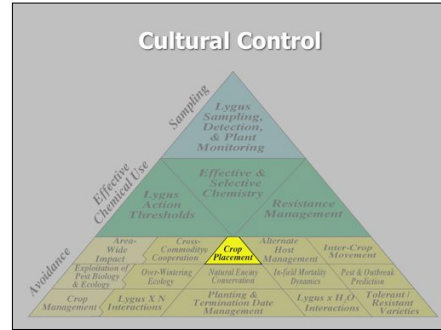
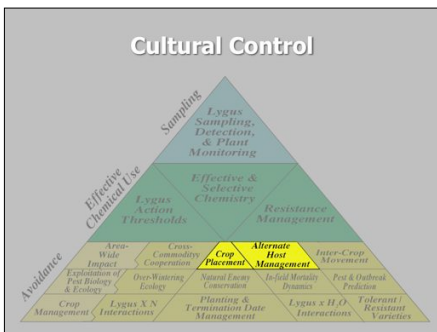




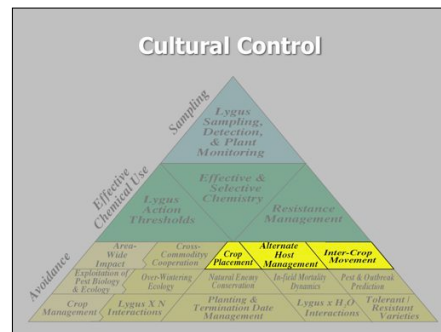
This interactive session is a demo of the Lygus Simulation Training Environment that was developed in Arizona as a "serious" game for teaching growers advanced concepts of spatial ecology as they related to risk of damage by Lygus to cotton in multi-crop communities.



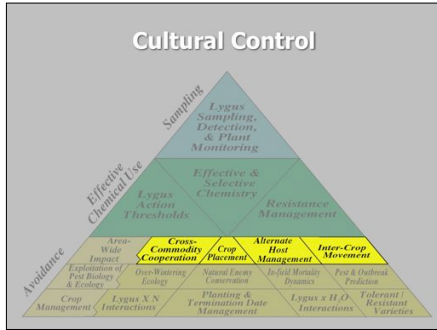
Right at the heart of our IPM strategy is "Crop Placement". Crop placement is central to its availability to pests. By strategically considering how we arrange and place our crops both in space and time, we can help to deny our crops as a resource for pest insects. This is the central concept of the game. The problem until now is that we have had only very limited information on how to strategically arrange our crops to prevent or minimize damage from insect pests.



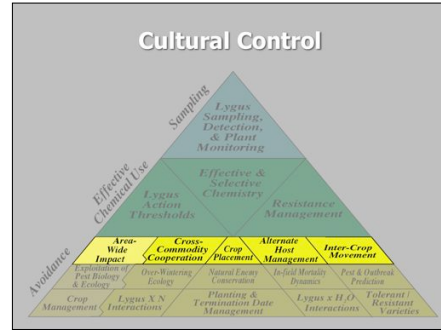
But by arranging crops, we can effectively help in source reduction and "alternate host management".



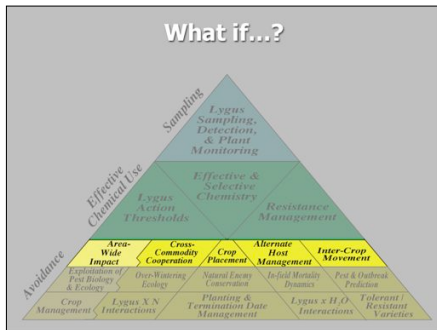
Which capitalizes on the knowledge we've gained in predicting Lygus inter-crop movement.



