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

Dr. Gabriel Díaz-Padilla *
Rafael A. Guajardo-Panes
J. Isabel López-Arroyo
Ignacio Sánchez-Cohen

* *Conference speaker*
Researcher – Modeling and Agrometeorology Program
National Institute for Forestry, Agriculture and Livestock Research (INIFAP)

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

Institutional Objective

Develop and promote strategic research to contribute to the solution of major problems of the agricultural and forestry sector.

INIFAP has a presence in whole Mexico

8 Regional Research Centers, 38 Experimental Stations
1100 researchers

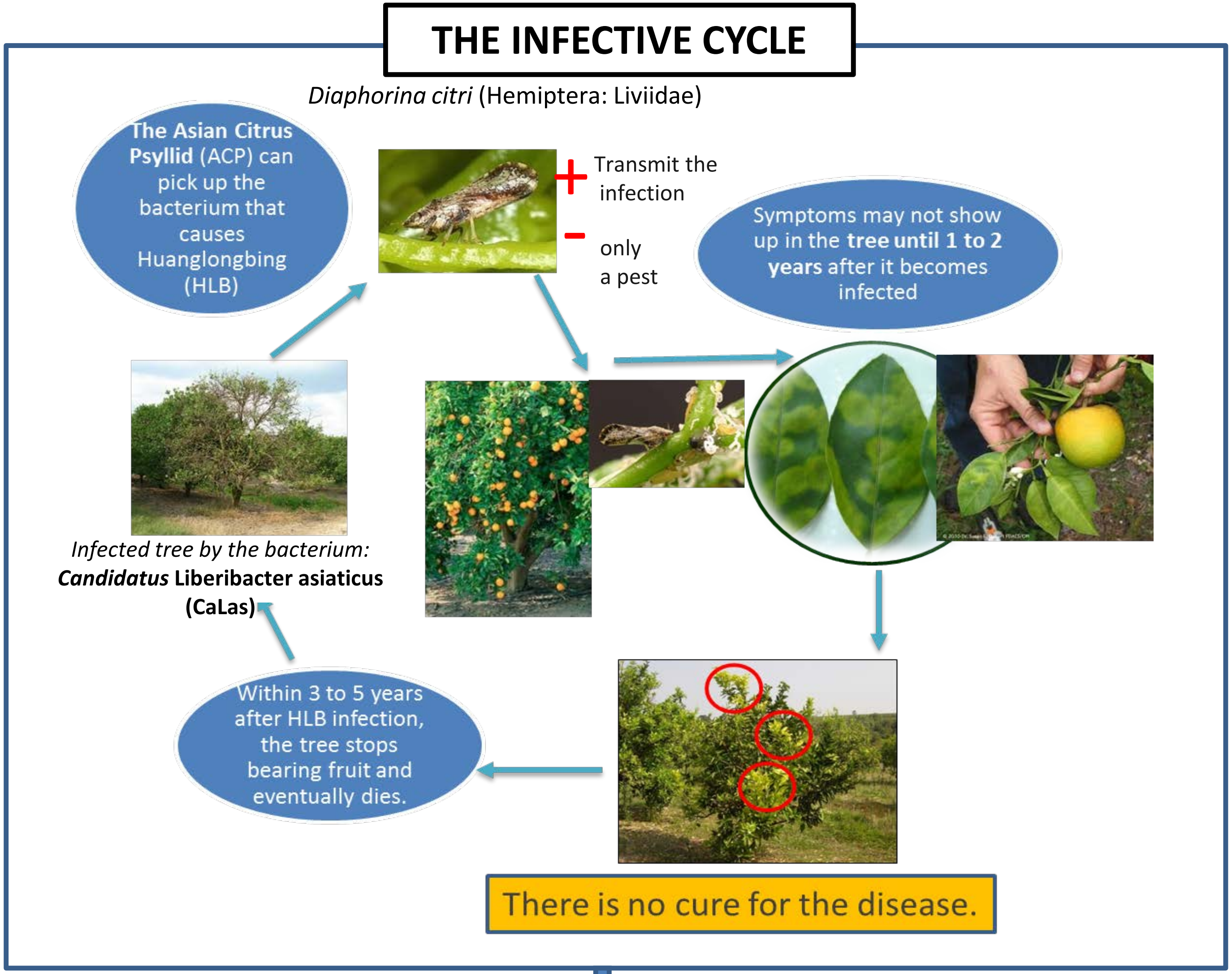
Where are we?

-Cotaxtla Experimental Station in the State of Veracruz

Program of Modeling and Agrometeorology

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

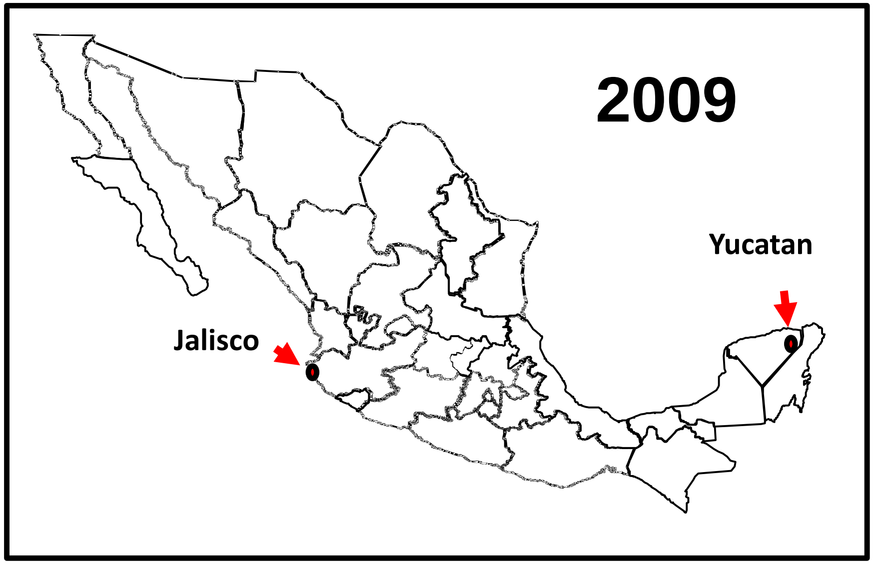
The Situation: is one of the most destructive diseases of citrus worldwide.



