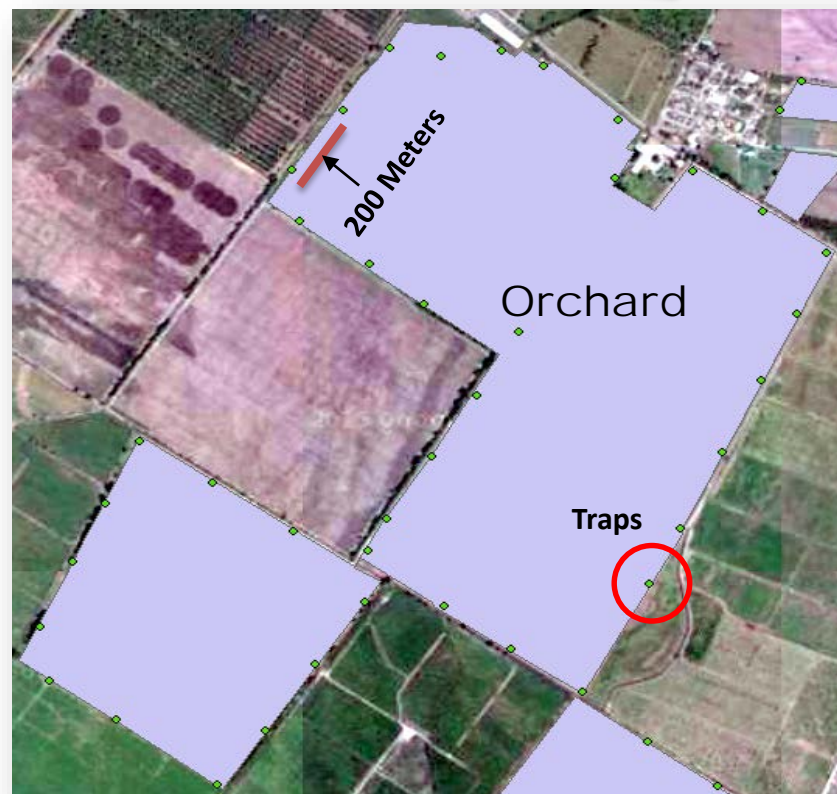
The registration of capture in the network traps was performed weekly.

The sampling scheme is not based on statistical or GeoStatistical methods.

The number of traps and its location, depend mainly on the available money.

The distribution of the traps was every 200 meters

The distances among orchards with traps does not have a theoretical base



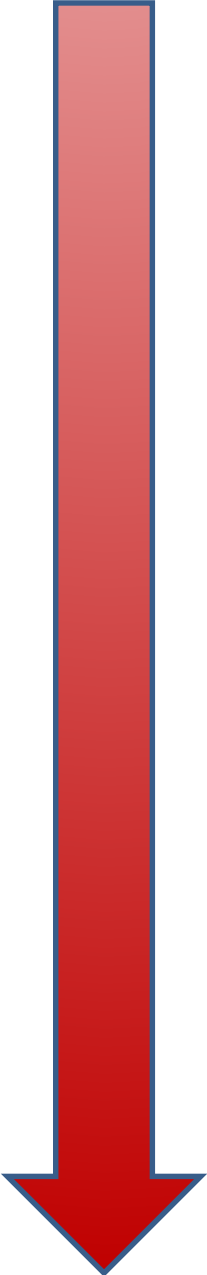
Some questions about the protocol of monitoring - 2015

- ❖ Are there a lot of traps in the orchards?
- ❖ Are enough traps in monitoring?
- ❖ Are they correctly located, distanced and oriented?
- ❖ Should they be more grouped?

?



OLD SCHEME OF MONITORING 2015

- 
- 1 ● Database integration
 - 2 ● Mapping the potential risk of *D. citri*
 - 3 ● Exploratory analysis
 - 4 ● Resample (Average and standard deviation)
 - 5 ● Negative binomial
 - 6 ● Geographical orientation

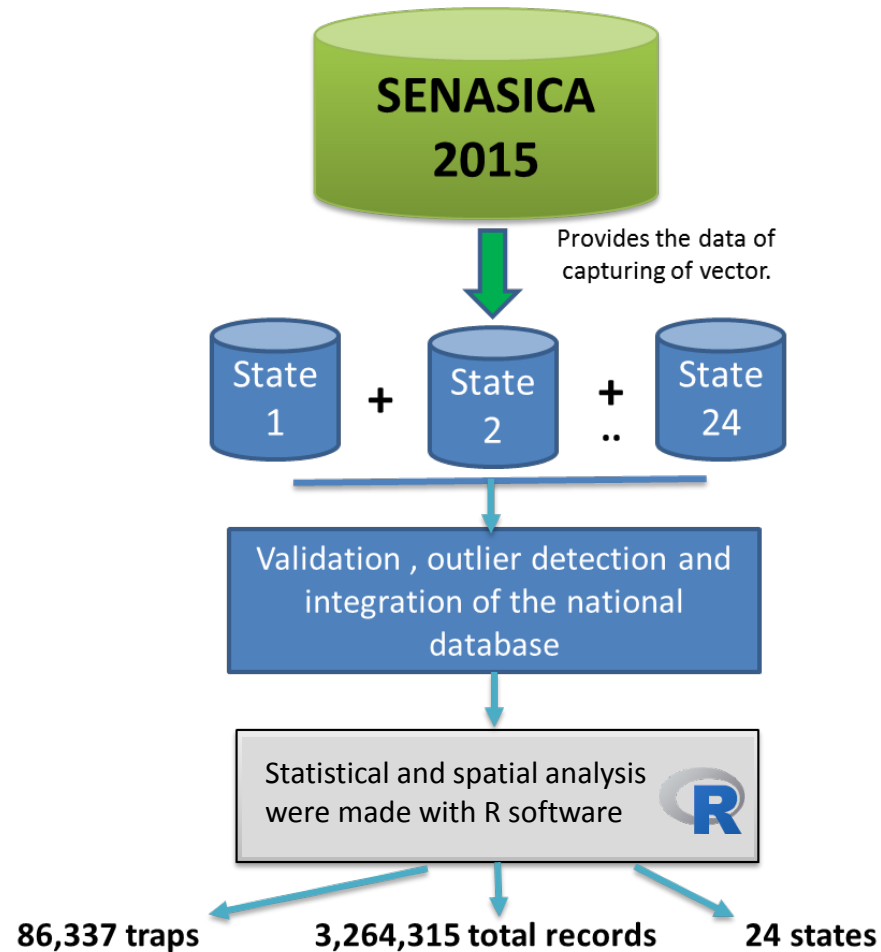
$$\bar{x} = \frac{\sum_{i=1}^n x_i}{n} \quad s = \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}}$$