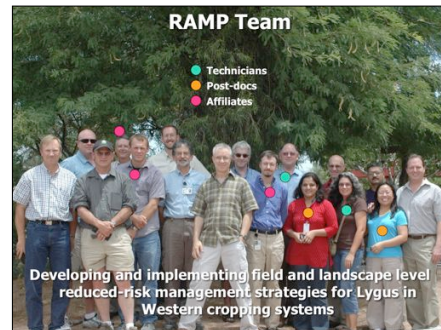
And, hopefully as part of this serious game and through even a minimum dialog with your neighbors (fellow game players), cross-commodity cooperation further leverages management power.



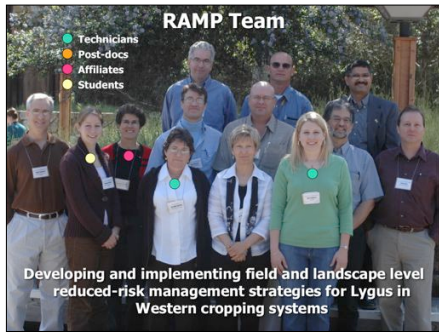
Taken together, each of these cultural practices permits us to contribute to an overall area-wide impact on Lygus populations, lowering the risk to individual growers and for the entire community.



The game we will play poses the question, what if we knew enough about the spatial ecology of Lygus in a system that we could re-organize crop resources to minimize risks of Lygus infestation?



This was just one project of 32 in a very large cooperative USDA-Risk Avoidance and Mitigation Program team. Most, but not all members of that team are shown here (including collaborators). We wished to advance our understanding of Lygus movement and management across the entire agroecosystem of the West and integrate that with existing IPM programs. As part of our project, we organized the 2<sup>nd</sup> international Lygus symposium. The project team. Missing PIs: David Kerns (Texas A&M); Scott Bundy (NMSU).



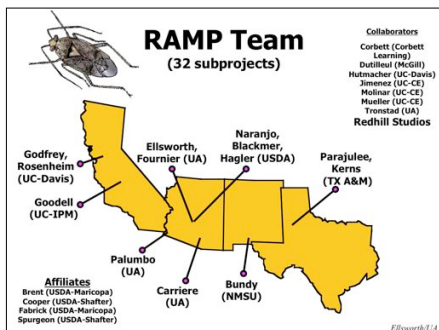
We are so large that we never had everyone in one spot at one time, but this is about half of the overall team (including collaborators). As part of our project, we organized the 2nd international Lygus symposium.

The project team. Missing PIs: Larry Godfrey (UC-Davis); David Kerns (Texas A&M); Jay Rosenheim (UC-Davis); Scott Bundy (NMSU).

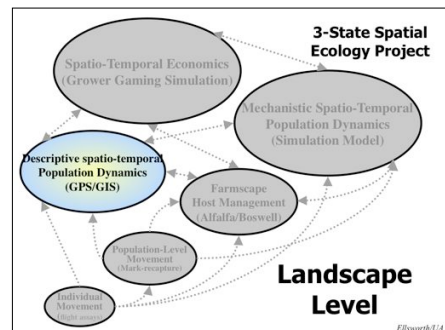
This picture is from the 2nd International Lygus Symposium held at Asilomar Conference Center, Pacific Grove, CA, 15-19 April 2007, and sponsored in part by the APMC and the USDA-RAMP grant.



Here are the project leaders of the TX team. Kerns, Carroll, and Parajulee.

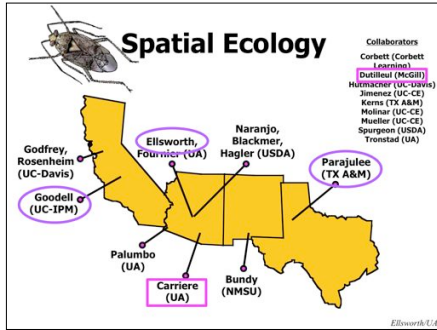


4 states and multiple institutions were involved in the overall RAMP project.



