The Bioeconomics of Integrated Pest and Pollinator Management: The Case of Neonicotinoid Insecticides

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Outline

1. Neonicotinoid insecticides (neonics): pest control, damage to pollinators, mitigation strategies.
2. Bioeconomic model description:
   a. Yield function
   b. Ecological dynamics
      i. Farm-level wild and commercial pollinator dynamics;
      ii. Plant-level pest dynamics;
   c. Management strategies
      i. Wild and commercial pollinator management;
      ii. Pest management.
3. Simulations and results

1. Neonicotinoid Insecticides (NNI; neonics)

Most widely used insecticides in the world.

-Advantages:

Low toxicity to humans, high water solubility (works well as a systemic insecticide), controls a wide diversity of insect pests.

-Problem:

Lowers pollinators' ability to pollinate => can affect pollinator-dependent crops' yield as a result.

-Management options:

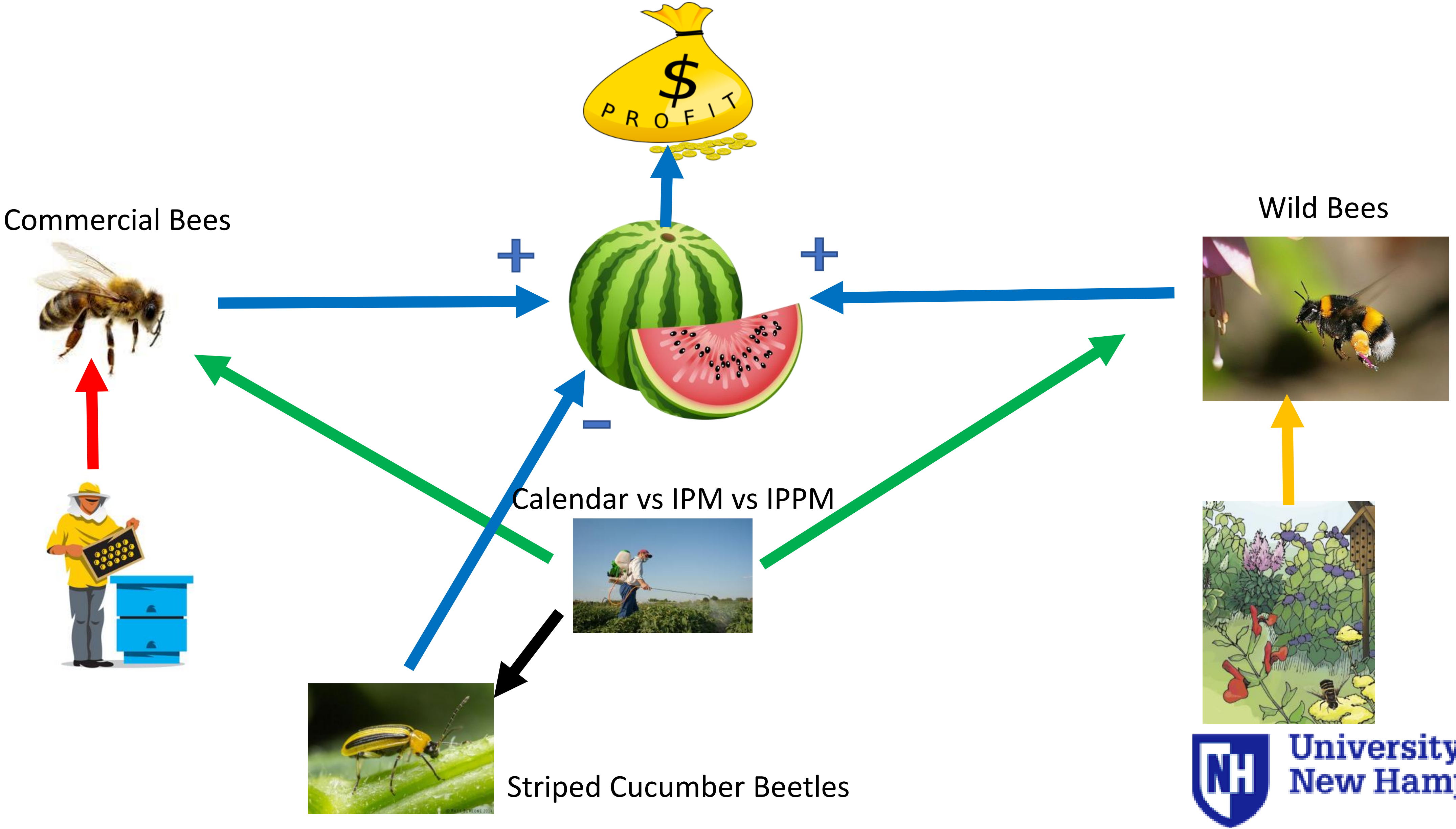
1. Calendar sprays (*most used*): do regular foliar sprays 2-6 weeks later in the season;
2. Integrated Pest Management, or IPM (*recommended by extensionists*): spray when pests cross a specific threshold (5 beetles/plant);
3. Integrated Pest and Pollinator Management, IPPM (*conceptual*): same as IPM but also minimizes pollinator exposure to neonics.

