
Predictive landscape ecology for improving insect pest management
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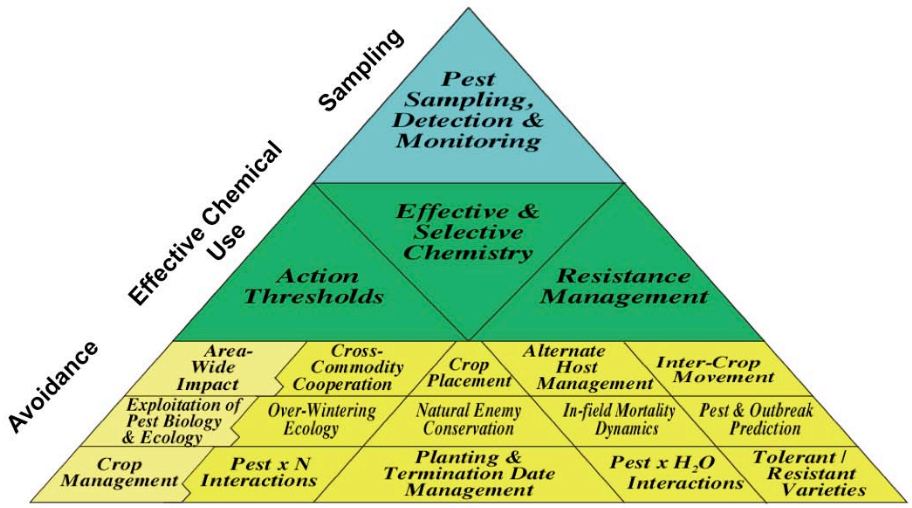
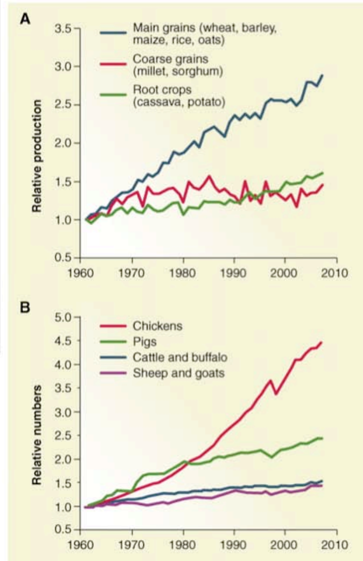
Integrated Pest Management



PC Ellsworth

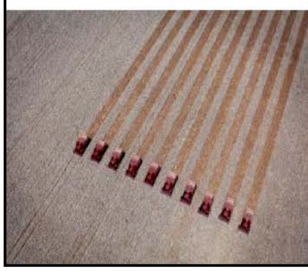
Changes in the global production of crops and animals since 1961 (relative production scaled to 1 in 1961).

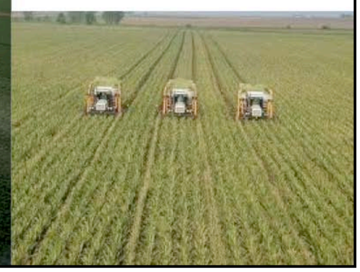


H C J Godfray et al. 2010. Science.

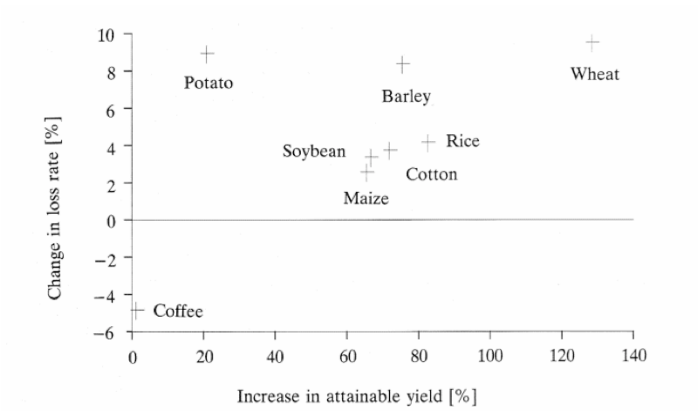
Increased crop productivity through agricultural intensification from 1960 to now