{ Spatial distribution of Psyllids
Number of traps

NEW IMPROVED SCHEME 2016 - 2017

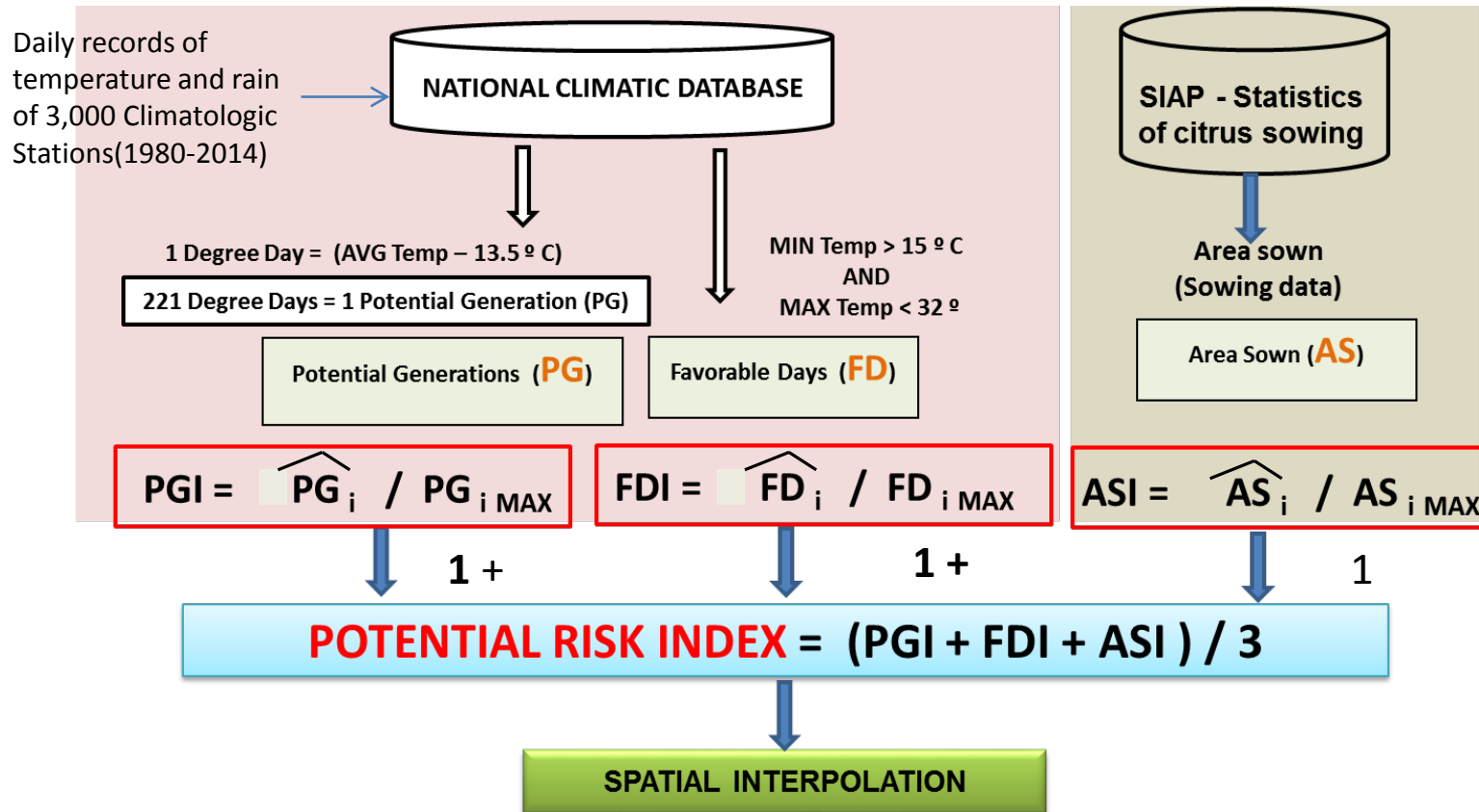
1 Database integration

The Federal institution in charge to keep the national database of the whole monitoring in Mexico



A GREAT BUNCH OF DATA TO ANALYZE IN 6 MONTHS

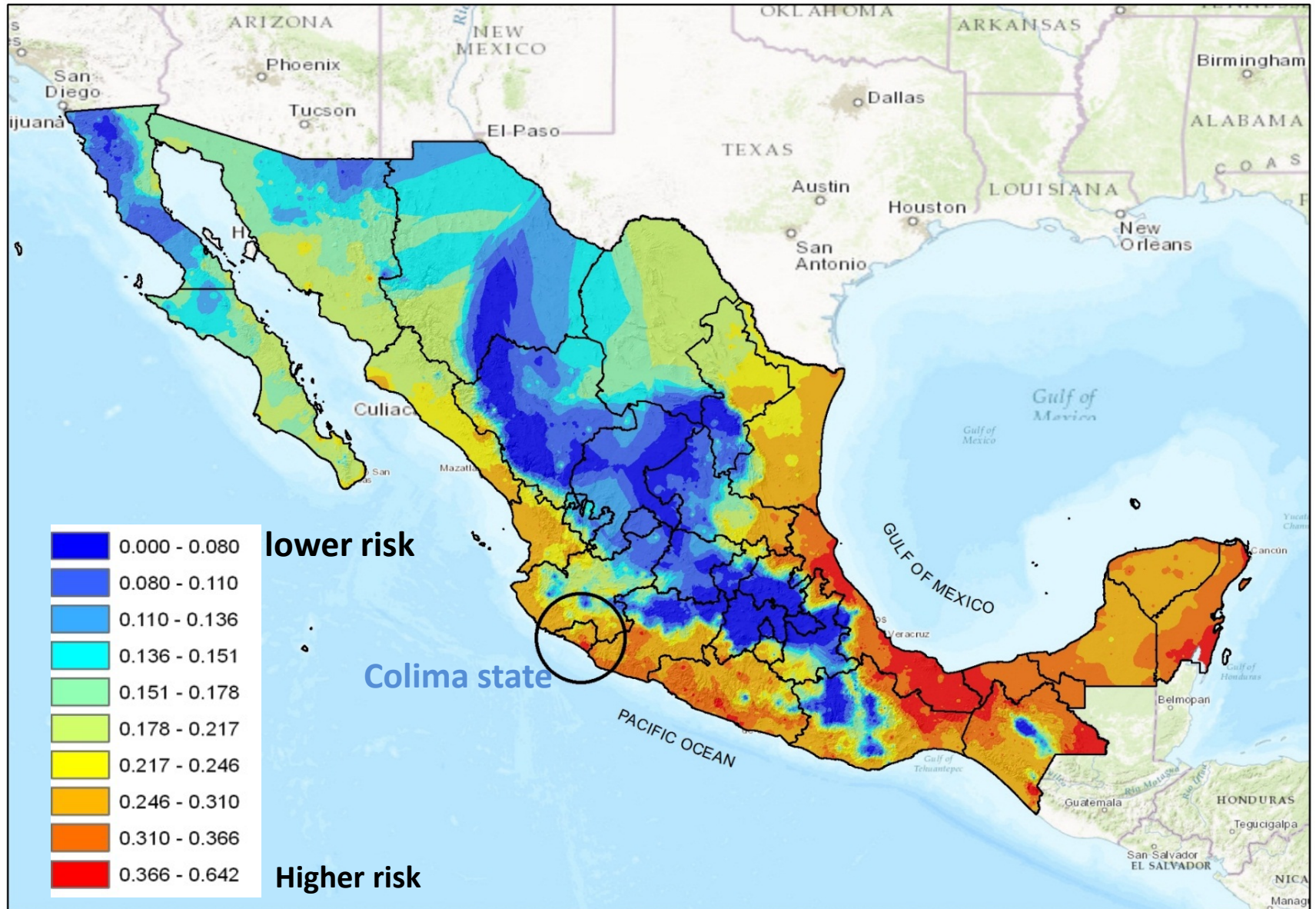
2 Mapping the potential risk of *D. citri*