How do farmer’s pest and pollinator management actions affect crop yields?

Three Channels:

1. Neonics applications (Calendar vs. IPM vs. IPPM) (+ and -):
    - Limits yield damage by controlling insects;
    - Decreases yield by impeding pollination.
2. Pollinator habitat (+):
    - Mitigates wild bee (WB) pollination decline and therefore limits yield loss caused by neonics.
3. Renting Commercial Bees (CB) (+):
    - Mitigates commerical bee pollination decline and therefore limits yield loss caused by neonics.

Tradeoff between pest control and pollination



Commercial Bees

Wild Bees

Calendar vs IPM vs IPPM

Striped Cucumber Beetles

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Literature on the relationship between commercial and wild pollinators

Kleczkowski et al. (2017, *Ecol. Mod.*)

- When neonics impairment is high: rely exclusively on commercial bees, provide zero habitat for wild bees, allow wild pollinators to go locally-extinct
- Renting commercial bees masks decline of wild bees
- **ASSUMPTION**: Commercial (*Apis mellifera*) and wild bees (Non-Apis) are *perfect substitutes*
- $PS = a + b\,(WB + CB)$

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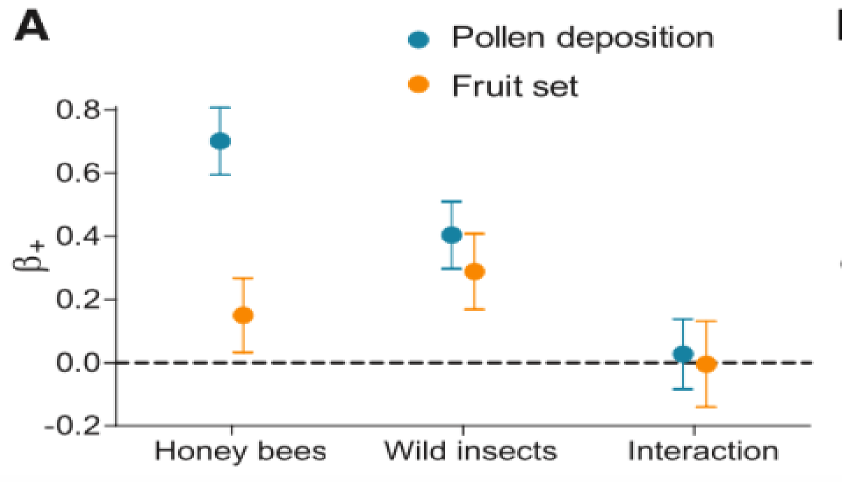
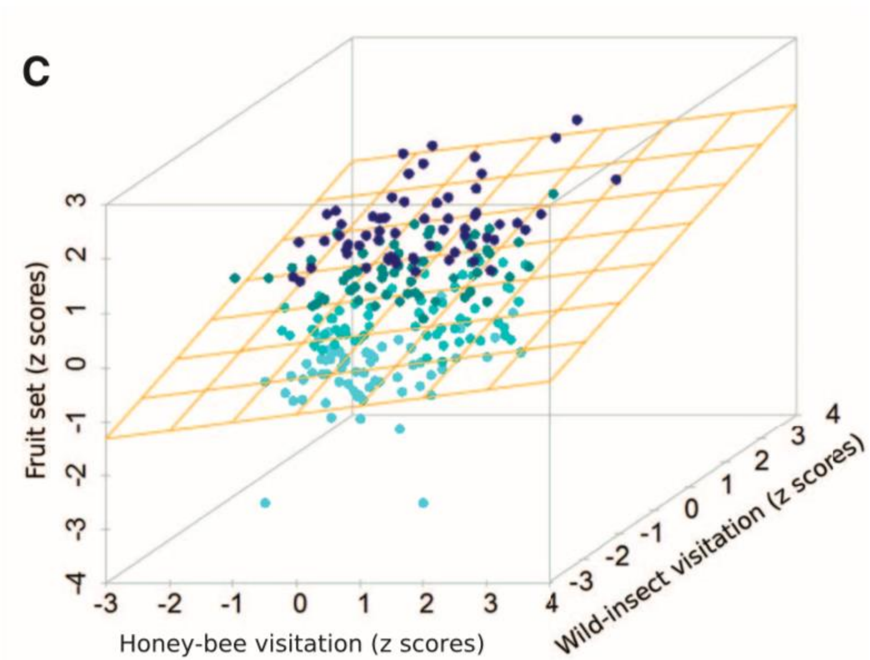
Literature on the relationship between commercial and wild pollinators