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

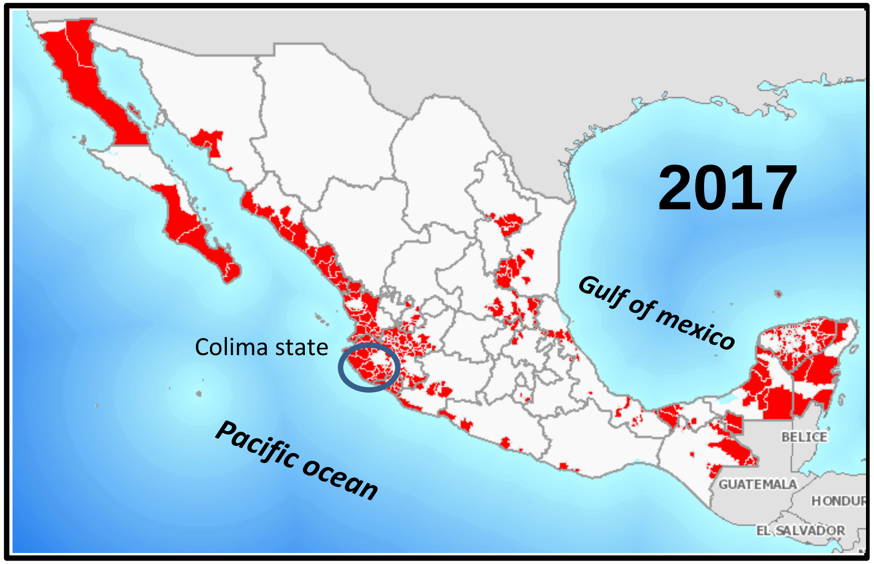
Status of the HLB in Mexico

Firsts outbreaks reported in Mexico



The insect vector (Diaphorina citri) is widely disseminated.

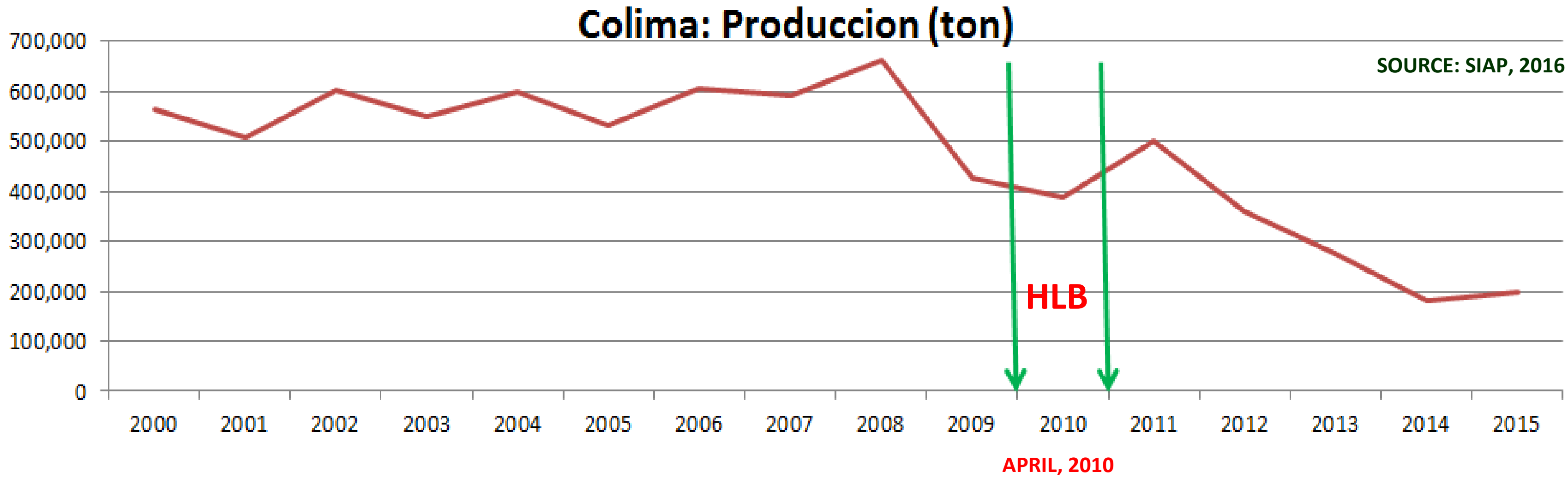
Dissemination of HLB in Mexico – July 2017



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



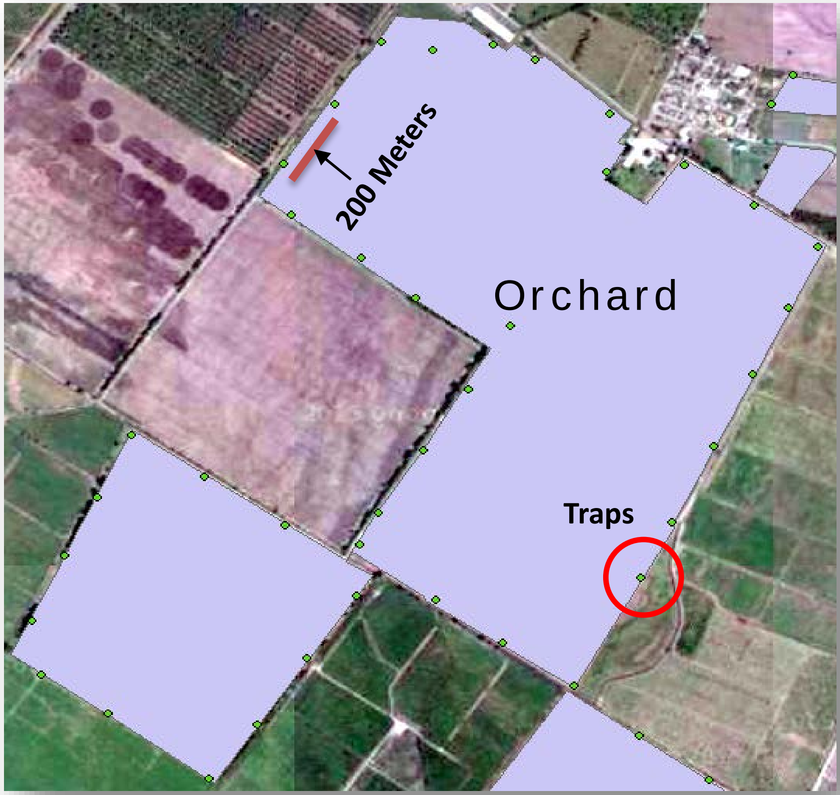
The greatest damage is found in Colima state which is the main mexican lemon producer.