- Selection of cultivars with high-yield responses to fertilization and irrigation
- Selection of cultivars resistant to pests (e.g. , wheat rust)
- Greater use of pesticides, fertilizers and irrigation
- Up-scaling of field sizes and increased cover of monocultures in agricultural landscapes



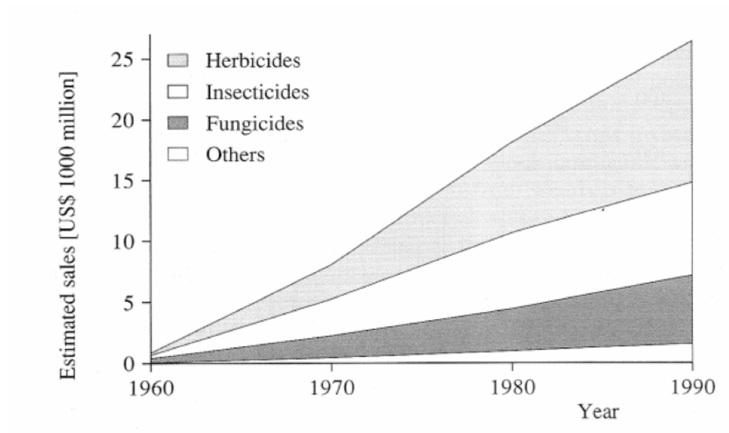


Changes in crop losses to pests associated with agricultural intensification from 1965 to 1990.

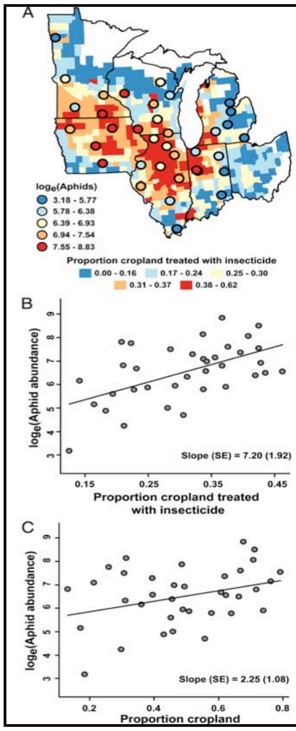


E-C Oerke et al. 1994. in Crop production and crop protection: estimated losses in major food and cash crops.

Changes in relative expenditure on crop protection products (adjusted for inflation) from 1960 to 1990.



E-C Oerke et al. 1994. in Crop production and crop protection: estimated losses in major food and cash crops.



Association between proportion of agricultural landscape occupied by crops, aphid pest abundance, and proportion of cropland treated with insecticides.

Bird cherry-oat aphid

Corn leaf aphid

Soybean aphid

T D Meehan et al. 2011. PNAS

Effects of agricultural landscape architecture on pest population dynamics

How does landscape architecture influences interactions of pests with their natural enemies?

- **Agronomic intensification reduces abundance and diversity of natural enemies**

