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

Palmer amaranth Management Guide

Palmer is a Big Deal

Management Strategies

Amaranthus palmeri

Get prepared for Palmer amaranth: Join us at our conference:

Combating Herbicide Resistant Weeds and Palmer Amaranth:
Multiple Perspectives

Jan 4, 5, & 6, 2018

Join producers, scholar, agronomist, extension officers, stakeholders, and decision makers for an informational conference about Palmer amaranth and herbicide resistant weeds.

www.Simpson.edu/the-palmer-project
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

![Table showing county ranks](image)
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.)

<table>
<thead>
<tr>
<th>Attribute 1</th>
<th>(1.7) Diverse Herbicide Program</th>
<th>(1.6) Ditch Maintenance</th>
<th>(1.5) Owning Equipment</th>
<th>(1.4) Cleanliness of Machinery</th>
<th>(1.3) Collaboration</th>
<th>(1.2) Add 1+ Crop</th>
<th>(1.1) Awareness of Superweeds</th>
<th>Total Attribute Score</th>
<th>Overall Attribute Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attribute</td>
<td>0.9</td>
<td>0.9</td>
<td>1.1</td>
<td>1.1</td>
<td>0.8</td>
<td>1.1</td>
<td>0.9</td>
<td>9.51</td>
<td>0.970</td>
</tr>
<tr>
<td>Neutral</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>9.8</td>
<td>1.000</td>
</tr>
</tbody>
</table>

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

\[ r = \text{Risk Score} \]
\[ c = \text{Character Rank} \]
\[ S = \text{Total Attribute Score} \]

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 ÷ 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** = Risk Value
- **a** = Attribute Rank
- **c** = Attribute Weight

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

\[ Pr(\text{palmer} = 1|X = x) \]
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
- **Interpretative**
  - 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
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>
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</tr>
</thead>
<tbody>
<tr>
<td>Revenue</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Est. Yield (bu/acre)</td>
<td>175</td>
<td>177</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Base Price ($/bu.)</td>
<td>3.99</td>
<td>4.14</td>
<td>9.68</td>
<td>9.5</td>
</tr>
<tr>
<td>Regional Price Adj. ($/bu.)</td>
<td>0.02</td>
<td>0.02</td>
<td>0.07</td>
<td>0.07</td>
</tr>
<tr>
<td>Crop Revenue ($/acre)</td>
<td>701.75</td>
<td>736.32</td>
<td>487.5</td>
<td>478.5</td>
</tr>
<tr>
<td>Total Crop Nutrient Expense</td>
<td>$ 881</td>
<td>$ 917</td>
<td>$ 947</td>
<td>$ 538</td>
</tr>
<tr>
<td>Total Crop Protection Expense</td>
<td>$49.43</td>
<td>$53.42</td>
<td>$29.45</td>
<td>35.34</td>
</tr>
<tr>
<td>Total Variable Costs</td>
<td>393</td>
<td>404</td>
<td>200</td>
<td>211</td>
</tr>
<tr>
<td>Contribution Margin (Revenue Less Variable Expenses)</td>
<td>309</td>
<td>332</td>
<td>288</td>
<td>268</td>
</tr>
<tr>
<td>Total Overhead (Fixed Expenses)</td>
<td>311.58</td>
<td>307.26</td>
<td>311.58</td>
<td>307.26</td>
</tr>
<tr>
<td>Earnings or (losses) from Operations</td>
<td>-$ 2.54</td>
<td>$24.59</td>
<td>-$ 23.64</td>
<td>-$ 39.29</td>
</tr>
<tr>
<td>Estimated Government Payments ($/acre)</td>
<td>$ -</td>
<td>$ -</td>
<td>$ -</td>
<td>$ -</td>
</tr>
<tr>
<td>Total Earnings or (Losses)</td>
<td>-$ 2.54</td>
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<td>$23.64</td>
<td>$39.29</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.)

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


Heartland  Heartland  Heartland

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