Garibaldi et al. (2013, *Science*)

- Evidence that wild bee visitation increases the fruit set by twice as much as an equivalent increase in honey bee visitation
- $PS=a+bWB+cCB$ where $b>c$
  - Fig. A → MP (WB) > MP(CB)
  - Fig. C → $a > 0$, $b>0$, $c>0$





Data from 41 different agricultural systems

In our model:

- Commercial bees (CB) and wild bees (WB) are imperfect substitutes:
  - The model recognizes that CB and WB alone cannot reach the maximum level of watermelon yield (Winfree et al. 2017);
- Mitigation strategies are pollinator-specific:
  - Renting commercial bees recovers pollination decline from CB only;
  - Habitat helps recover decline from WB only.

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2. Bioeconomic model description

- A watermelon farmer seeks to maximize farm profits over 5 years.

- By choosing the optimal mix of the following strategies:
  1. Applying neonics (calendar vs. IPM vs. IPPM);
  2. Setting aside pollinator habitat (binary);
  3. Renting commercial bee colonies (binary).

- Application to a representative watermelon farm in Indiana.

Bioeconomic Model

Economic objective: maximizing profits that revenue minus costs

$$max_{\{N,H,R\}}\pi(t)=\sum_{t=0}^{T}\rho^{t}[py\left(PS_t^{WB},PS_t^{CB},N\right)-C(N,H,R,y)]$$

Ecological constraints: pollinator dynamics (decline and mitigation) & pest dynamics

$s.t.\ \ PS_t^{WB}=f_n(PS_{t-1}^{WB},N,H)$ wild pollinator (WB) pollination service (PS) dynamics

$PS_t^{CB}=f_n\left(PS_{t-1}^{CB},N,R\right)$ commercial pollinator (CB) pollination service (PS) dynamics

$Pest_t=f_n(Pest_{t-1},N,T)$ pest dynamics

Where crop yield: $y=[Y_{max}(1-m^{WB}(PS_t^{WB}))(1-m^{CB}(PS_t^{CB}))][1-b(N, \text{threshold})]$

PS: Pollination Services
N: Spraying Neonicotinoids
H: Setting Habitat
R: Renting Commercial Bees
Ymax: Maximum Level of Yield w/o Pests

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$$y=[\underbrace{Y_{max}}_{\text{Maximum possible yield}}(1-\underbrace{m^{WB}(PS_t^{WB})}_{\text{Yield loss due to neoncic effect on WB}})(1-\underbrace{m^{CB}(PS_t^{CB})}_{\text{Yield loss due to neonic effect on CB}})][1-\underbrace{b(N,\text{threshold})}_{\text{Pest damage b is reduced through neonic application}}]$$

$$\frac{\partial b}{\partial N} < 0$$

Total Yield Level	Yield loss due to neonic effect on CB	Yield loss due to neonic effect on WB
High	0	0
Moderate	0<yM<1	0<ym<1
Low	0<yL<1	0<yl<1

- $\frac{\partial m}{\partial PS} < 0$, The lower the pollination level, there will be greater yield damage