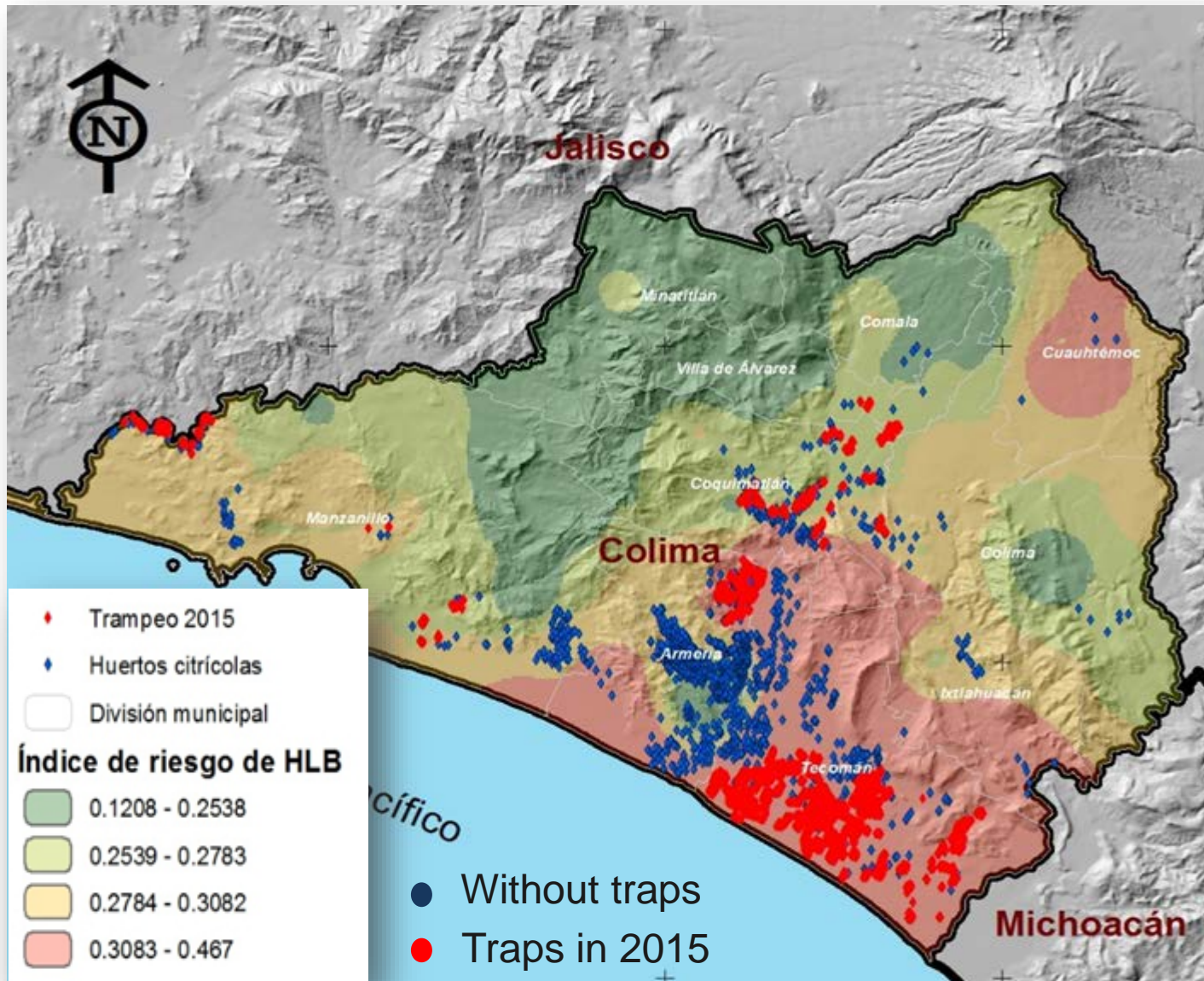
PGI: Potential Generations Index
FDI: Favorable Days Index
ASI: Area sown Index

i: climatic station

Spatial distribution of potential risk of *D. citri*



Colima state



3 Exploratory analysis (2015)

No.	State	Number of traps	Total records	Average of capturing per trap / year	standar deviation	PORCENTAGE OF TRAPS WITH			Maximum number of captured psyllids per trap in a week
						0	1	2	
						CAPTURED PSYLLIDS			
1	COLIMA	2,845	106,085	1.211	4.468	0.7081	0.1032	0.0638	216
2	VERACRUZ	8,873	450,382	0.283	1.851	0.8825	0.0641	0.0265	326
3	MICHOACAN	9,044	216,546	1.080	2.905	0.5099	0.2114	0.1784	426
4	NUEVO LEÓN	1,365	60,043	0.052	0.401	0.9683	0.0216	0.0059	31
5	YUCATAN	5,364	149,693	0.026	0.689	0.9814	0.0145	0.0031	254
6	BAJA CALIFORNIA	644	32,775	0.031	0.204	0.9739	0.0212	0.0046	4
7	BAJA CALIFORNIA SUR	1,389	41,005	0.689	3.880	0.7996	0.0817	0.0490	415
8	CAMPECHE	4,542	180,274	0.015	0.206	0.9897	0.0079	0.0017	26
9	CHIAPAS	3,993	194,974	0.098	0.529	0.9348	0.0448	0.0134	120
10	GUERRERO	3,209	152,561	0.038	0.420	0.9707	0.0270	0.0009	76
11	HIDALGO	1,597	81,212	0.010	0.120	0.9910	0.0081	0.0007	8
12	JALISCO	5,071	204,574	0.243	2.186	0.8928	0.0596	0.0248	700
13	MORELOS	466	22,436	0.188	0.725	0.8810	0.0792	0.0279	24
14	NAYARIT	2,856	118,467	0.099	0.779	0.9442	0.0392	0.0097	83
15	OAXACA	2,328	90,101	1.060	5.300	0.7792	0.0741	0.0451	400
16	PUEBLA	3,869	85,432	0.276	1.027	0.8497	0.0884	0.0368	69
17	QUINTANA ROO	3,230	162,406	0.009	0.282	0.9963	0.0020	0.0008	60
18	QUERETARO	637	32,853	0.247	1.241	0.8740	0.0848	0.0216	67
19	SONORA	3,578	24,814	0.406	2.951	0.8437	0.0852	0.0344	260
20	TABASCO	6,300	269,904	0.121	0.825	0.9300	0.0453	0.0188	105
21	TAMAULIPAS	10,560	421,360	0.088	0.694	0.9592	0.0230	0.0091	57
22	SAN LUIS POTOSI	1,399	52,080	0.002	0.083	0.9986	0.0012	0.0001	9
23	SINALOA	2,777	97,207	0.424	2.791	0.8346	0.0705	0.0485	633
24	ZACATECAS	401	17,531	0.031	0.209	0.9750	0.0197	0.0047	4
		86,337	3,264,715	0.280	1.449	89%	5%	3%	