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

The National Campaing for the managment, 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 theorical 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)

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$

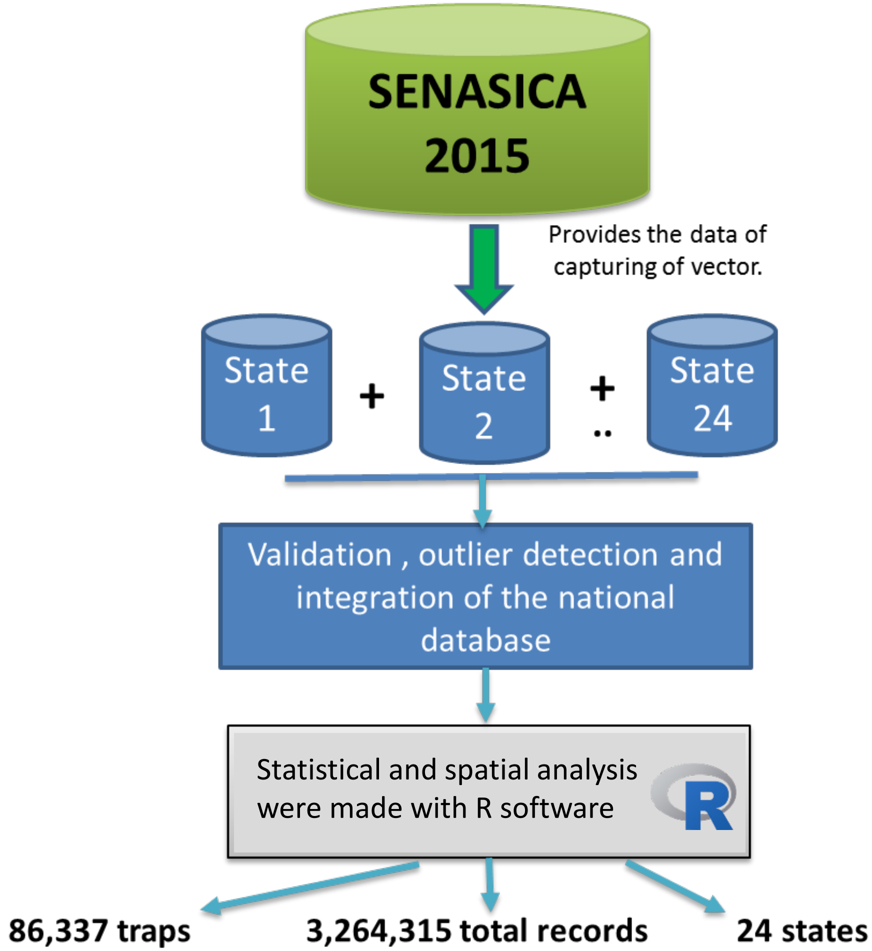
$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}}$$