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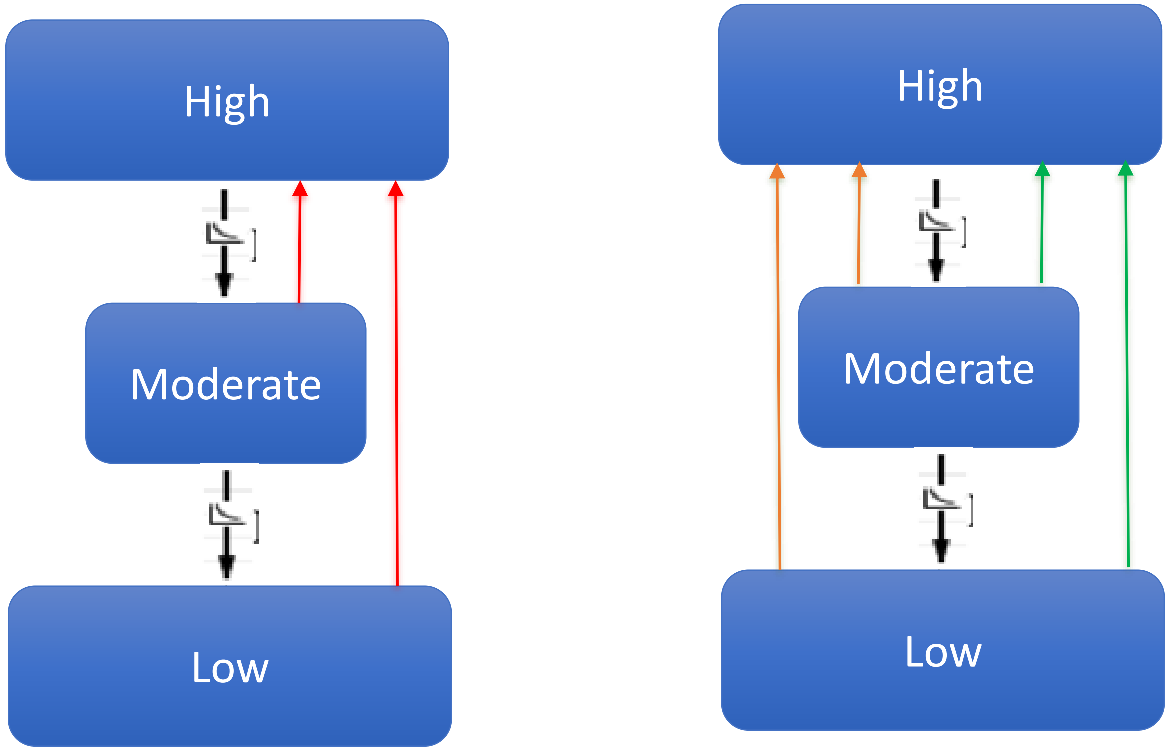
Farm-level pollinator dynamics model

- Modeling unit: farm level, representing 1 acre plot
- Daily time step (May. 31st to Aug. 31st=92 Days)
- Five growing seasons
- State variables: level of pollination services (wild and commercial)

Pollinator dynamics model: state variables and state transitions



Commercial bee pollination level

High

Moderate

Low

Wild bee pollination level

High

Moderate

Low

Setting Aside Habitat

Renting Commercial Bees

Wild bees natural recovery (1st day of each year)

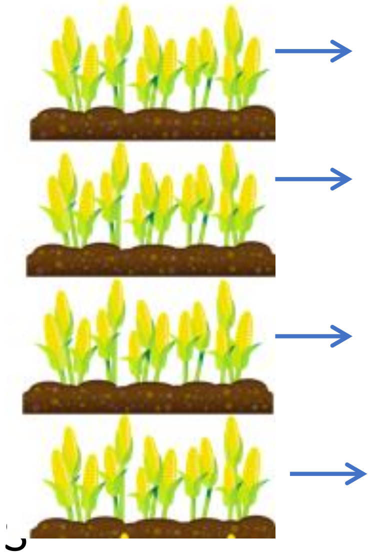
Pollination decline (transition rate):
- higher for calendar spray, lower for IPM and IPPM.

Pollinator dynamics model: state variables and state transitions

- We also consider the case where the watermelon farm is adjacent to corn fields;

- Corn is non-pollinator-dependent.