4 Resample

10,000 resamples of size n

2015

Average

Standard Deviation

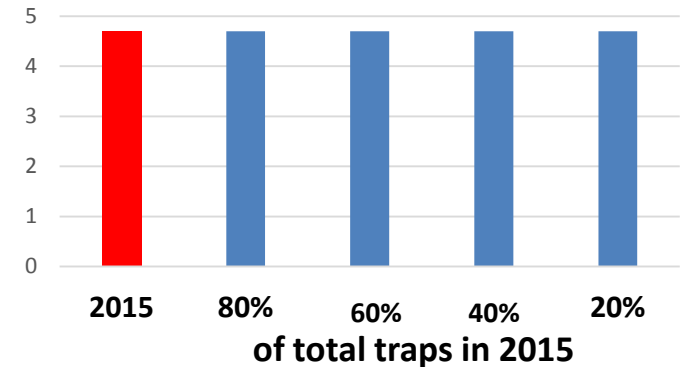
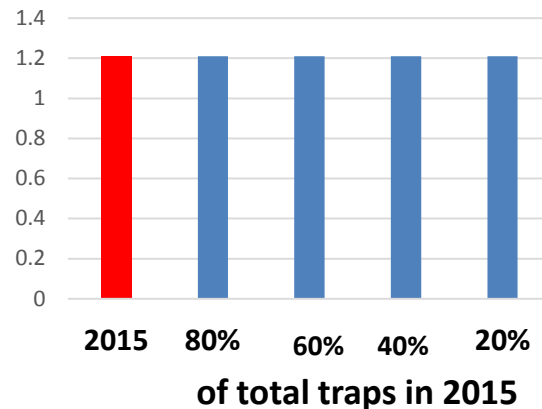
State	Traps	Average of capturing	Standard Deviation	80 % of traps		60 %		40 %		20 %		80 %	60 %	40 %	20 %
				n	AVG	n	AVG	n	AVG	n	AVG	SD	SD	SD	SD
				COLIMA	2845	1.2105	4.4685	2276	1.21	1707	1.21	1138	1.209	569	1.211
VERACRUZ	8873	0.2827	1.8512	7098	0.2826	5324	0.2826	3549	0.2825	1775	0.2827	1.857	1.854	1.842	1.83
MICHOACAN	9044	1.0799	2.9048	7235	1.08	5426	1.08	3618	1.08	1809	1.08	2.891	2.887	2.881	2.849
NUEVO LEÓN	1365	0.0523	0.4011	1092	0.0524	819	0.0524	546	0.0524	273	0.0523	0.4001	0.3994	0.3974	0.3975
YUCATAN	5364	0.0263	0.6894	4291	0.0264	3218	0.0264	2146	0.0264	1073	0.0263	0.5977	0.5676	0.5118	0.4645
BAJA CALIFORNIA	644	0.0313	0.2042	515	0.0313	386	0.0314	258	0.0313	129	0.0314	0.204	0.2041	0.204	0.2037

By reducing the number of traps, the average and the standard deviation of the data do not have very significant changes.

Colima state, Mexico

Average

Standar deviation

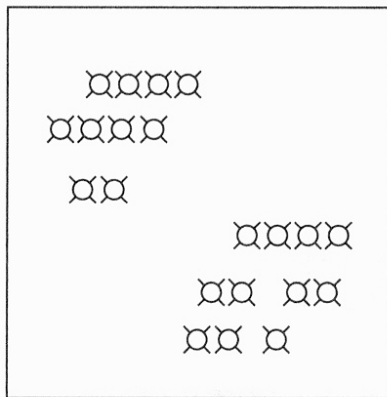


5 Negative binomial

(Spatial distribution of Psyllids)

$$N \ln \left(1 + \frac{\hat{m}}{\hat{k}} \right) = \sum_{i=1}^{nc} \left(\frac{A(x_i)}{\hat{k} + x_i} \right)$$

maximum likelihood method



Aggregated distribution
Low dispersion

	NATIONAL CONCENTRATE			
n	Size (K)	AVG	SD	MAX
200	0.0575	0.5649	3.0455	30
400	0.1200	0.2100	0.7739	10
600	0.1878	0.2000	0.6169	5
800	0.0699	0.2662	1.4884	26
1000	0.0618	0.1849	0.8680	11
1500	0.0794	0.2633	1.5644	45
2000	0.0902	0.2650	1.5877	59
10000	0.0728	0.2597	1.7703	90
100000	0.0749	0.2651	1.5872	153
1000000	0.0734	0.2668	1.9079	700
2000000	.073023	0.2667	1.8821	700
3264660	0.0731	0.2664	1.7868	700

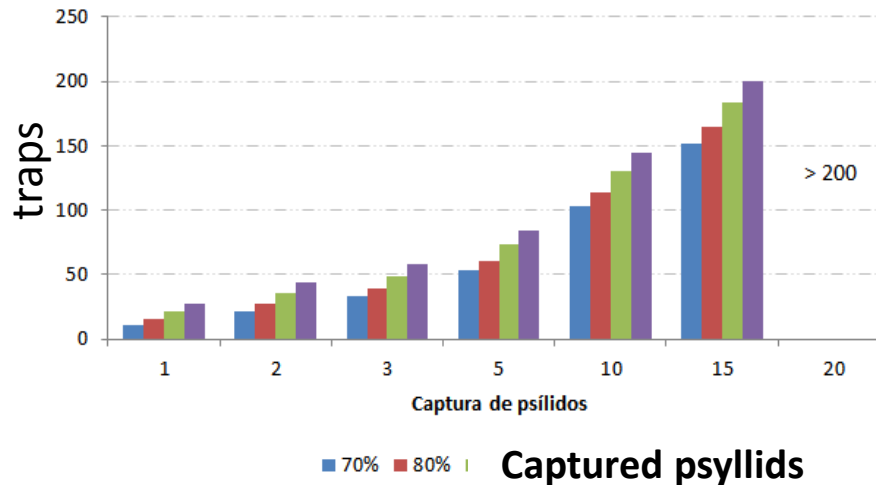
If the values of the parameter (K) are close to zero, it is likely that the incidence of psyllids in the orchard will be aggregated.