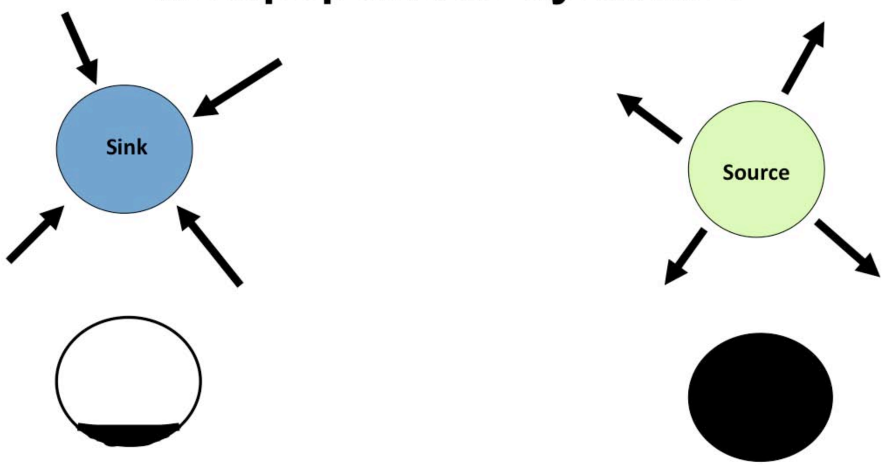
How does landscape architecture affect pest population dynamics?

- **Agronomic intensification increases the capacity of pests to find and exploit hosts**

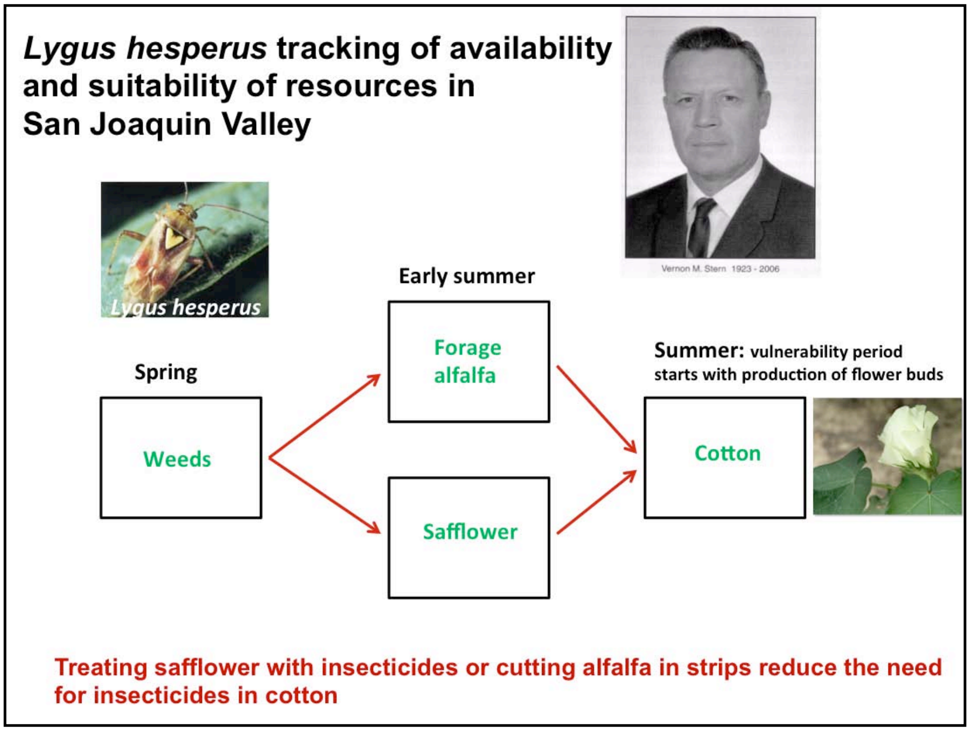
Metapopulation dynamics

Population density in a patch may be as much or more influenced by the type and proximity of other habitats as by the resources and conditions in that patch.

Metapopulation dynamics




Can we use a landscape / metapopulation dynamics approach to manipulate agricultural landscapes to disrupt the capacity of pests to find and exploit crops?

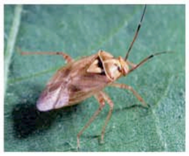


(Stern et al. 1959, *Hilgardia* 29: 81–101) notion of "integrated control"

Table 1. Subjective ranking of crops as lygus hosts found within San Joaquin Valley study areas in 2001.