-Close to 100% of corn seeds in the U.S. are treated with neonics, which drift through air to neighboring farms (Douglas and Tooker 2015);



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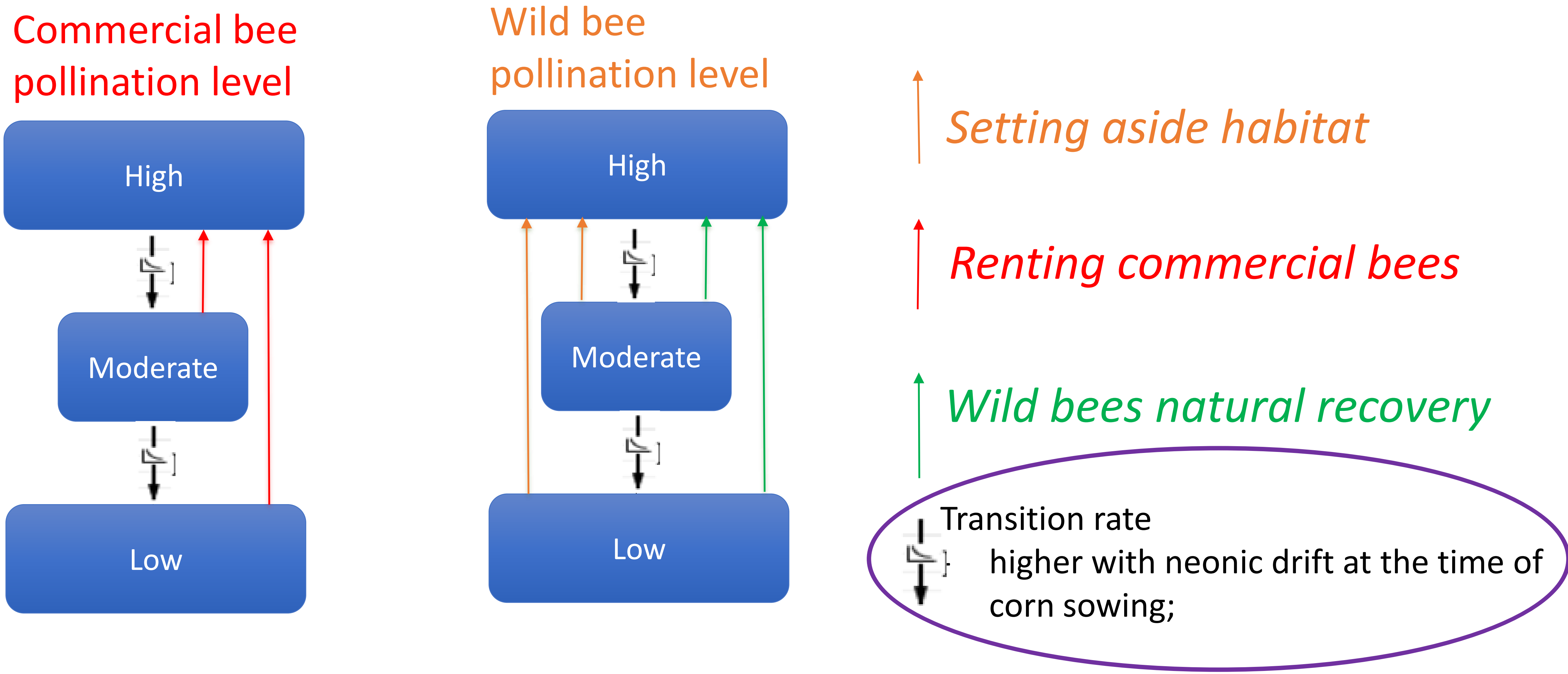
- A problem for the co-existence of pollinator-dependent and non-pollinator-dependent crops.

Pollinator dynamics model: state variables and state transitions in the presence of an adjacent corn farm.