5. Negative binomial
   - Spatial distribution of Psyllids
   - Number of traps
6. Geographical orientation

NEW IMPROVED SCHEME
2016 - 2017

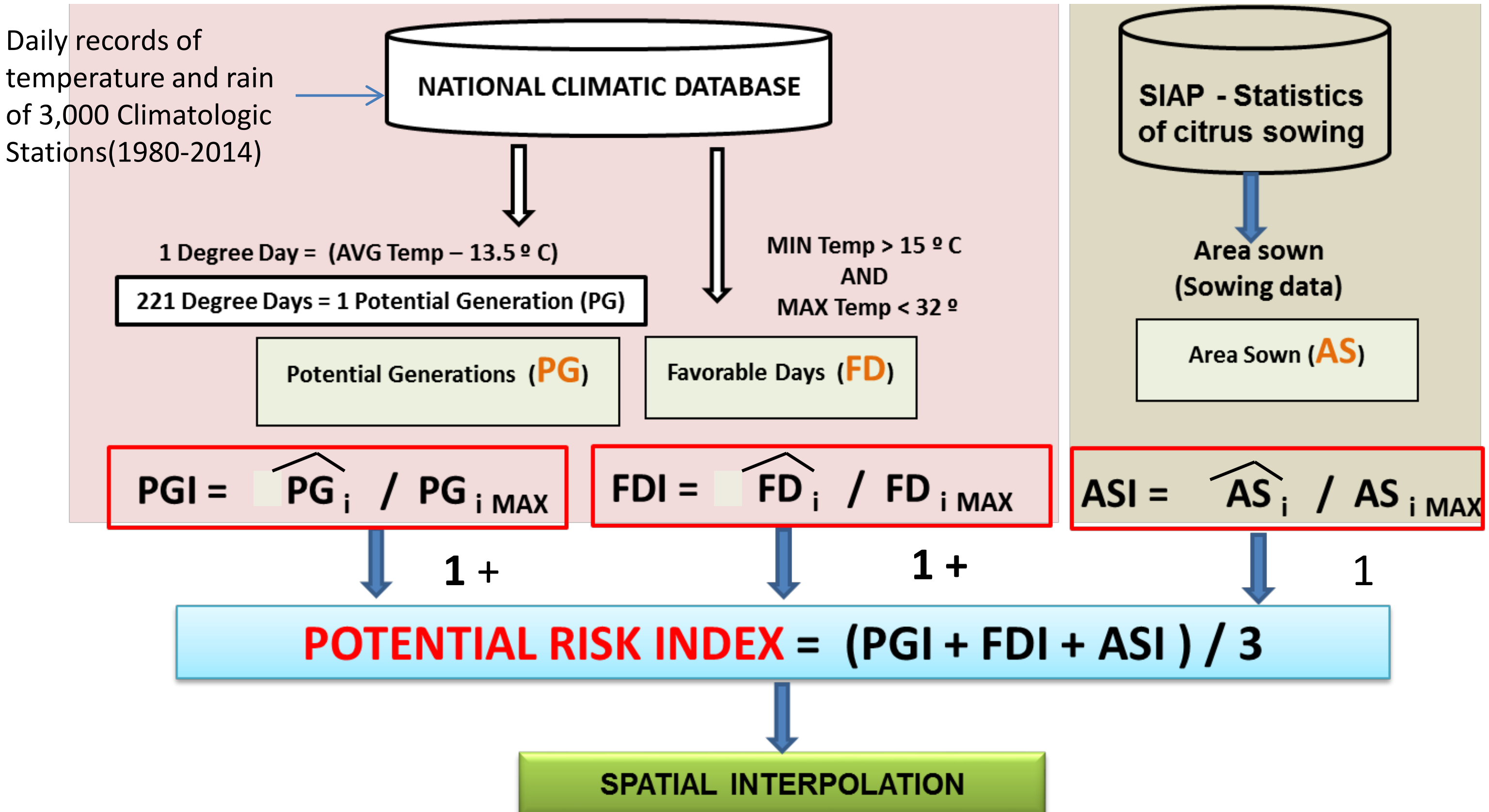
1 Database integration

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



A GREAT BUNCH OF DATA TO ANALIZE IN 6 MONTHS

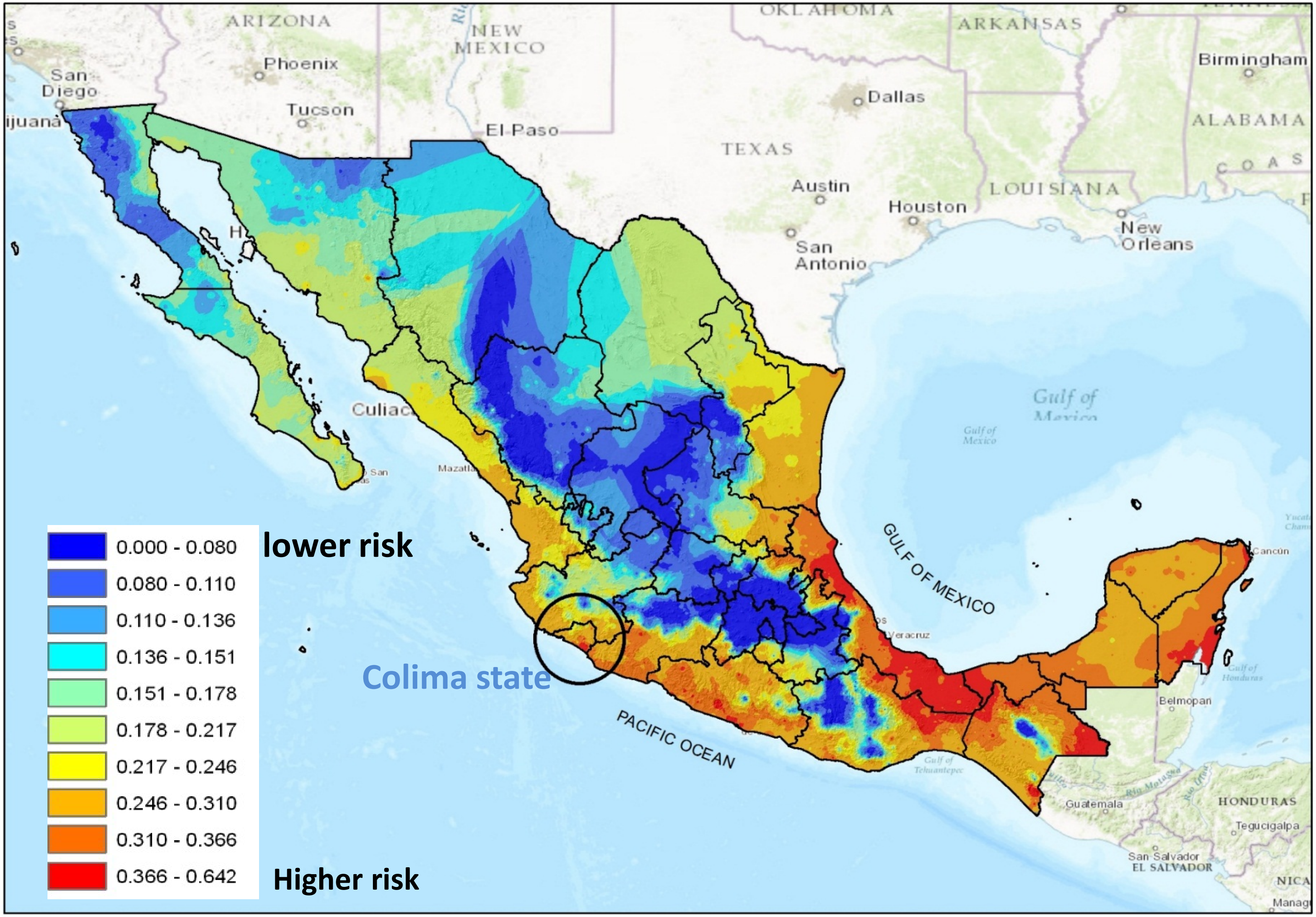
2 Mapping the potential risk of *D. citri*



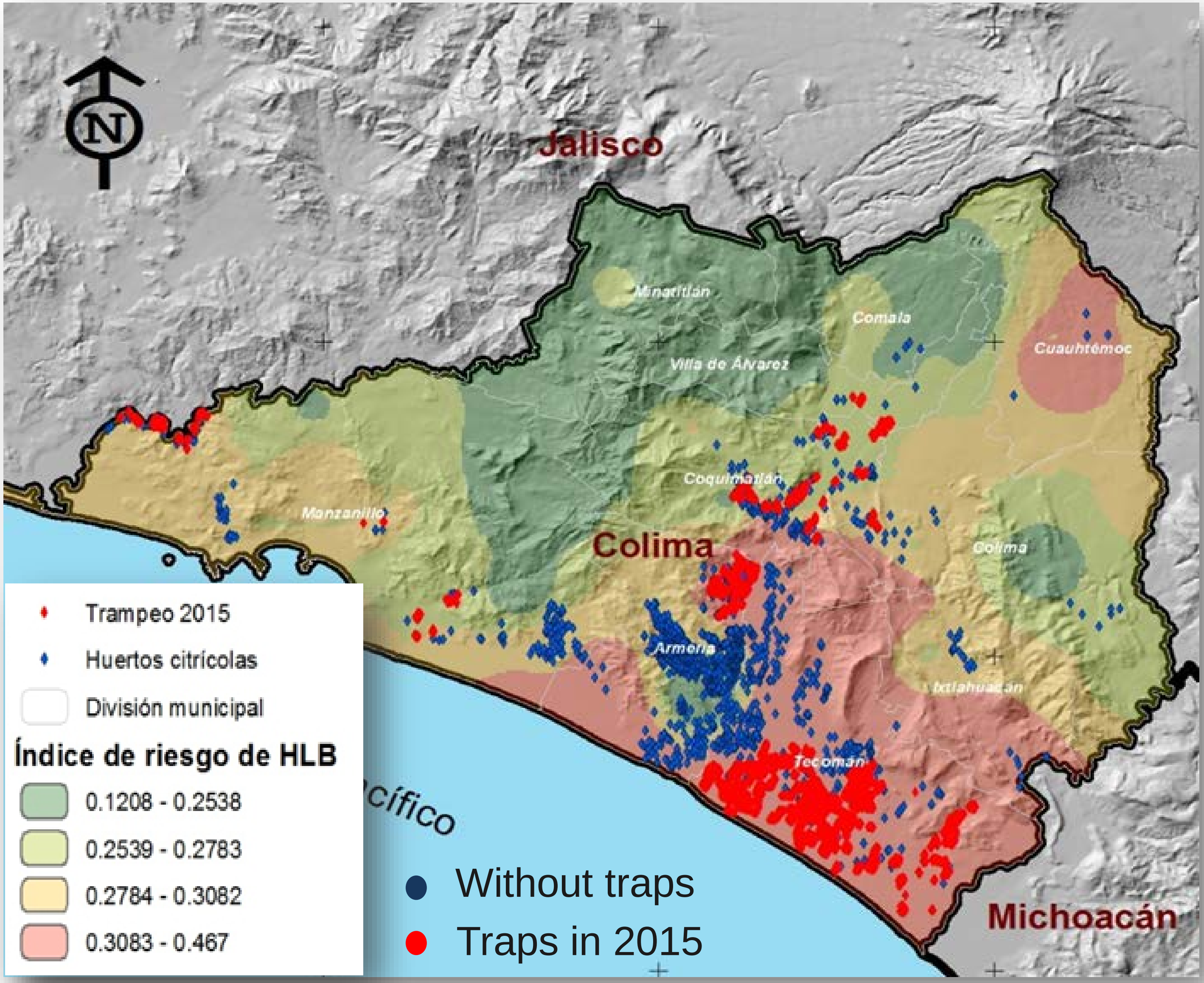
PGI: Potential Generations Index
FDI: Favorable Days Index
ASI: Area sown Index

i: climatic station

Spatial distribuition 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 0 CAPTURED PSYLLIDS	PORCENTAGE OF TRAPS WITH 1 CAPTURED PSYLLIDS	PORCENTAGE OF TRAPS WITH 2 CAPTURED PSYLLIDS	Maximum number of captured psyllids per trap in a week
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%	