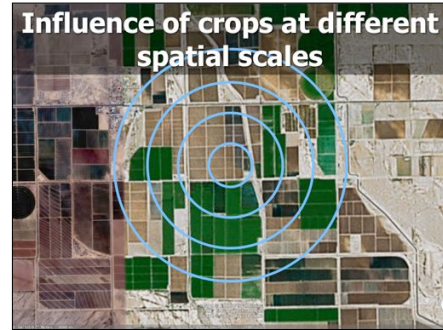
A conceptual flow-diagram of the RAMP project delineating components of the three major elements (field-level research, landscape-level research and outreach) and their interrelationships. Arrows depict the flow of information; black arrows indicate a one-way flow and red arrows depict flows with feedback. Within the Landscape-Level domain the size of the ovals indicate the spatial context of that element from very localized (e.g., individual movement) to regional and multi-state (e.g. spatio-temporal economics).

The "game" depended on empirical work conducted on a grand scale to examine the spatial dynamics of Lygus in the TX, AZ and CA agroecosystems.



There are many projects in this grant designed to help us understand Lygus management and movement across the landscape. The large study that supported this Lygus simulation was conducted in the central valley of California under Dr. Goodell's leadership, in west Texas under Dr. Parajulee's leadership, and right here in central Arizona under my leadership.

Drs. Yves Carriere & Pierre Dutilleul developed the spatially-explicit statistical approach used to analyze data from these large experiments.

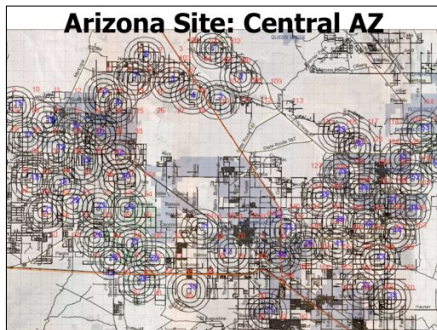


This large study was focused on this question. How is the cotton field in the center of these rings impacted by the cropping diversity in the rings that surround it?

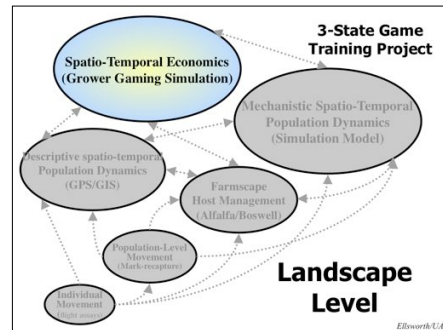
The ring analysis permitted us to infer the relative influences of crops as sources or sinks for Lygus over different spatial scales.

This sort of effort is the kind of advance we need to make to reach higher levels of integration in IPM.

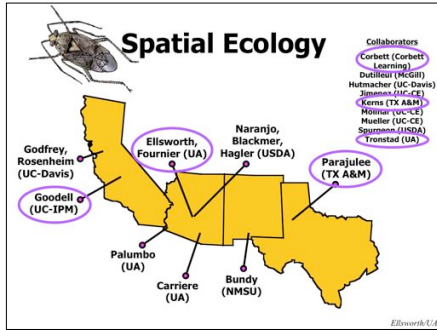
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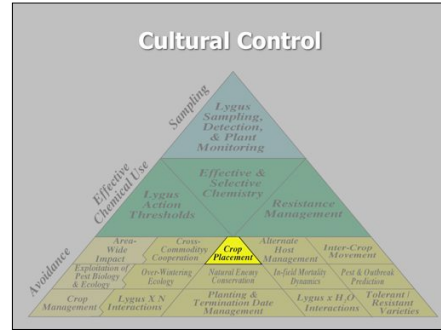
This was our experimental area, nearly all of Pinal County! Each set of rings surrounds a cotton focal field in which we took detailed measurements of Lygus numbers. We also measured crop diversity and location across a 3 km radius of each focal field. We sampled about 55 fields for each of 3 years, 2007–2009.