Commercial bee pollination level

High

Moderate

Low

Wild bee pollination level

High

Moderate

Low

Setting aside habitat

Renting commercial bees

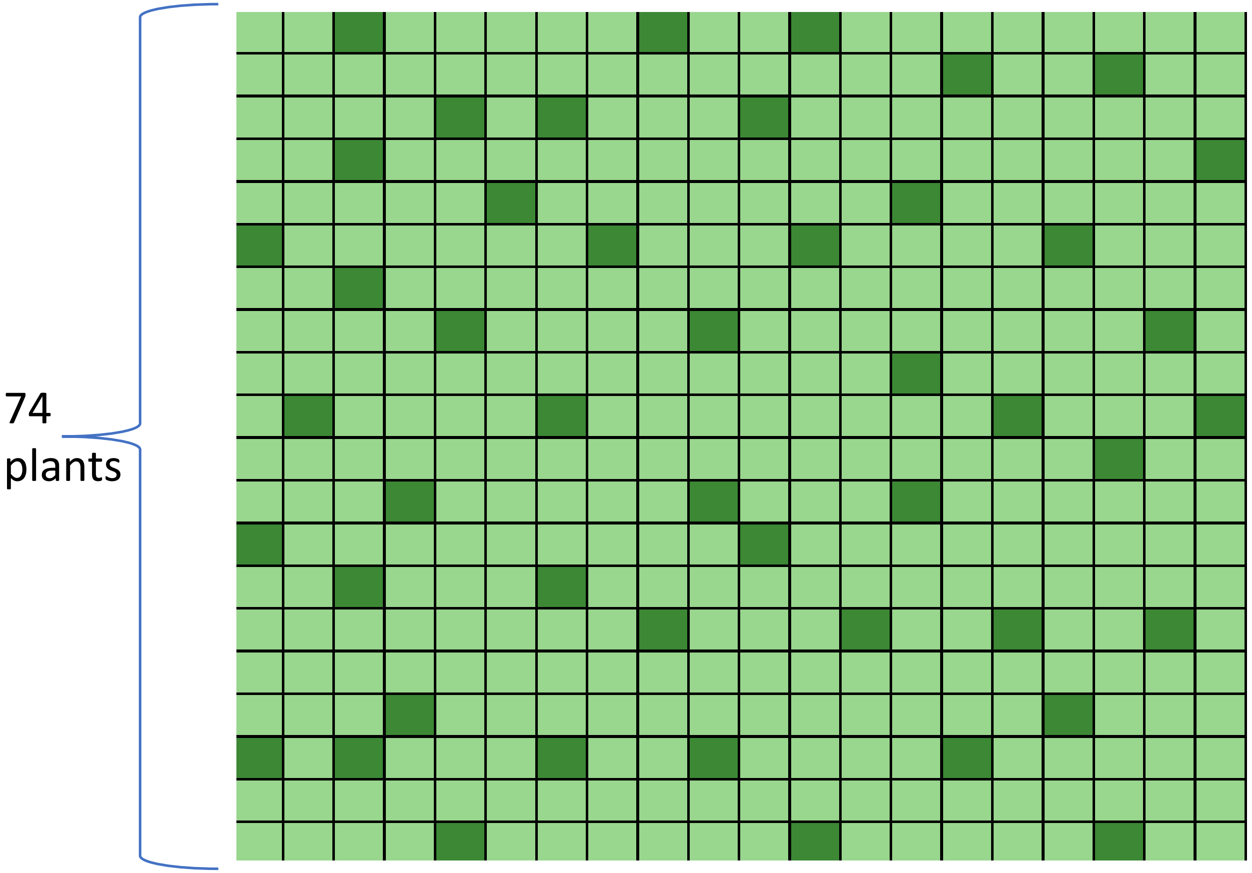
Wild bees natural recovery