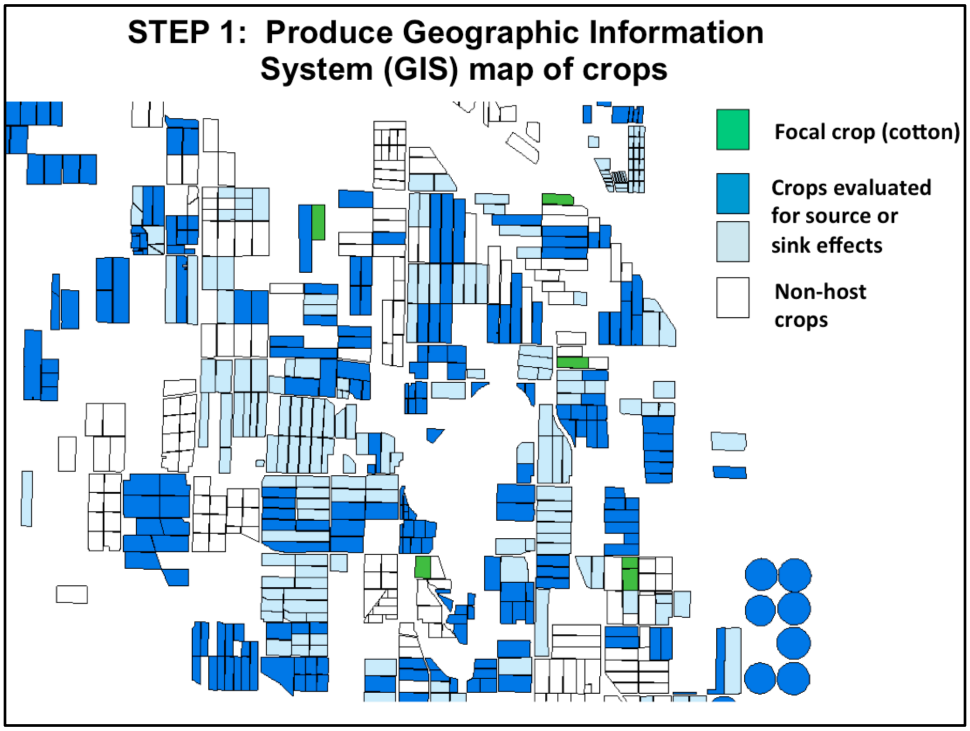
Crop	Host classification	Numerical ranking
→ Alfalfa	excellent	4
Almond	Fair	2
Apples	Fair	2
Broccoli	Fair	2
Cherry	Poor	1
Corn	Fair	2
Cotton	Good	3
Garbanzo	Poor	1
Garlic	Fair	2
Grain	Poor	1
Grape	Fair	2
Lettuce	Fair	2
Melons	Poor	1
Onions	Fair	2
Peach	Good	3
Pistachio	Fair	2
→ Safflower	excellent	4
Sugar beets	excellent	4
Tomato	Fair	2
Tomato, processing	Good	3
Veg. Seed Crop	Good	3
Wheat	Poor	1