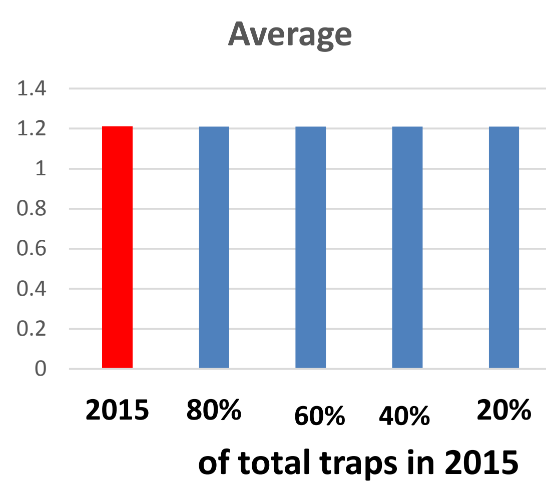
4 Resample

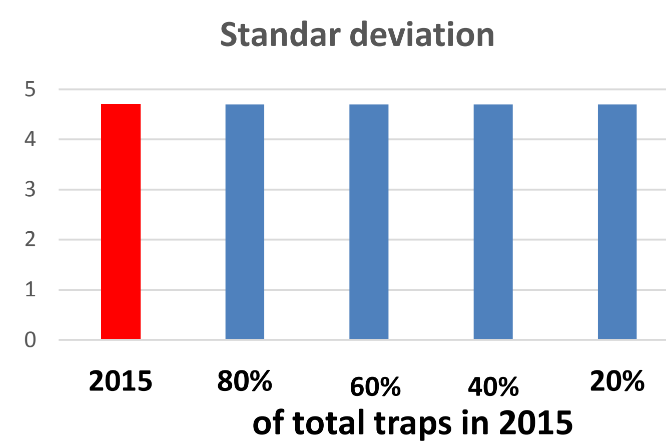
10,000 resamples of size n

State	Traps (2015)	Average of capturing (2015)	Standard Deviation (2015)	Average: 80 % of traps n	Average: 80 % AVG	Average: 60 % n	Average: 60 % AVG	Average: 40 % n	Average: 40 % AVG	Average: 20 % n	Average: 20 % AVG	Standard Deviation: 80 % SD	Standard Deviation: 60 % SD	Standard Deviation: 40 % SD	Standard Deviation: 20 % SD
COLIMA	2845	1.2105	4.4685	2276	1.21	1707	1.21	1138	1.209	569	1.211	4.474	4.47	4.458	4.469
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

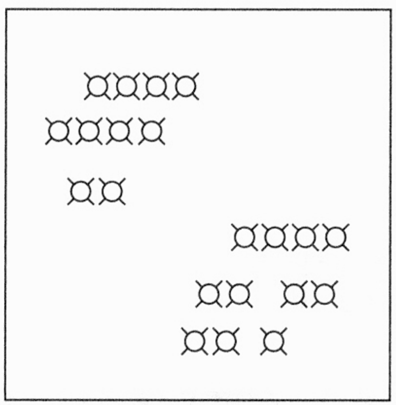




5 Negative binomial (Spatial distribution of Psyllids)

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

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

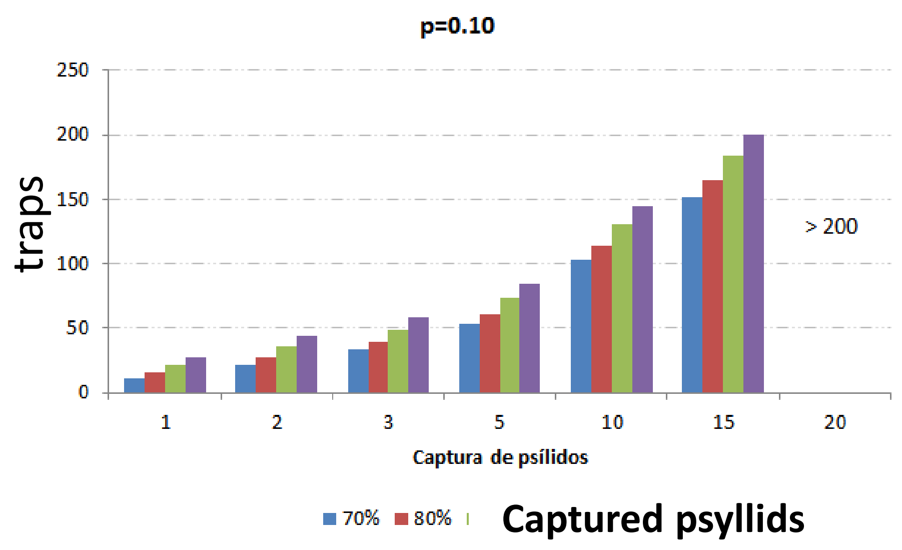
(Number of traps)