5 Negative binomial (Number of traps)

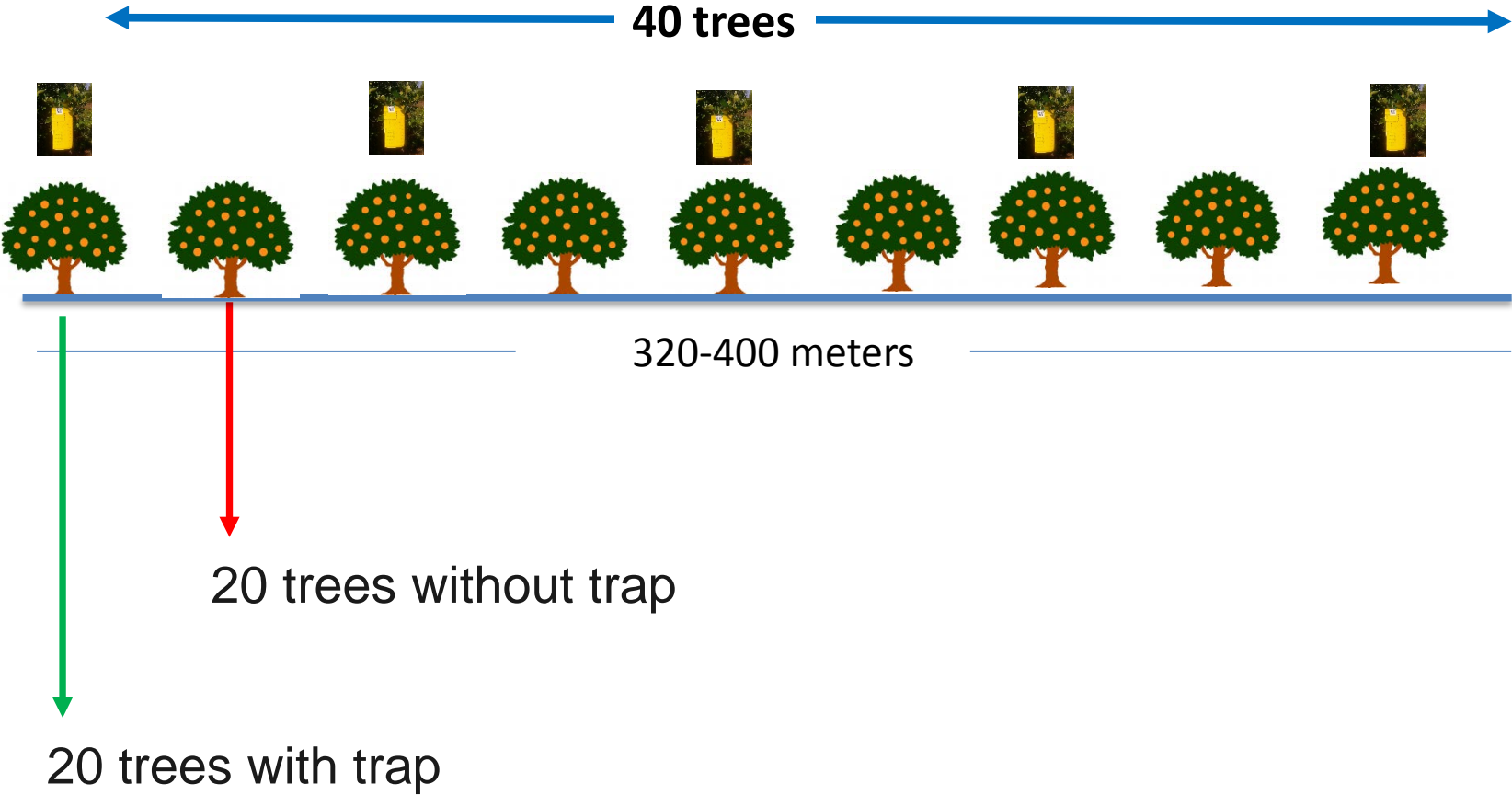
p = 0.10

Captured psyllids	Psilidos			
	Psilidos (k)	70%	80%	90%
1	11	15	21	28
2	22	27	36	44
3	33	39	49	58
⋮	⋮	⋮	⋮	⋮
5	53	61	73	84
⋮	⋮	⋮	⋮	⋮
10	103	114	130	144
⋮	⋮	⋮	⋮	⋮
15	152	165	184	200
⋮	⋮	⋮	⋮	⋮
20	> 200	> 200	> 200	> 200