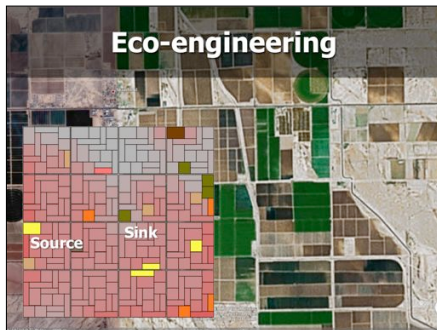
The "game" we play is our attempt to extend our findings to growers and pest managers so that they can learn the importance of crop placement on Lygus risk and individual and community economic outcomes.



These were the cooperators who participated in the development of the game.



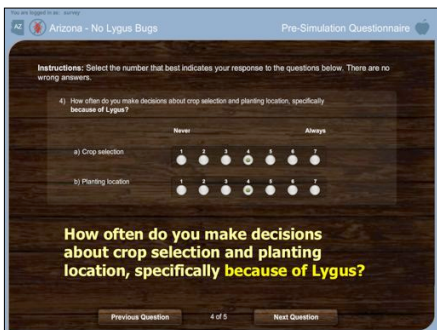
Before now, our recommendations in this basic cultural control have been very generic. Avoid planting "near" sources of pests. This study and the game enable growers to appreciate the specific scales of sources and sinks for Lygus.



Ultimately this is a where IPM is headed in the future, and is a form of eco-engineering where we attempt to "build-out" pests by manipulating the arrangement of crops that source pests and sensitive sink crops that receive and are damaged by pests. This is depicted here in a "heat" map that shows the intensity of Lygus infestation across a landscape as shades of pink.

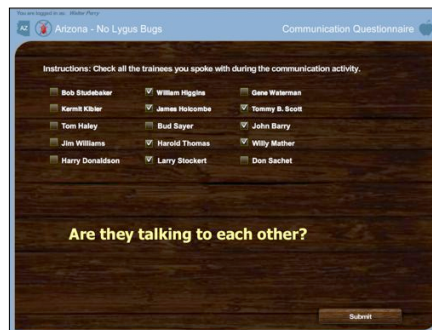


The goal of our game is to increase knowledge and skills of its users that hopefully translate into real world practices that improve Lygus management. Certainly there is much for everyone to learn about Lygus movement and management, but there are also the very important goal of conditioning farmers to better communicate and cooperate with each other to improve individual and community outcomes.



In order to know if we have impact on growers knowledge and skills, we developed an assessment component to the game.

There is a pre-questionnaire that they must answer.



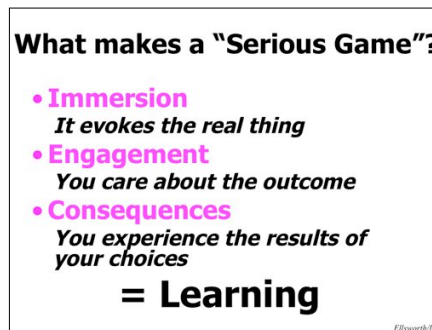
Mid-play, we pause to deploy a simple question that prompts farmers to tell us who they interacted with during the session as a means to measure if they are learning that it is important to talk with one another in order improve outcomes.



All of this is a game, though we refrain from using this term, because some growers are put-off by this term. Who wants to "waste time playing a game?"

But, this is part of a large, academic and practical effort worldwide to incorporate and deploy games for training and understanding of serious occupations or situations. The most famous of which is a rather depressing game sponsored by the UN called "Darfur is Dying". Look it up and give it a try!


These games are broadly classified as "serious" games, because of what they address and intend to accomplish. They are used as training tools in many sectors and we envision this as a viable and powerful approach to increasing farmer and pest manager abilities to confront pest challenges.



### Goal & Flow

- To improve Lygus management both locally (field to field) & over broader landscape\*
- Select crops to plant to each field on their farm (fallow fields are an option)

\*from a cotton perspective




The goal of the training is this...

Our flow depends on each farmer managing their own farm (a section in size), where he/she selects and plants crops where they prefer.