p = 0.10

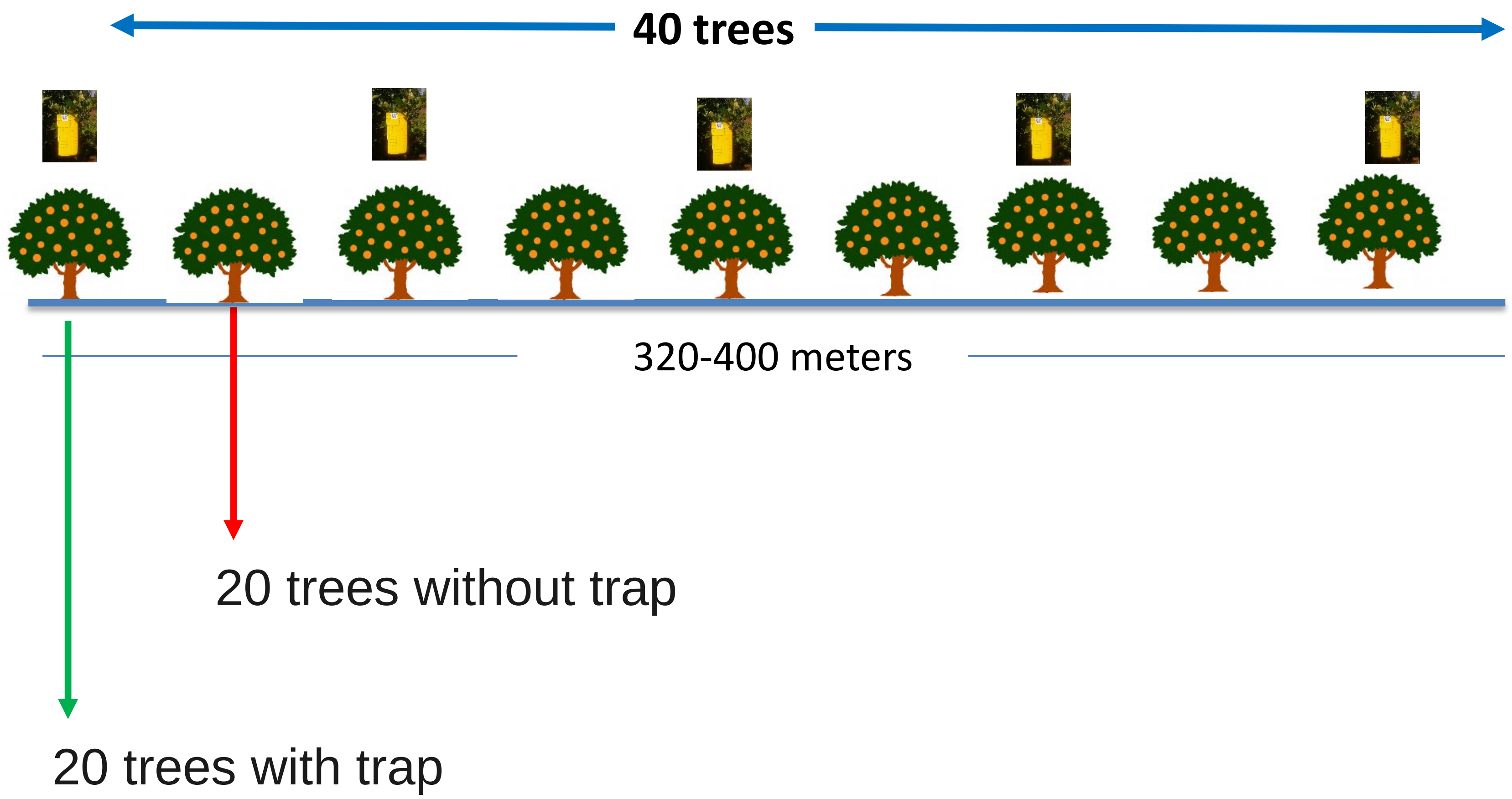
Psìlidos

Captured psyllids

Psìlidos (k)	70%	80%	90%	95%
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

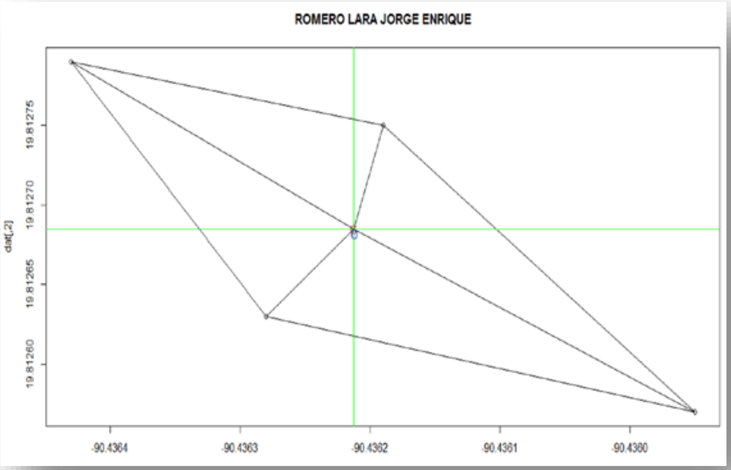


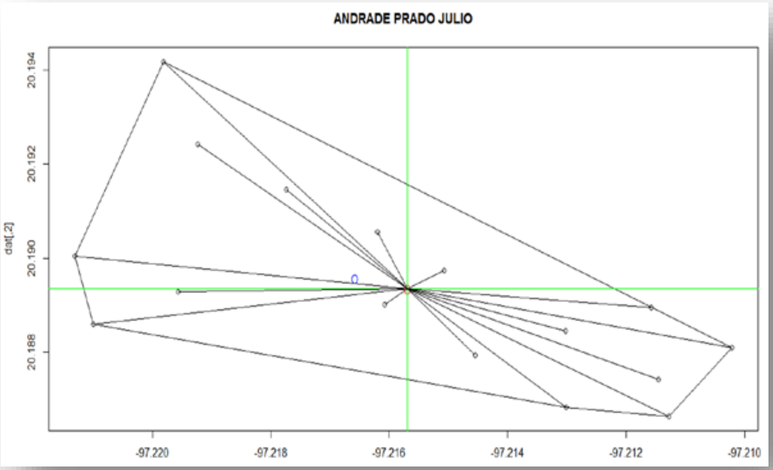
Disaggregation of a sampling line

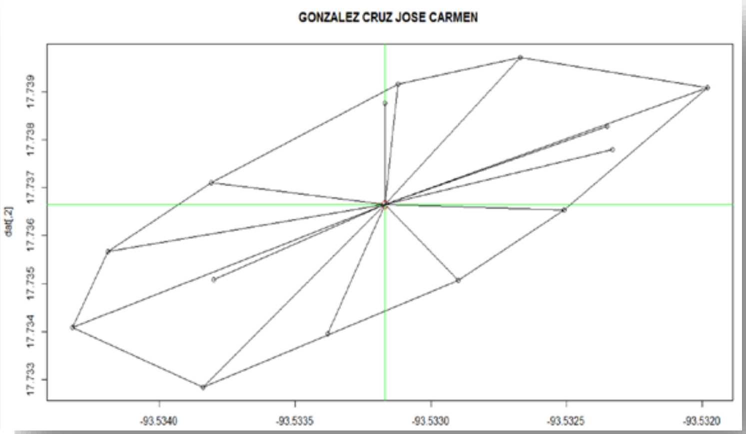


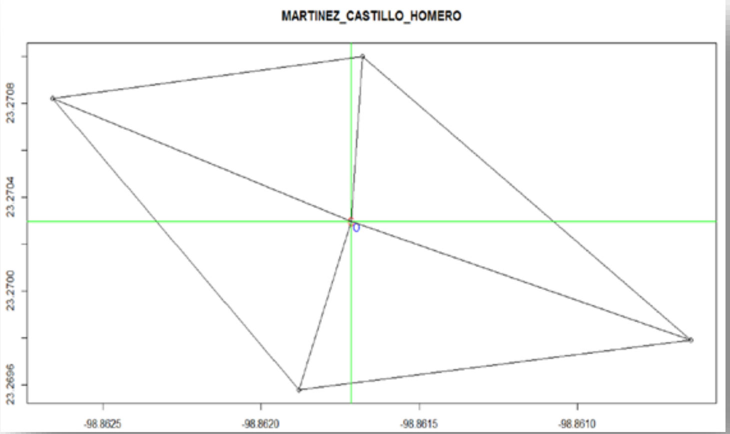
6 Geographical orientation to capture more psyllids

