Cross-crop spillover effects of pesticide use: Modeling reduced lygus damage to California cotton

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Cross-crop spillover effects of pesticide use: Modeling reduced lygus damage to California cotton

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Motivation

- Agricultural landscapes often include a diversity of crop species.
- A common problem of such cropping patterns is that pest infestations and management in one crop can be heavily influenced by surrounding ones.
- Lygus is the most important pest of California cotton.
- In the San Joaquin Valley (SJV), lygus migrates through a clear, annual cycle of host crops.
  - ➢ Lygus initially develops its populations in alfalfa and safflower fields in early April to late July.
  - ➢ When alfalfa and safflower are harvested, adult lygus may then migrate into cotton (Sevacherian and Stern 1974).
- Lygus is not an economic pest for safflower or for alfalfa.
- One of the strategies to control lygus in cotton:
  - ➢ Apply pesticides to alfalfa and safflower in the early season to reduce lygus migrations into cotton (UC IPM 2013).
- Cotton growers may benefit from the **cross-crop spillover effect** of pesticide use if pesticide use in nearby alfalfa and safflower fields helps reduce lygus migrations into cotton.
  - ➢ Alfalfa and safflower growers who apply such pesticides create ***positive externalities*** for cotton growers.
  - ➢ If they grow cotton, provide ***cross-crop benefits*** for themselves.
- **Main Objective:**
  - ➢ Use daily field-level data on applications of pesticides that are targeted at or incidentally control lygus in alfalfa, safflower, and cotton in the SJV;
  - ➢ Develop a bioeconomic simulation model to estimate the reduction in economic losses to cotton producers that have resulted from pesticide applications made to alfalfa and safflower fields;
  - ➢ Quantify the economic values of reduced cotton yield losses, distinguishing positive externalities from cross-crop benefits.

Research Gaps

- **First,** prior literature often discusses that externalities generated by nearby growers are a common problem in pest management
  - ❑ Due to the general unavailability of crop management data, there have been **fewer empirical studies** that can accurately identify externalities and/or **distinguish externalities from spillover effects** (exception: Karagiannis and Tzouvelekas (2012))
- **Second,** previous studies that examine the effectiveness of pest management strategies on crop yield and profitability tend to use observational data from one or a few representative and/or experimental fields (e.g., McKee, 2011)
  - ❑ These studies typically **cannot quantify the economic values** of pesticide use decisions **at the larger landscape level** because pest management benefits and costs are highly variable by
    - ✓ location and timing of infestations
    - ✓ choice of pesticide products
    - ✓ number of pesticide applications

Data

This study employs data for five SJV counties of Fresno, Kern, Kings, Merced, and Tulare spanning from 2010 to 2019. Our dataset combines information from multiple sources.

- **Pesticide use data**
  - ➢ Pesticide Use Report (PUR) database from California Department of Pesticide Regulation (DPR)
  - ➢ Store comprehensive, field-level pesticide application information
    - ❑ application time and date; application method; crop, field, grower, and county identification numbers; the acreage planted and treated; and amount of active ingredient and pesticide product used
  - ➢ Allow for GIS mapping, combined with geo-coded data from CalAgPermits
  - ➢ Nearby fields: within the central field's 3-km radius

- **Weather data**
  - ➢ UC IPM
  - ➢ Keep daily temperature data for all weather stations in California
  - ➢ Translate daily minimum and maximum temperatures to degree-days using the single sine method
- **Crop price data**
  - ➢ County Agricultural Commissioner's (CAC) reports
  - ➢ Annual county-level cotton price (in $/lbs) and planted acreage

Image source: https://images.app.goo.gl/NyCPrZcT7mRkMhNi6

Method

We employ a **three-step procedure** for the empirical analysis.

1. Develop a **parameterized model** to
   - ▪ simulate the size of the lygus population and its daily development in individual alfalfa, safflower, and cotton fields
     - ❖ based on the spatial-temporal relationships of crop production and pesticide use
   - ▪ combine the model with grower behavior for managing lygus in one field, while accounting for the effect of management activities in nearby fields
   - ▪ derive lygus populations with and without considering pesticide applications made to nearby alfalfa and safflower fields.
2. Employ a **bioeconomic simulation model** to estimate
   - ▪ the effect of the cumulative lygus population density on cotton square and boll development
   - ▪ the resulting impact on cotton yield and profitability.
3. Determine the **economic values of reduced cotton yield losses** due to the effect of pesticide applications to nearby alfalfa and safflower
   - ▪ compare the magnitudes of cotton profitability derived based on the two sets of lygus population density
   - ▪ distinguish the values of positive externalities from those of cross-crop benefits
     - ❖ based on the information on crop management (by the same or different growers)

Results

Table 1. Economic values of reduced cotton yield losses that were attributable to cross-crop spillover effects of pesticide use, 2017-19

	Positive externality	Cross-crop benefit	Total spillover effect
Fresno County			
2017	195,867	258,161	454,028
2018	196,436	259,926	456,362
2019	170,018	186,656	356,674
Kern County			
2017	70,701	140,050	210,751
2018	40,725	104,993	145,718
2019	40,862	100,293	141,154
Kings County			
2017	351,135	701,327	1,052,461
2018	228,918	626,052	854,970
2019	288,062	616,397	904,459
Merced County			
2017	164,926	342,417	507,343
2018	126,067	298,419	424,486
2019	176,464	245,834	422,298
Tulare County			
2017	59,825	78,767	138,593
2018	49,645	100,492	150,137
2019	47,429	104,478	151,907
All counties			
2017	**842,454**	**1,520,723**	**2,363,176**
2018	**641,790**	**1,389,883**	**2,031,673**
2019	**722,834**	**1,253,657**	**1,976,491**
Three-year Average	**735,693**	**1,388,088**	**2,123,780**

- Pesticide applications to cotton's nearby alfalfa and safflower did help reduce cotton yield losses.
- By quantifying the change in revenue over the years 2017 to 2019, we estimate that the corresponding economic value was about $2.1 million.
  - ➢ The positive externalities accounted for $0.74 million (35%).
  - ➢ The remaining $1.39 million was captured by cotton growers who grew at least one of the other two crops near their cotton fields.

Implications

- A clearer understanding of the dynamics of lygus populations, the management decisions made by growers of the three crops, and their economic impacts on crop production is critical as this information can be useful to cotton growers who may benefit from spillover effects of pesticide use.
- The bioeconomic model developed in this study can be calibrated as a decision aid to guide growers' crop management and pesticide use decisions in the future.

Selected references

Karagiannis, G., and V. Tzouvelekas. 2012. "The Damage-control Effect of Pesticides on Total Factor Productivity Growth." European Review of Agricultural Economics 39(3):417–437.

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