p=0.10

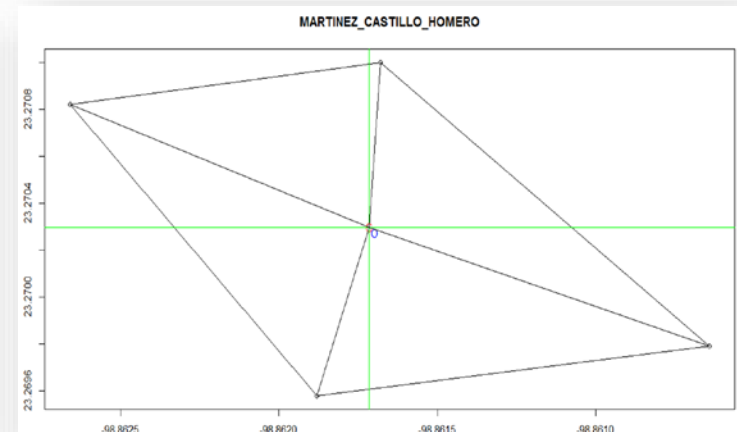
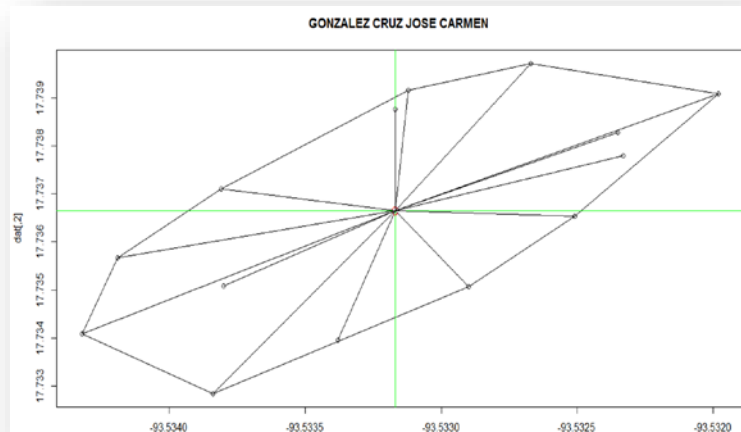
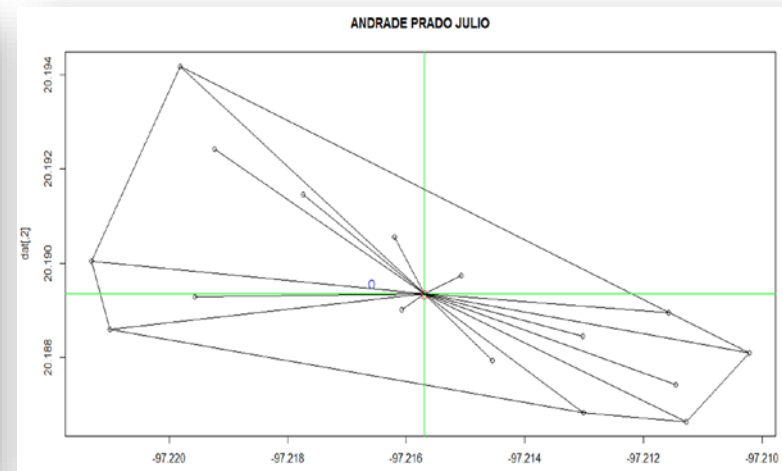
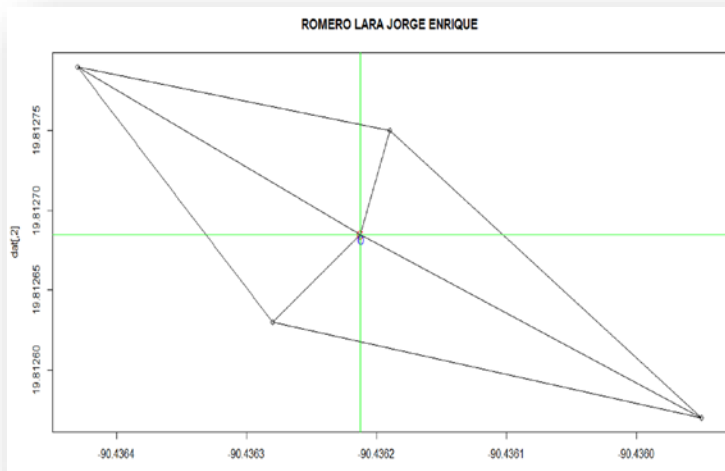


Disaggregation of a sampling line



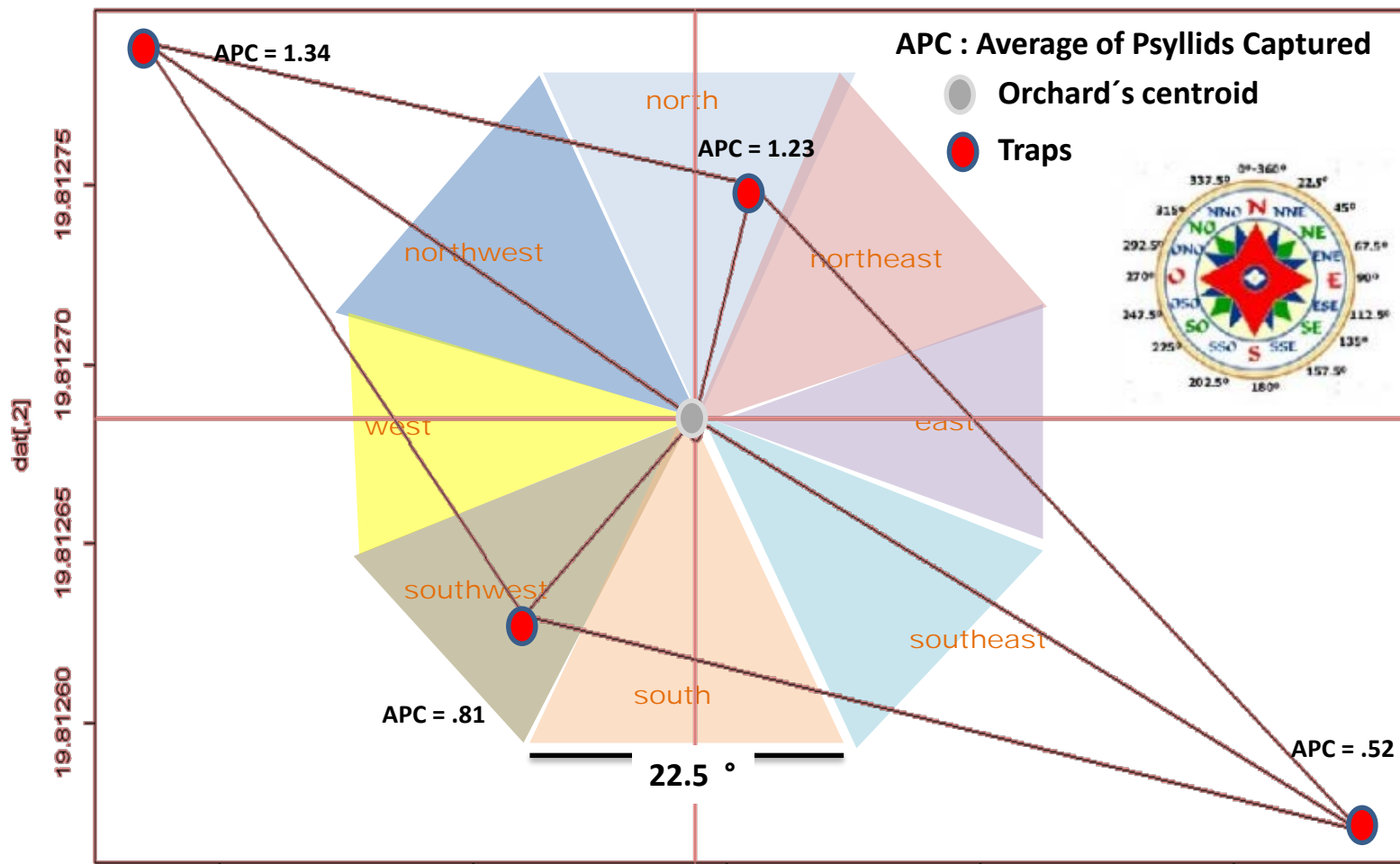
6 Geographical orientation to capture more psyllids

