Palmer Amaranth Risk Analysis in Iowa

Summer Seminar Series
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Advisors: Professor John Pauley and Dr. Clint Meyer
Outline

- History and biology of Palmer amaranth
- Palmer Project outreach
- Demographic model
- Geographic model
- Synthesis model
- Economic impact study
- Future work and conference
Project began in May of 2015

- Predictive analytics
- Qualitative, sociological research
- Educational outreach
- Curricular innovation

Agriculture makes up 33% of Iowa’s economy.
-Iowa Agricultural Statistics Bulletin, 2014
Biology of Palmer

- Closely related to waterhemp
  - Same genus
  - Similar appearance
- Dioecious
  - Develops herbicide resistance rapidly
- Grows 2-3 inches a day
  - 8 feet tall
- Germinates from May to September
- Prolific seed production
  - 500,000 - over 1 million
Awareness Campaign
Modeling Objectives

● What is the risk of Palmer infesting any particular area in Iowa?
● Three types of data
  ○ GIS Maps
  ○ County Data Information
  ○ Interviews
● Two characteristic maps
  ○ Demographic map
  ○ Geographic map
● Final synthesis of the two maps
  ○ Considers risk from both maps to create a final risk model
Predictions

- Higher risk in the southern counties
  - Less productive soil
- Higher risk near waterways
  - Increased animal traffic
- Higher risk near edge of state
  - Dispersal from neighboring states
Demographic Model

- **Characters**
  - Diverse Herbicide Programs
  - Ditch Maintenance
  - Owning Equipment
  - Cleanliness of Equipment
  - Community Collaboration
  - Add 1+ Crop
  - Awareness of Superweed

- **Attributes**
  - Average Expense
  - Primary Occupation
  - CRP Acres
  - Percent Owned
  - Average Farm Size
  - Average Income
  - Average Age
Demographic Model

- Information was gathered on relationships between characters and attributes
- Each character/attribute pair was given a score
  - Character/attribute potential risk score
- The characters were ranked based on greatest to least impact on mitigating Palmer infestations
Demographic Model

Spreadsheet for scores

- Top = Characters (Diverse herbicide program, ditch maintenance, etc.)
- Side = Attributes (Small farm, large farm, etc.)

Example with Attribute 1:

\[
S_{attribute} = c_1(r_1) + \ldots + c_i(r_i)
\]

where:
- \( r \) = Risk Score
- \( c \) = Character Rank
- \( S \) = Total Attribute Score

Example with Attribute 1: 
\[
1.7(0.9) + 1.6(0.9) + 1.5(1.1) + 1.4(1.1) + 1.3(0.8) + 1.2(1.1) + 1.1(0.9) = 9.51
\]

Overall Attribute Rank = Total Attribute Score \( \div \) Neutral Attribute Score

- Neutral Attribute Score = 9.8
- From previous example: Overall Attribute Rank = 9.51/9.8 = 0.970
Demographic Model

- All county attribute data were collected from agcensus.usda.gov
- We ranked each attribute based on its potential to mitigate Palmer
- Each data point per county was given a rank as well, corresponding to the 0.6 - 1.4 scoring system

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Expense</td>
<td>1.7</td>
</tr>
<tr>
<td>Primary Occupation</td>
<td>1.6</td>
</tr>
<tr>
<td>CRP</td>
<td>1.5</td>
</tr>
<tr>
<td>Percent Owned</td>
<td>1.4</td>
</tr>
<tr>
<td>Average Farm Size</td>
<td>1.3</td>
</tr>
<tr>
<td>Average Income</td>
<td>1.2</td>
</tr>
<tr>
<td>Average Age</td>
<td>1.1</td>
</tr>
</tbody>
</table>
Demographic Model

$$R_{\text{county}} = \frac{(r_1)(a_1)(c_1) + \ldots + (r_i)(a_i)(c_i)}{R_{\text{neutral}}}$$

- $r = \text{Risk Value}$
- $a = \text{Attribute Rank}$
- $c = \text{Attribute Weight}$