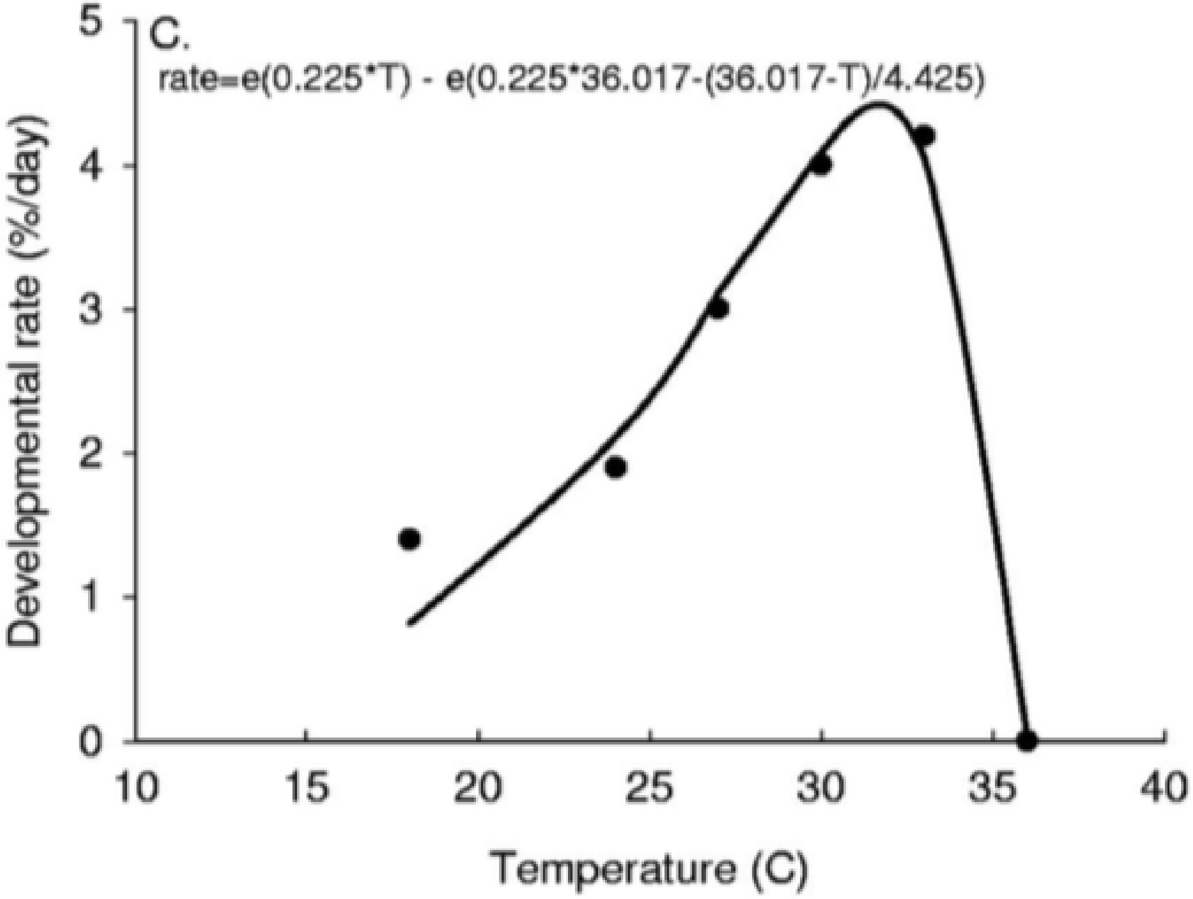
Transition rate

higher with neonic drift at the time of corn sowing;

Plant-level pest dynamics model

Striped Cucumber Beetle





Ellers Kirk et al. (2006)