Pete Goodell,
University of California

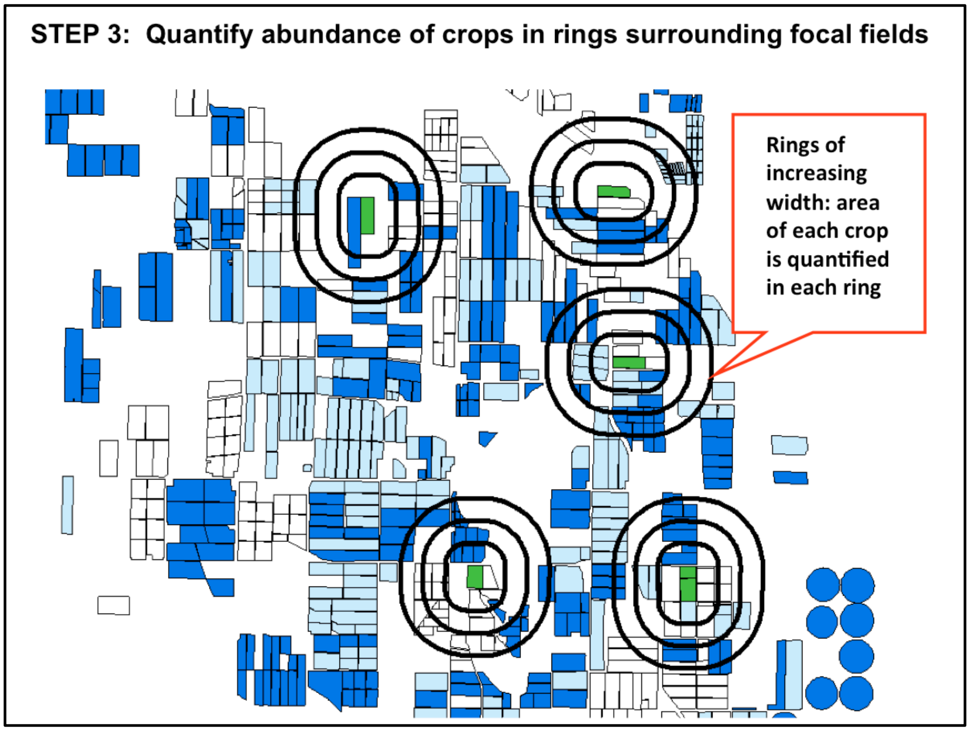


Metapopulation approach for *Lygus* management in San Joaquin valley

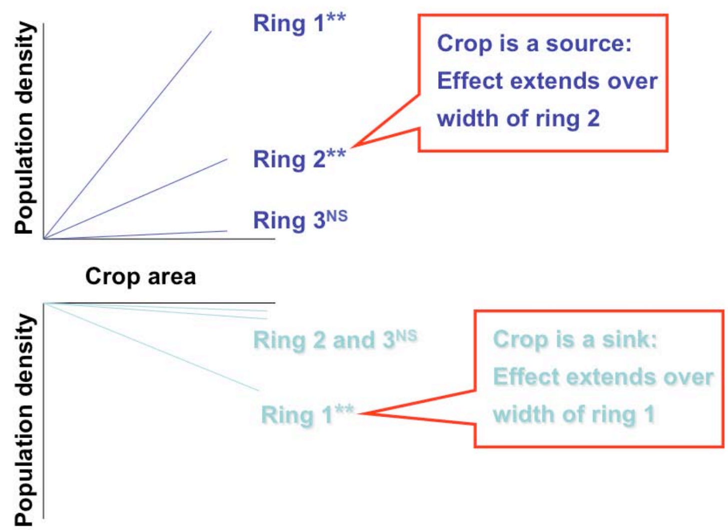
- **What are the source or sink effects of different crops and uncultivated habitats for cotton?**
- **At what distance are source and sink effects acting?**
- **Can we manipulate the distribution of crops and of local factors to reduce *Lygus* outbreaks in cotton?**


STEP 1: Produce Geographic Information System (GIS) map of crops
Focal crop (cotton)
Crops evaluated for source or sink effects
Non-host crops

STEP 2: Measure population density in each focal field (N > 40)


STEP 3: Quantify abundance of crops in rings surrounding focal fields
Rings of increasing width: area of each crop is quantified in each ring

STEP 4: Evaluate association between area of crops in rings of a given width and population density in focal crops



Density $_{\text{focal field}}$ = intercept + cropRing i + cropRing i + error

STEP 5: Adjust statistical tests of regression coefficients for spatial autocorrelation effects

- Autocorrelation in *Lygus* density and other variables across fields may lead to underestimation of *P* values associated with regression coefficients