$R_{\text{county}} = \text{County Rank}$

### Table

<table>
<thead>
<tr>
<th></th>
<th>Average Expense</th>
<th>Primary Occupation</th>
<th>CRP Acres</th>
<th>Percent Owned</th>
<th>Average Farm Size</th>
<th>Average Income</th>
<th>Average Age</th>
<th>Overall County Rank</th>
<th>County Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osceola County</td>
<td>0.9 1.7 1.6 1.5</td>
<td>0.6 0.7 0.8 0.6</td>
<td>1 1 1 1</td>
<td>1 1 1 1</td>
<td>1 1 1 1</td>
<td>1 1 1 1</td>
<td>1 1 1 1</td>
<td>1 1 1 1</td>
<td>1 1 1 1</td>
</tr>
<tr>
<td>Buena Vista County</td>
<td>1 1 1 1</td>
<td>0.7 0.7 0.8 0.7</td>
<td>1 1 1 1</td>
<td>1 1 1 1</td>
<td>1 1 1 1</td>
<td>1 1 1 1</td>
<td>1 1 1 1</td>
<td>1 1 1 1</td>
<td>1 1 1 1</td>
</tr>
<tr>
<td>Emmet County</td>
<td>1 1 1 1</td>
<td>0.8 0.8 0.8 0.8</td>
<td>1 1 1 1</td>
<td>1 1 1 1</td>
<td>1 1 1 1</td>
<td>1 1 1 1</td>
<td>1 1 1 1</td>
<td>1 1 1 1</td>
<td>1 1 1 1</td>
</tr>
<tr>
<td>Sioux County</td>
<td>0.6 1 1 1</td>
<td>0.8 0.8 0.8 0.8</td>
<td>1 1 1 1</td>
<td>1 1 1 1</td>
<td>1 1 1 1</td>
<td>1 1 1 1</td>
<td>1 1 1 1</td>
<td>1 1 1 1</td>
<td>1 1 1 1</td>
</tr>
</tbody>
</table>

$R = r \times a \times c$
Demographic Risk Map
Geographic Model

- Palmer risk based on natural conditions that cannot be changed
- 5 GIS maps from USDA Geospatial Data Gateway
  - Corn Suitability Rating (CSR2)
  - Average Maximum Temperature
  - Elevation
  - Average Yearly Rainfall
  - Average Wind Potential
- ≈ 325,000 data points

Geographic Model

- Quadratic Discriminant Analysis (QDA) is a supervised machine learning method commonly used in classification problems.
- We can “predict” which counties contain Palmer Amaranth based on the geographic factors.
Geographic Risk Map

\[ Pr(palmer = 1 \mid X = x) \]
Final Risk Map Synthesis
Conclusion

- Accurate prediction on the edges of the state
- Accurate prediction on the rivers
- Noticeably less risk than anticipated in extreme south central
Model Advantages

- Adaptable
  - Easy to update maps and datasets

- Expandable
  - New maps can easily be implemented

- Interpretable
  - Straightforward visual representation

- High granularity
  - One point equivalent to 100 acres of land
Model Disadvantages

- Inconsistencies are expected
  - Large scale data are rarely completely accurate
  - Intrinsic to predictive analytics

- Specific Palmer locations are not readily available
  - Improved correlations come from more specific output data

- Difficult to test and validate
  - Uses a classification method, but doesn’t require a high prediction accuracy rate
  - Improved testing comes from more specific output data

- Processing power
Future Model Objectives

- Obtain more accurate data detailing Palmer’s location
  - Better testing, validation, and accuracy
  - Drone image processing
- Explore unsupervised learning techniques
  - K-Means Clustering
- More detailed effects of CRP
  - Improve accuracy of risk map
- Create a custom Palmer risk assessment webtool
  - Producers input geographic and demographic scenarios to assess land risk
Economic Impact

Objectives
- Establish a conservative model for potential yield lost due to Palmer amaranth infestation
- Relate plants per acre to total yield loss number then to per acre revenue loss
- Create a county case study that can be applied statewide and eventually to each individual acreage used in agriculture.
Economic Impact

Palmer and Yield Loss

Documented losses ranging from 11% to 91% & 17% to 68% yield losses in corn and soybeans, respectively

Figures to be used:
0.5 plants / m for Palmer infestation in corn

Conservative yield loss projection for minimally infested corn acreages = 11% yield loss

Rafael A. Massinga, Randall S. Currie, Michael J. Horak, and John Boyer Jr., 2001
**Economic Impact**

Macroeconomic Climate: Yield projections at historic highs, prices near 10YR lows

NASDAQ Markets, 10/18/17
**Economic Impact**

**Assumption:** Microeconomic farm finance is sufficiently homogeneous geographically to model IA impact using American Enterprise Institute (AEI) Heartland projections.