Opportunity exists to select a Lygus threshold, I.e., the level of Lygus you tolerate before spraying.

### Goal & Flow

- Select a threshold for controlling Lygus in cotton
- Operates in a cotton-centric world\*
- All outcomes are in terms of cotton profitability
  - In relative terms & based on crop loss & spray costs for Lygus



Key to our simplified view of this virtual farmscape is understanding that we have designed it around protecting cotton. Our goal is to optimize outcomes for cotton, not all the other crops in the system. We should note that in our systems, cotton is the most sensitive to Lygus damage. So this simplification is not unrealistic.

### Constraints

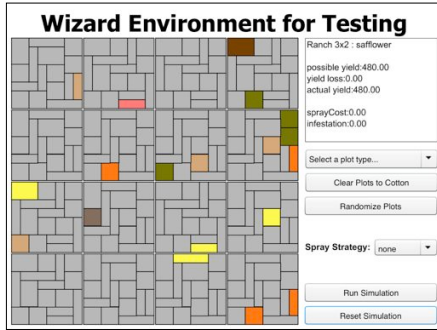
- All relationships among all crops are not fully known or understood
- Results are NOT prescriptive!
  - but should guide practice
- Operates in a cotton-centric world\*



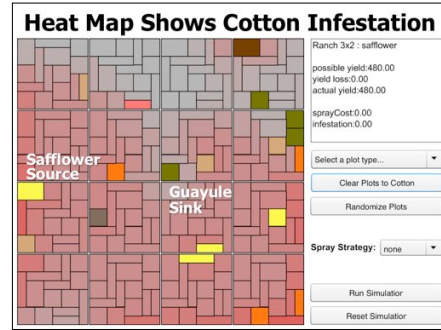


The game still needs some adjustments and improvements. We have not widely deployed it yet in grower settings. We have conducted a number of farmer and other focal sessions to better hone its deployment.

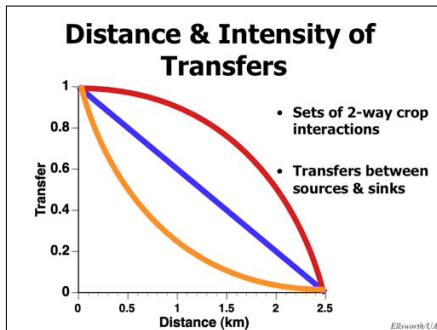
This is a focal group of farmers in Marana, AZ.



**There is a wizard that the instructor can use in advance to set parameters. Many things are flexible and adjustable. This gives the instructor a quick way to examine scenarios pre-deployment.**

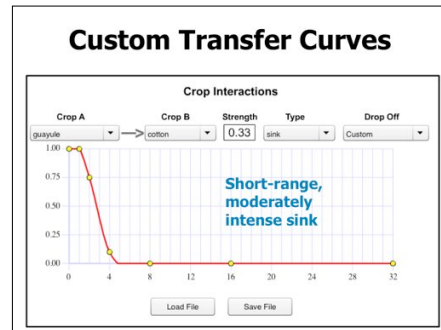


**The simulation will depict lygus infestations across cotton (only) by changing the normally gray colored cotton fields to shades of pink and red to represent intensity of infestation.**



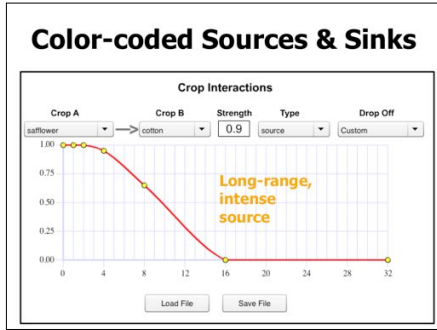
**The simulation is an integration of 2-way interactions between sources and sinks for Lygus. The transfer between crops can be customized as to intensity, distance and drop-off.**

**We have based our parameters in part on the empirical outcomes of the large scale field studies that were conducted.**



**This is an example of a short-range, moderately intense sink relative to cotton. Guayule is a newly commercialized crop that does appear to be an insensitive sink for Lygus, meaning it receives Lygus but is not ostensibly damaged by this insect. It appears to operate over a relatively small spatial scale, but our data is limited on this point.**





This is an example of a longer range and relatively intense source for Lygus to cotton, Safflower.