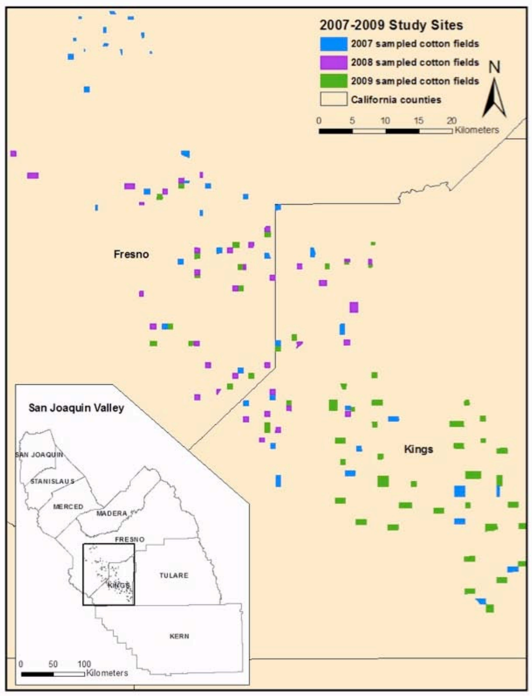
- If needed, measures of spatial autocorrelation are used to adjust the number of degrees of freedom in tests of regression coefficients

Pierre Dutilleul, Guillaume Larocque, McGill University

Outcome of analysis

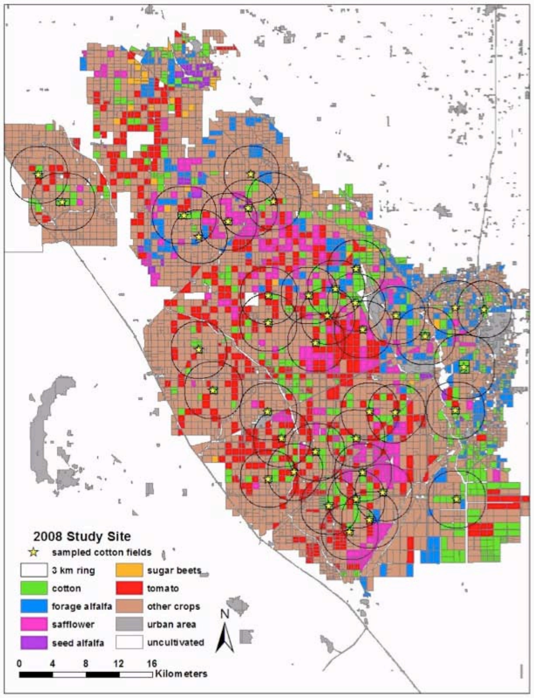
- **Identification of crops/habitats acting as source or sink for focal crop (from value of regression coefficients)**
- **Evaluation of spatial extent of source and sink effects (from identification of ring where effects become non-significant)**

→ **Information relevant for manipulating crop placement to reduce pest problems**



Experimental design:

- Study over 3 years (2007-2009) in San Joaquin Valley
- *Lygus* density measured in 36-57 focal fields in a region of c.a. 2000 km^2



Experimental design:

- Crops within 3 km of focal fields identified from the ground
- Uncultivated habitats mapped with GIS and validated with Google Earth
- Local variables measured in focal cotton fields:

  a) Number of insecticide applications

  b) Cotton flowering date
- Regional variables:

  Area of six types of crops and uncultivated habitats surrounding focal cotton fields

Analyses

- *Lygus* density during two periods (mid-June to mid-July; mid-July to mid-August) was analyzed to investigate seasonal changes in source/sink effects

- Analyses were performed at each of 12 spatial scales (rings of 250 m to 3000 m)