<table>
<thead>
<tr>
<th></th>
<th>Heartland</th>
<th>Heartland</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Revenue</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Est. Yield (bu/acre)</td>
<td>175</td>
<td>177</td>
</tr>
<tr>
<td>Base Price ($/bu.)</td>
<td>3.99</td>
<td>4.14</td>
</tr>
<tr>
<td>Regional Price Adjust. ($/bu.)</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>Crop Revenue ($/acre)</td>
<td>701.75</td>
<td>736.32</td>
</tr>
<tr>
<td>Total Crop Nutrient Expense</td>
<td>$881</td>
<td>$917</td>
</tr>
<tr>
<td>Total Crop Protection Expense</td>
<td>$49.43</td>
<td>$53.42</td>
</tr>
<tr>
<td>Total Variable Costs</td>
<td>393</td>
<td>404</td>
</tr>
<tr>
<td>Contribution Margin (Revenue Less Variable Expenses)</td>
<td>309</td>
<td>332</td>
</tr>
<tr>
<td>Total Overheard (Fixed Expenses)</td>
<td>311.58</td>
<td>307.26</td>
</tr>
<tr>
<td>Earnings (losses) from Operations</td>
<td>-2.54</td>
<td>24.59</td>
</tr>
<tr>
<td>Estimated Government Payments ($/acre)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total Earnings or (Losses)</td>
<td>-2.54</td>
<td>$24.59</td>
</tr>
</tbody>
</table>

AEI Crop Budget Estimates, Brent Gloy and David Widmar, 2017
Economic Impact

Breakdown of Expenses

- Variable Exp. + Non-Family Labor
- Land
- Non Cash Expense
- Price ($/bu.)

$/bushel

- $12.00
- $10.00
- $8.00
- $6.00
- $4.00
- $2.00
- $-

<table>
<thead>
<tr>
<th>Crop</th>
<th>Year</th>
<th>Region</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn</td>
<td>2017</td>
<td>Heartland</td>
<td>$2.00</td>
</tr>
<tr>
<td>Corn</td>
<td>2018</td>
<td>Heartland</td>
<td>$2.00</td>
</tr>
<tr>
<td>SB</td>
<td>2017</td>
<td>Heartland</td>
<td>$8.00</td>
</tr>
<tr>
<td>SB</td>
<td>2018</td>
<td>Heartland</td>
<td>$8.00</td>
</tr>
<tr>
<td>Wht</td>
<td>'17</td>
<td>Heartland</td>
<td>$4.00</td>
</tr>
<tr>
<td>Wht</td>
<td>'18</td>
<td>Heartland</td>
<td>$4.00</td>
</tr>
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Economic Impact

County Case Study: Washington County

Average Risk Value: 0.9414179
Average CSR2: 68

Projected Yield (bushels/acre) = 188.8
Est. 2017 Revenue/Acre = $50.00

Projected Yield after conservative reduction from Palmer amaranth infestation of 0.5 plants m$^{-1}$ = 168.03
Est. 2017 Loss/Acre = ($31.00)
Cumulative Economic Impact

Average CSR2: 68.4
Total 2017 Corn Production
Acres: 13,700,007

Current Price ($/Bushel): 3.48

Projected Average Yield after conservative reduction from Palmer amaranth infestation of 0.5 plants m\(^{-1}\) = 168.65
Est. Average Loss/Acre = ($41.78)
Est. Average Post Palmer Loss/Acre

= ($114.73)

Cumulated Yearly Revenue Lost due to Conservative Palmer Infestation: ($1,368,979,431.85)

Sassman & Burras, Iowa CSR2 Weighted Means by County, May 2017
Future Work on Economic Impact

- Isolate acres used for agricultural purposes from Synthesis Risk Map to find accumulated probability of potential yield loss
- Establish potential yield figures for soybean production as a function of CSR2 or other geographic characteristics
- Find projected yield figures for Palmer infestations less dense than those examined by Massinga et al., 2001
Academic Consultants

- Meaghan Anderson - ISU Extension
- Josh Bruett - Agronomist, BB&P Feed and Grain
- Carolyn Dallinger - Professor of Sociology, Simpson College
- Mike Gunderson - Agro Economist, Purdue University
- Dr. Bob Hartzler - ISU Extension
- Mark Johnson - ISU Extension
- Jason Norsworthy - University of Arkansas
- Aaron Sassman - Agronomist, ISU
- Dr. Brady Spangenberg - Market Intelligence and Analytics, BASF Chemical; Visiting Scholar, Simpson College
- Amy Tlach - Iowa Soybean Association
- Murphy Waggoner - Professor of Mathematics, Simpson College
Acknowledgements

- Simpson College
- Brady Spangenberg and BASF Corporation
- Dr. Albert H. & Greta A. Bryan
- Roy J. Carver Charitable Trust Foundation
  - Authors of the grant: Kelley Bradder, Jackie Brittingham, Chris Goodale, Michelle Johnson, Marilyn Leek, John Pauley, and Rick Spellerberg
- Archers Daniels Midland - American Global Food Processing Company
- Robert and Susan Fleming
- Ned and Mickey Burmeister
- Jay Simmons - President of Simpson College
- Kent Eaton - Academic Dean
- Bob Lane - Vice President of College Advancement
- Manda Gibson - Media Service Coordinator
- Sandy Condon - Administrative Assistant to Academic Dean
- Linda Sinclair - Administrative Assistant in Mary Berry
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