**Economic Parameters**

Crop: cotton, Unit Cell Yield: 1000

**Economics**

- Yield losses
- Costs of spraying
- By infestation levels

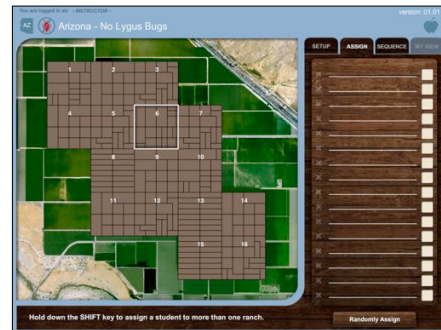
Unit Field Loss				
	none	high	medium	low
0	0	0	0	0
0.2	0.1	0.05	0	0
0.4	0.35	0.15	0.05	0.04
0.6	0.66	0.25	0.075	0.066
0.8	0.8	0.4	0.1	0.1

Cost of spraying a field				
	none	high	medium	low
0	0	0	0	0
0.2	0	0	180	360
0.4	0	180	270	540
0.6	0	270	360	630
0.8	0	360	540	610

There are a number of economic parameters that can be set for each game.



There are 3 landscapes that can be deployed including this one for Texas where there are center pivots and both irrigated and non-irrigated fields, including the dry corners of square fields that encompass the center pivots.



This is a typical AZ landscape. The geometries do not literally mimic any one community, but the arrangements and sizes/shapes of fields are from actual farmer fields in AZ.

The white area is one "farm", a section in size which is one mile on each side and encompasses 640 A.

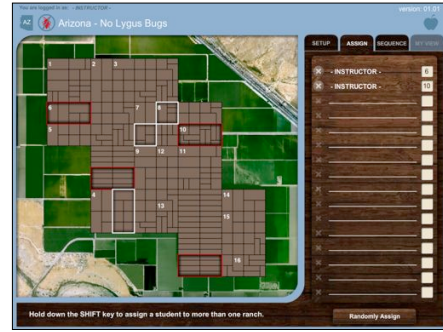


The basic game assumes that a farmer's landholdings are all contiguous as shown in the previous slide. This has consequences for decision-making for crop placement.

However, in AZ it would be unusual for a farmer to have all his/her holdings in one location. So we have a discontinuous deployment of our game that separates their holdings into 1, 2 or 3 locations across the landscape. Sometimes these holding are close together, sometimes more distant.

This can have dramatic impacts on game play.

Here is a farm (white outline) with two locations (2 half sections).

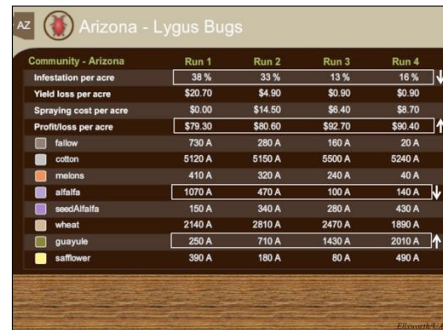


Here is one with 3 locations (white outline).



At anytime during play, we can deploy a "score sheet" of sorts that tells the individual how well they have done individually and as an entire farming community.

It contains information like %infestation over time.



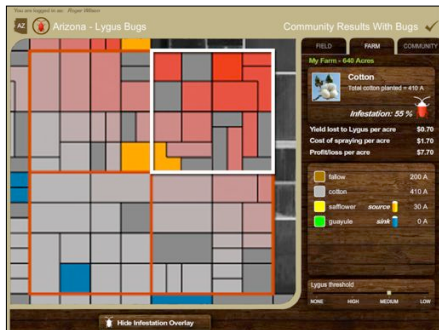
Economic profit per acre, and change in size (acreage) of their crops over multiple runs.