Stepwise regression — To identify significant local and regional variables

↓

Multiple regression — To evaluate the effect of selected variables

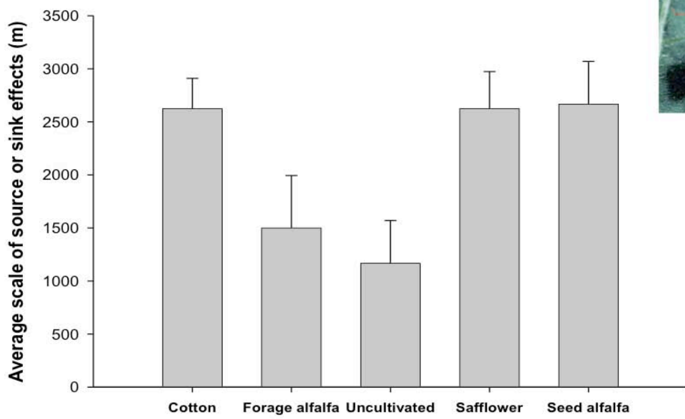
Effects of local and regional variables on density of *Lygus hesperus* in focal cotton fields during the two periods

Variables	Mid-June to mid-July			Mid-July to mid-August		
	2007	2008	2009	2007	2008	2009
Cotton	-	-	-	-	-	-
Forage alfalfa	+	-				
Uncultivated habitats	-			-		-
Safflower	+	+	-			-
Seed alfalfa*	+			+		+
Sugar beet* &				+		
Tomato	-					
Flowering date		+		+		
Insecticide sprays						-

* Not analyzed in every year because crop was rare in rings

& Regression coefficient changed with scale but was positive on average

Average scale of source and sink effects (mean + SE) of crops and uncultivated habitats.



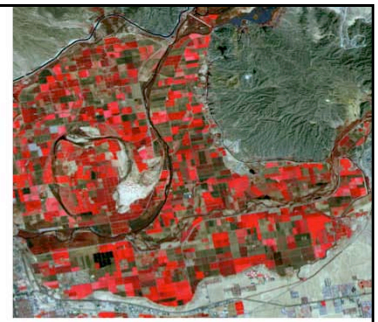
Conclusions

1) Factors with consistent effects across periods and years: cotton and uncultivated habitats (sinks), seed alfalfa (source), and flowering date (positively associated with *Lygus* density).

2) Safflower and forage alfalfa had variable effects

3) Tomato, sugar beet and insecticide applications were rarely associated with *Lygus* density

Potential recommendations



1) Cotton fields should be planted early

3) Cotton fields should be clumped

5) Seed alfalfa should be planted at > 3000 m from cotton
(maximum scale of source effects)

7) Cotton fields should be planted near uncultivated habitats
(< 500 m, minimum scale of sink effects)

Model development for predicting *Lygus* density in cotton

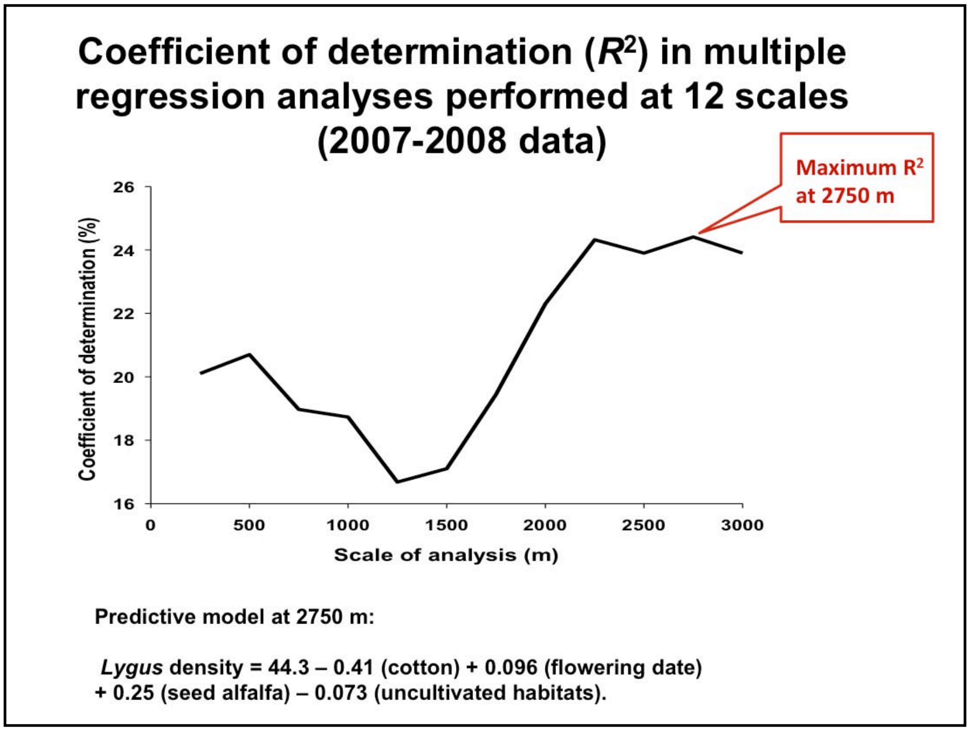
1) Data from first 2 years (2007-2008) were pooled to fit multiple regression model; a single period (mid-June to mid-August) was considered)