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



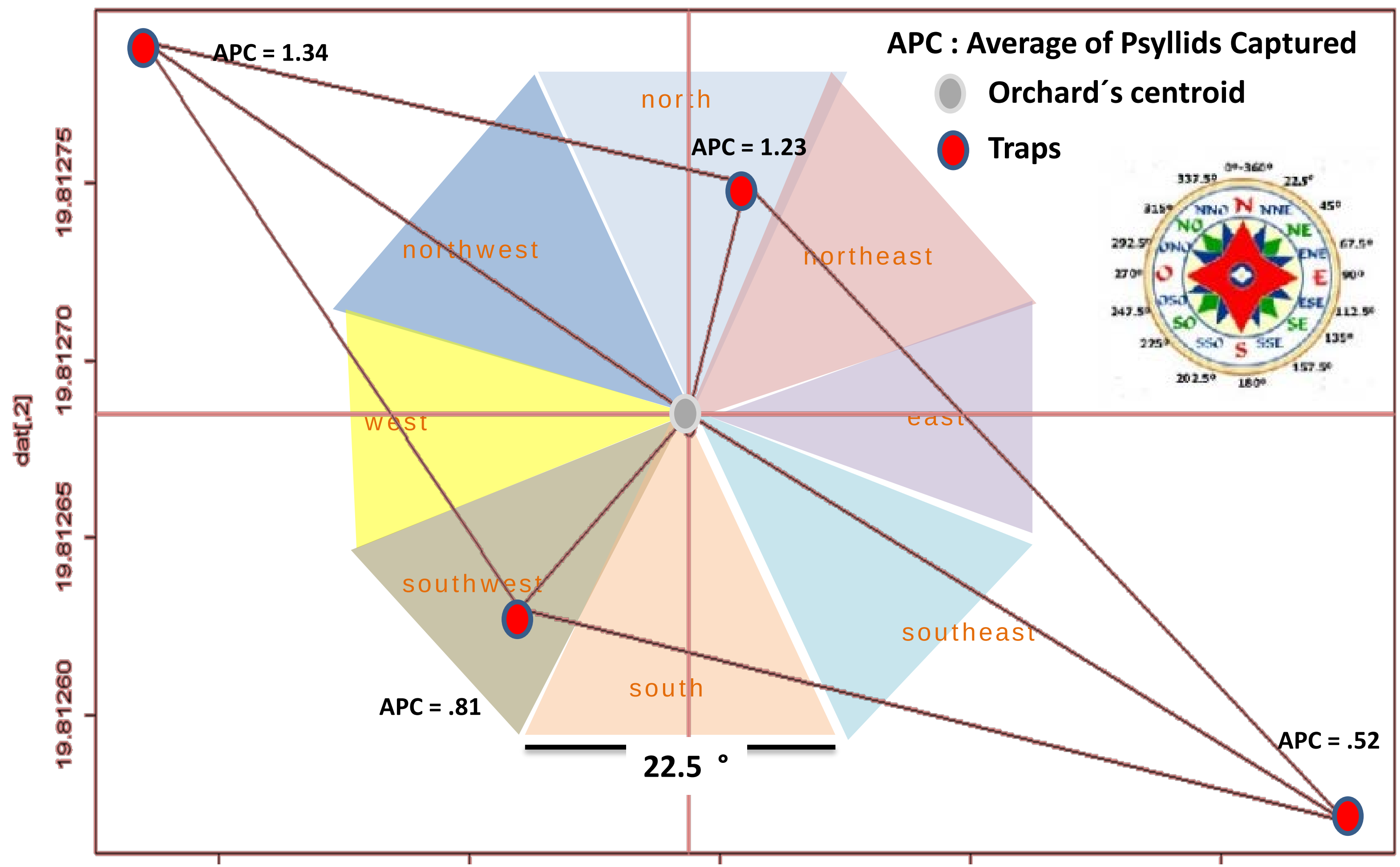






Effect of trap´s orientation on the number of captured psyllids

Orchard's owner: ROMERO LARA JORGE ENRIQUE

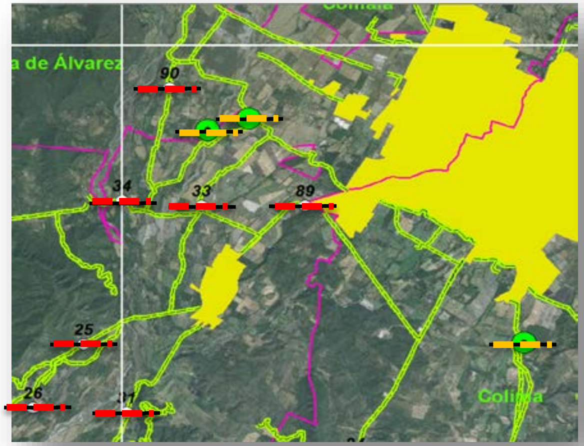


Average of psyllids captured according to the trap's orientation

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%

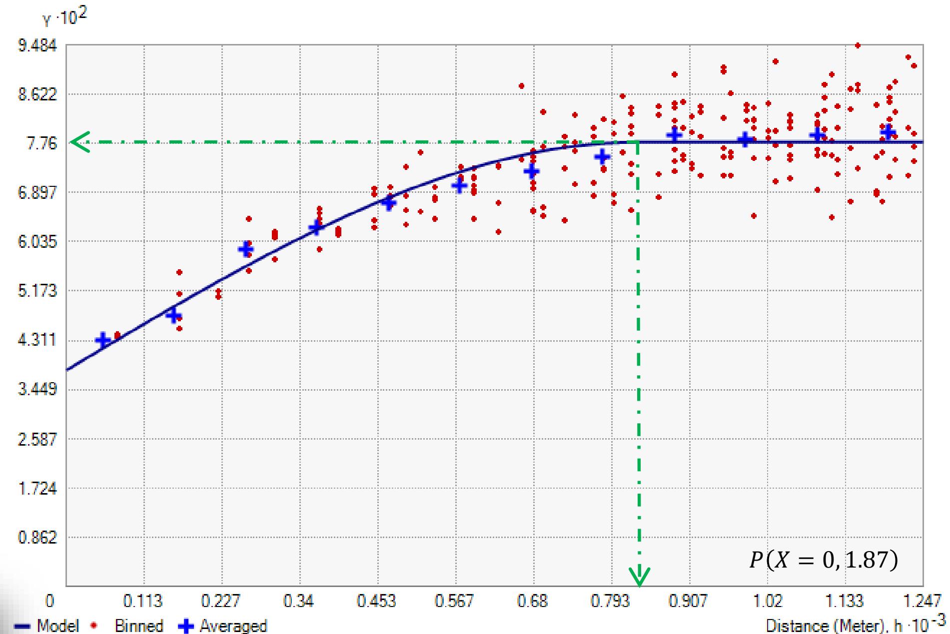
Geostatistical analysis

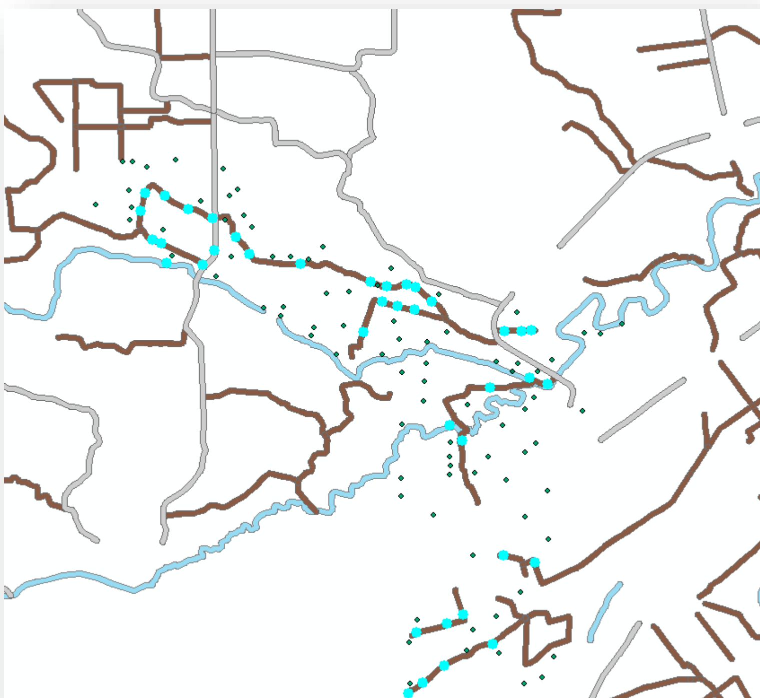
- The distance between trapping lines
- It is convenient to place the traps near to rivers and roads