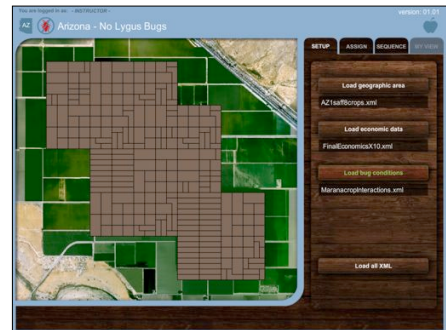
Here is a typical community with 5000 A of cotton, about half the land mass.



This heat map shows the extent and intensity of Lygus infestation, in cotton only, which averages 38% over the entire community. Other crops change to their respective colors as sources (orange) or sinks (blue).



Tabs above allow the farmer to explore individual farms or fields.



A set of parameters are loaded by the instructor prior to game start.



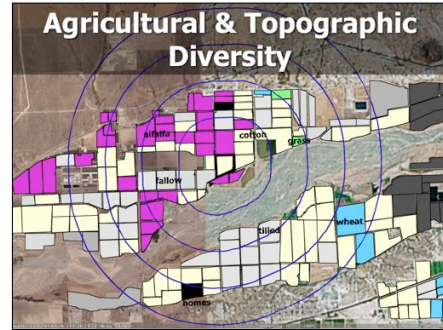


Thank you for your attention.

Thanks, too, to the many growers, pest control advisors and others who have already collaborated with us and allowed us into their fields and provided pesticide records for this project.

The Arizona Pest Management Center (APMC) as part of its function maintains a website, the Arizona Crop Information Site (ACIS), which houses all crop production and protection information for our low desert crops, (<http://cals.arizona.edu/crops>), including a copy of this presentation.

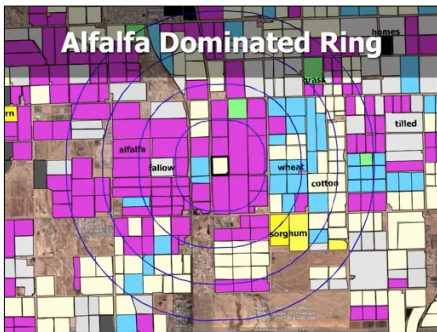
Photo credit: J. Silvertooth



Arizona is both agriculturally and topographically diverse. So we looked at many situations so that we can compare them and identify the best arrangements for crops.

Alfalfa (in purple) is a consistent element of our system. Cotton is in light yellow, fallow and tilled ground are colored gray, wheat is light blue, and homes and other buildings are black. Each ring or donut depicted here represents a 0.75km slice progressively out to 3km around the field.

By examining Lygus densities in the focal fields and relating this to densities of different habitats in each successive ring, we can geostatistically correlate the rise and fall of bug densities with specific arrangements of surrounding habitat. When the correlation is strong and

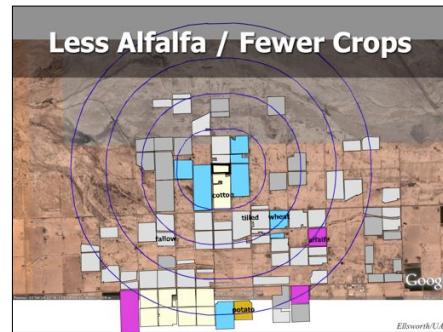


In this example, alfalfa dominates the landscape around the focal cotton field and throughout the 3km area.

Is this a situation that protects or harms cotton with respect to risk of Lygus colonization and damage there?

By examining the donut slices, we can estimate how far these relationships extend, whatever they are.