Using the **convex hull** algorithm in **R software**, it was possible to delimit the polygon formed by the traps located in a citrus orchard



Effect of trap's orientation on the number of captured psyllids

Orchard's owner: **ROMERO LARA JORGE ENRIQUE**



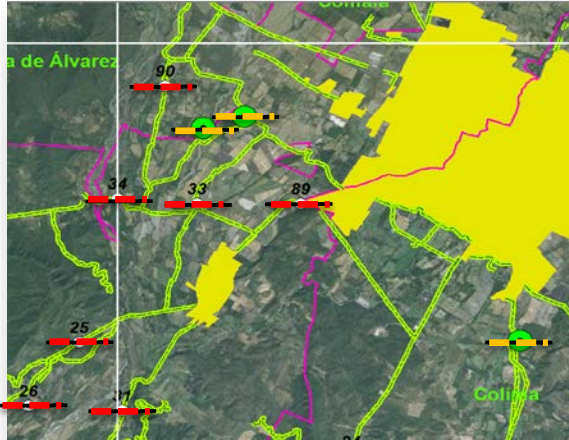
Average of psyllids captured according to the trap's orientation

National concentrate for geographic orientation reference

State	East	Northeast	Northwest	North	West	South	Southeast	Southwest
BAJA CALIFORNIA	0.0124176	0.0474360	0.0343244	0.0187548	0.0191374	0.0192444	0.0497519	0.0376530
BAJA CALIFORNIA SUR	0.8056566	0.6898925	0.5447348	0.5592583	0.7434729	0.7033287	0.8233296	0.6315953
CAMPECHE	0.0156049	0.0159901	0.0127139	0.0152466	0.0142817	0.0139931	0.0167737	0.0155432
CHIAPAS	0.0926320	0.0968328	0.1051527	0.0955556	0.0981320	0.0893973	0.0969537	0.0949389
COLIMA	1.3734095	1.0646024	1.2561511	1.0865371	1.3952885	1.1169554	0.9856775	1.1039072
GUERRERO	0.0299281	0.0376741	0.0302681	0.0289829	0.0373858	0.0355713	0.0317820	0.0383401
HIDALGO	0.0107563	0.0097479	0.0151334	0.0122208	0.0081364	0.0083068	0.0093058	0.0088555
JALISCO	0.2447515	0.1604835	0.1860025	0.1723045	0.2099224	0.2088491	0.2902330	0.2036677
MICHOACAN	1.0513640	1.0216550	1.0965794	1.0309337	1.0468566	0.9663459	1.0080107	0.9955646



Conclusions



- The Sampling lines must be integrated by 20 traps, one trap every second tree
- The traps should be located in areas with high risk presence for *D.citri*.
- the psyllids' spatial distribution is aggregated
- The traps' geographical orientation should be based on the national concentrate
- Reduction of traps up to 40%

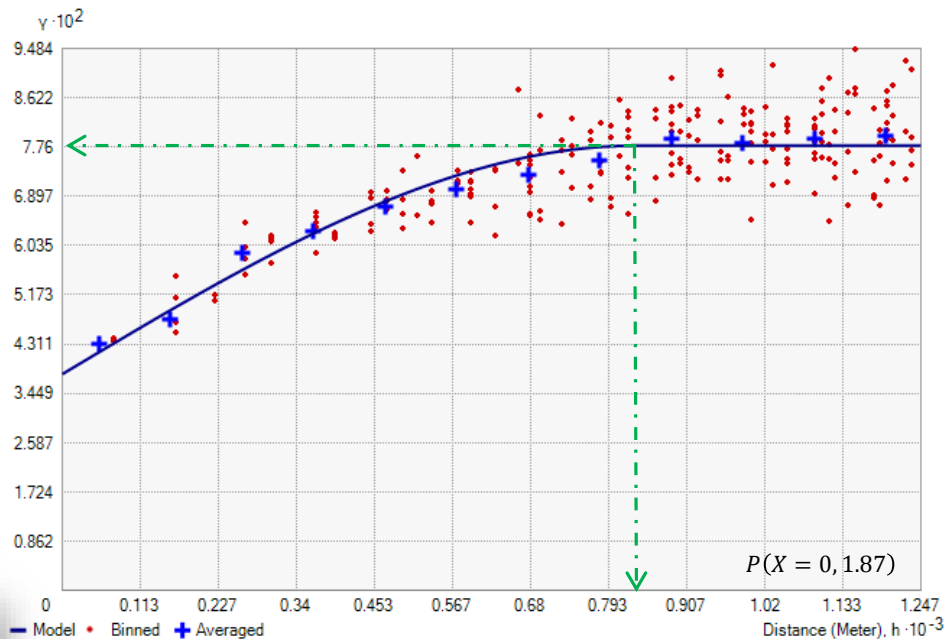
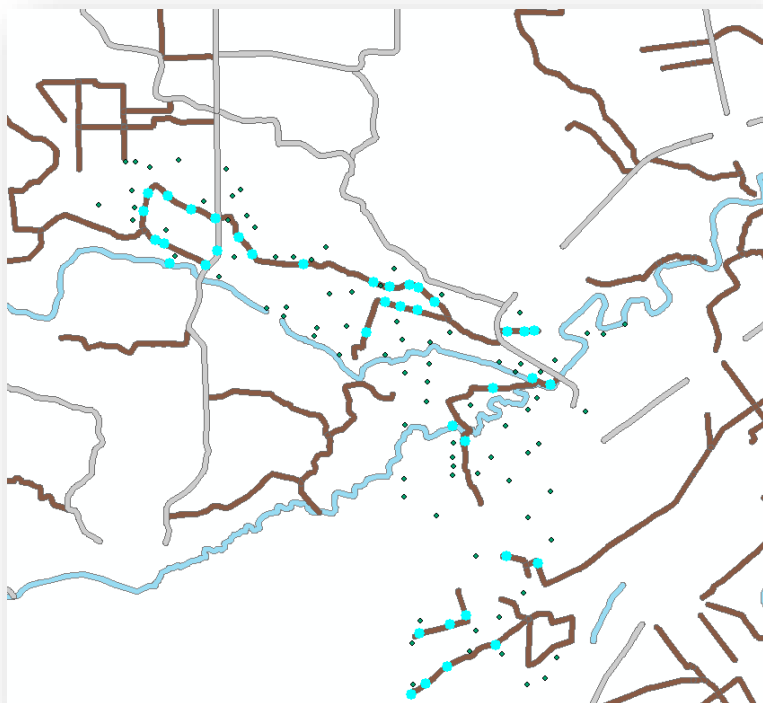
Geostatistical analysis

- The distance between trapping lines
- It is convenient to place the traps near to rivers and roads

Analysis through variogram

TO KNOW THE DISTANCES OF SAMPLING LINES

By overlaying the traps on highways, roads and rivers.



inirap DISTANCING AND ORIENTATION OF STICKY TRAPS FOR THE DETECTION AND MONITORING OF THE ASIAN CITRUS PSYLLID IN COLIMA STATE, MEXICO

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INTRODUCTION

In the state of Colima, Mexico, 80% of the citrus area is established with Mexican lime. The area cultivated in 2014 was 18,354 ha, which marks a historic low compared to the year 2000, representing a decrease of 8%, which is attributed mainly to the presence of Huanglongbing (HLB), a disease associated to the bacterium *Candidatus Liberibacter asiaticus* (CaL), which is transmitted by the Asian citrus psyllid, *Diuraphis citi* (Homoptera: Psyllidae).