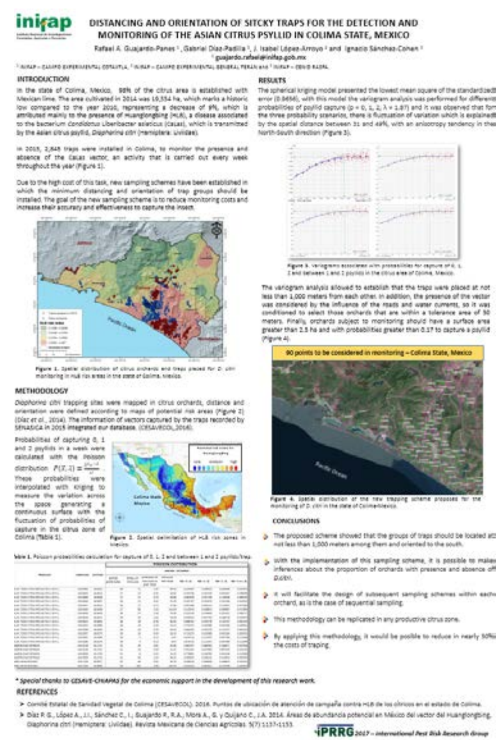
Analysis through variogram

TO KNOW THE DISTANCES OF SAMPLING LINES

By overlaying the traps on highways, roads and rivers.

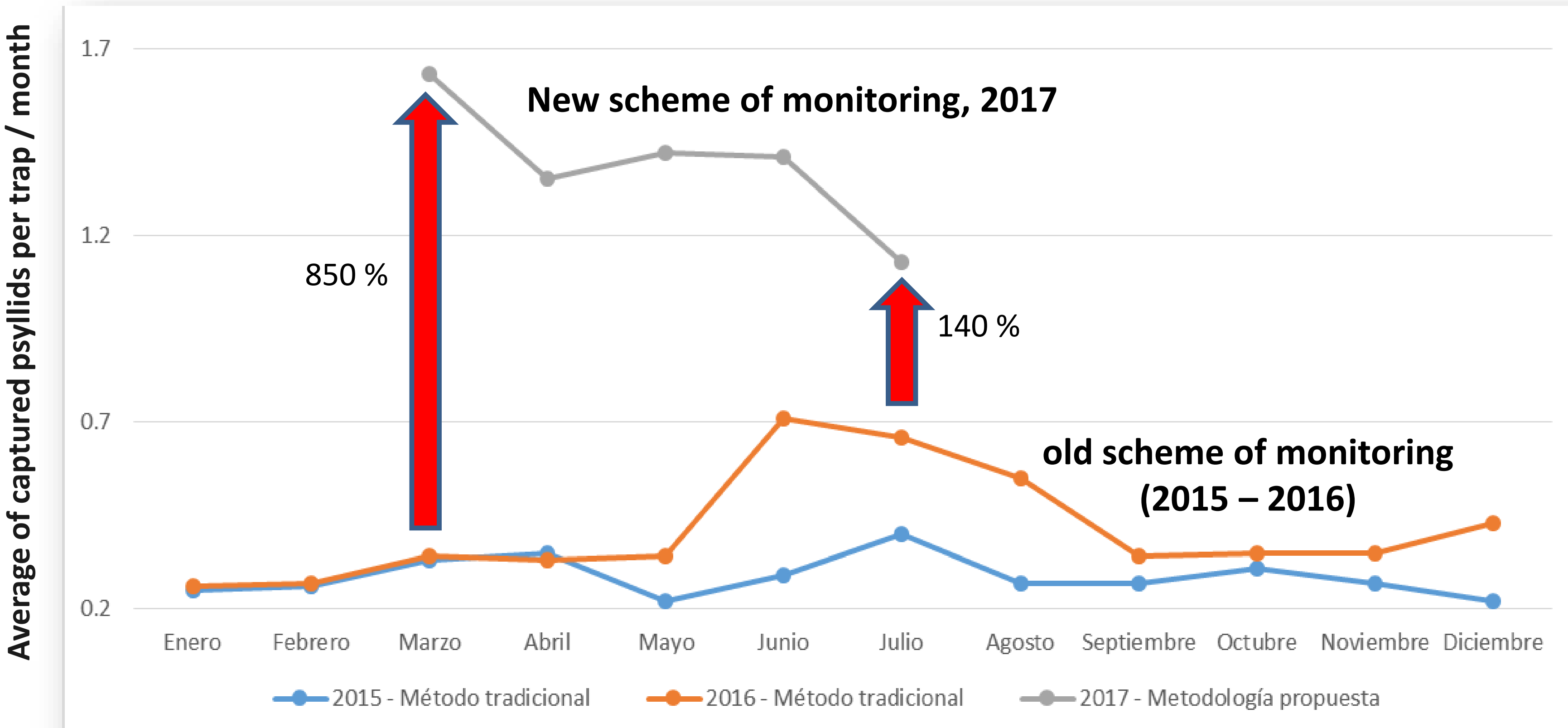






Impacts of using the new scheme of monitoring - 2017

- The results were presented in November 2016 to government authorities , they analized 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

Gabriel Diaz Padilla

diaz.gabriel@inifap.gob.mx

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www.inifap.gob.mx

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