1) Explanatory variables with consistent effects (cotton; flowering date; seed alfalfa; uncultivated habitats) were included in model

3) Model was fit across the 12 scales and scale with maximum R^2 was used for prediction

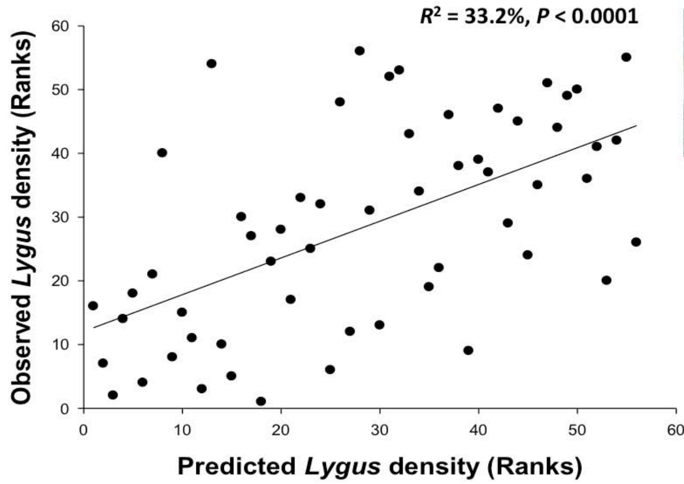
4) Values of the explanatory variables for each sampled field in 2009 were substituted in multiple regression model to calculate predicted *Lygus* density.

5) A rank-based simple linear regression was used to assess the association between predicted and observed values of *Lygus* density in 2009.



R2 is significant at scales of 2000 and above.

Rank-based simple regression between observed and predicted values of *Lygus hesperus* density across 56 cotton fields sampled in 2009



Conclusions

1) A model based on data from 2007-2008 and the four factors that consistently affected *Lygus* density was sufficient to predict *Lygus* density in cotton fields in 2009

2) A landscape approach based on manipulation of these factors could be useful to manage *Lygus* in the Fresno and Kings Counties of the San Joaquin Valley.

Advantages of the landscape / metapopulation approach (ring analysis):

1)GENERAL: The method was effective for predicting population dynamics (Lygus) and evolution of resistance to an insecticide (whiteflies). The method could likely be used to study spatial variation in other phenomena in focal patches (e.g., biodiversity; infection rates by pathogen)

2)SYNTHESIS: Effects of several local and regional variables can be evaluated simultaneously

3)SPATIALLY EXPLICIT: Can be used to evaluate the scale of regional effects

4)PREDICTIVE: Can determine whether a set of factors is sufficient to predict spatial variation in a given phenomenon, which increases the credibility of putative pest management strategies.

Acknowledgements

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RAMP PROGRAM