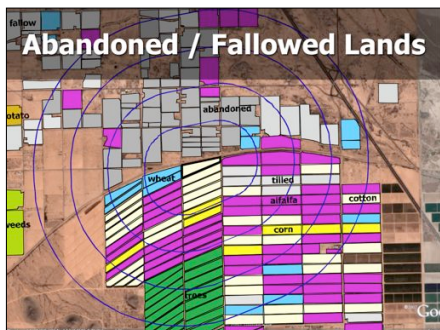
2007 FF#47



Here is an example with less alfalfa and just fewer crops overall. There is a lot of idle land here.

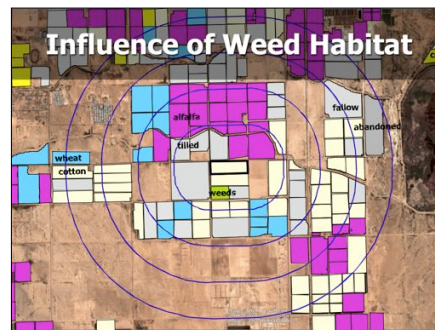
Is this a risky scenario?

2007 FF#06



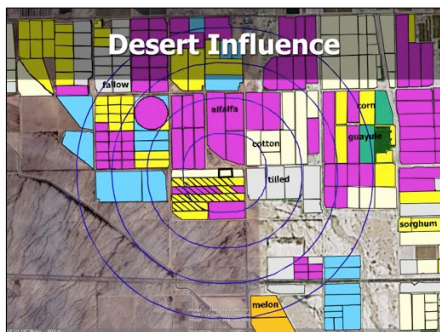
Here is another example where there is abandoned land that is slowly reverting back to native desert, a process that takes decades.

2007 Focal field #05.



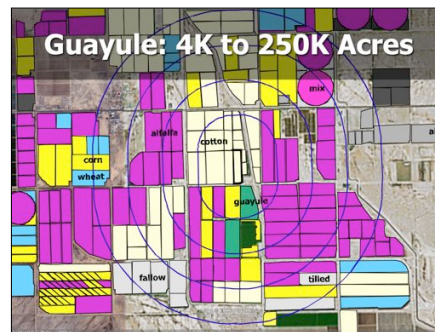
And while winter moisture was not abundant, we did have some areas in some years where fallowed lands developed into significant summer weed habitat nearby our focal cotton field.

2007 FF#42



Of course the desert influence is of interest to us as well. In some years, winter rains can feed spring weeds and other blooming plants that paint the desert yellow, purple and gold. Lygus can thrive in years like this and depending on the period of dry down can funnel Lygus directly to cotton or more usually to some other bridging cultivated host like alfalfa.

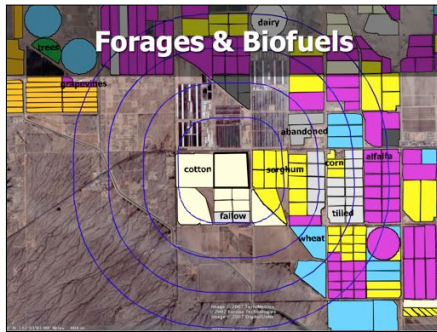
2007FF26



Guayule is a desert-adapted, commercial crop that may expand, with a projected western acreage of 250,000 A one day spanning W. TX to the SJV of CA. It is grown as a perennial and is a known reproductive host for Lygus. It was grown on about 4,000 A in AZ in 2007.

We did not have a lot of areas where we could test the influence of guayule; however, when we found an effect, it was serving as a sink for Lygus though over only a short range.

2007FF#27



**And one final example to underscore the watershed change to agriculture that even Arizona has not escaped. That is the impact of commodity prices and interest in biofuels. We have more demand by dairies and by biofuel refineries than at any other time in history. As a result we have more corn, sorghum and alfalfa than at any other time.**

**How will these land-use changes affect Lygus broad-scale dynamics?**

**Through this project we hope to help develop concrete recommendations for growers to adopt and make crop placement and other planting decisions.**