In 2005, 5,000 traps were installed in Colima, to monitor the presence and absence of the citrus vector, an activity that is carried out every week throughout the year (Figure 1).

Due to the high cost of this task, new sampling schemes have been established in which the minimum distancing and orientation of trap groups should be installed. The goal of the new sampling scheme is to reduce monitoring costs and increase trap security and effectiveness to capture the insect.

RESULTS

The spherical origin model presented the lowest mean square of the standardized error (SMAE), with this model the origin analysis was performed for different probabilities of psyllid capture ($\mu = 0, 0.1, 1$ and 1.87) and it was observed that from the three probability parameters, there is monitoring orientation which is explained by the spatial distance between 31 and 44%, with an anisotropy tendency in the north-south direction (Figure 2).

CONCLUSIONS

The proposed scheme showed that the groups of traps should be located at no less than 1,000 meters among them and oriented to the north.

With the implementation of this sampling scheme, it is possible to make inferences about the proportion of orchards with presence and absence of CaL.

It will facilitate the design of subsequent sampling schemes within each orchard, as is the case of sequential sampling.

This methodology can be replicated in any productive citrus zone.

By applying this methodology, it would be possible to reduce in nearly 50% the costs of trapping.

REFERENCES

* Special thanks to CESARÉ-CHARRA for the economic support in the development of this research work.

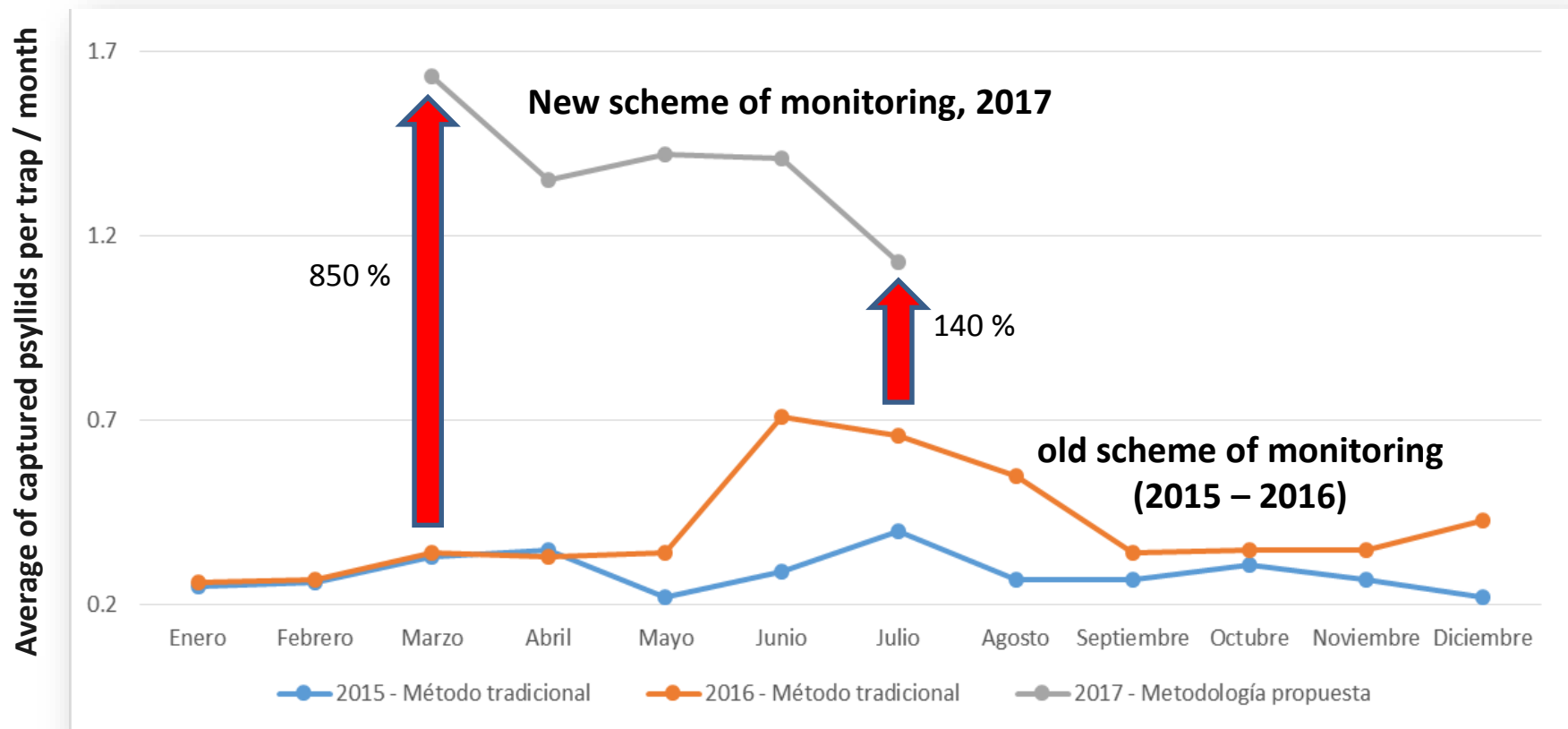
REFERENCES

> Comité Estatal de Sanidad Vegetal de Colima (CESAVECO). 2014. Puntos de observación de presencia de sanguijuela asiática-MC de los cítricos en el estado de Colima.

> Díaz R. G., López A. I., Sánchez C. I., Guzmán R., Mora A. S. y Quijano C. J. A. 2014. Área de abundancia potencial en México del vector del Huanglongbing, *Diuraphis citi* (Homoptera: Psyllidae). Revista Mexicana de Ciencias Agrícolas 5(7):1137-1153.

Impacts of using the new scheme of monitoring - 2017

- The results were presented in November 2016 to government authorities , they analyzed it and decided to implemented at the beginning of this year.
- The costs of monitoring have decreased by up to 30%.
- The increase in the capture of the psyllids is clearly reflected in graph.



WHY MEXICAN PEOPLE AND RESEARCHERS ARE WORRIED ABOUT THE PRESENCE OF HLB?



+

WORRYING SCALE

-



thanks

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Modeling and Agrometeorology Program