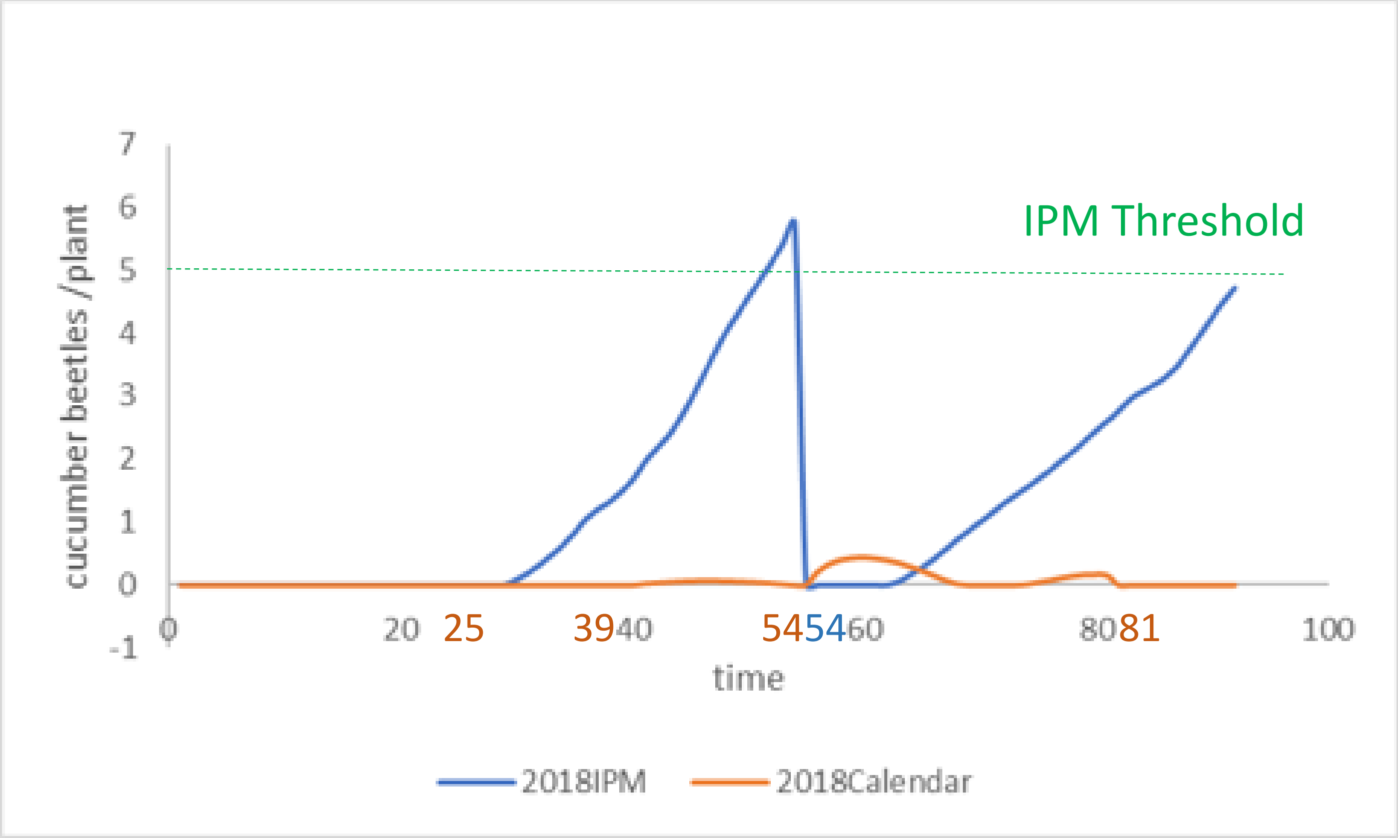
Management strategies

- Wild and commercial pollinator management;
  - Renting commercial bees;
  - Wild pollinator habitat

- Pest management:
  - Calendar spray: farm-level action;
  - Threshold-based spraying (IPM and IPPM): plant-level action;
    - Sample plants and count insects.
    - Spray if number of insects/plant >= threshold.

Calendar Spray vs. IPPM (Integrated Pest and Pollinator Management)

- Field data from Wanatah, Indiana 2018;



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Simulations and Results

- Simulate Yields and Profits for 44 scenarios:
- Pest management: calendar ***or*** IPM ***or*** IPPM

  Pollinator management: renting honeybees ***and/or*** habitat
- Scenarios = Calendar x renting honeybees (binary) x habitat (binary)

  \+ IPM (5 levels) x renting honeybees (binary) x habitat (binary)

  \+ IPPM (5 levels) x renting honeybees (binary) x habitat (binary)

  = 44

Note: (1) Each IPM and IPPM scenario is considered under 5 different pest threshold levels.

(2) Current farmers do calendar spray

Results w/o pesticide drift externality

	Optimal Combination Strategies	Yield (lbs/acre), 5 years	Revenue ($/acre), 5years	Cost ($/acre), 5 years	Profit ($/acre), 5 years
Calendar Spray	N, H, R	277,783	$88,989	$2,927	$86,062
IPM					
threshold=1	N	259,607	$83,379	$1,229	$82,150
threshold=2	N	268,747	$86,422	$848	$85,574
threshold=3	N	268,502	$86,320	$615	$85,705
threshold=4	N	277,133	$89,360	$615	$88,745
threshold=5	N	272,629	$87,804	$615	$87,190
IPPM					
threshold=1	N, H, R	306,046	$98,179	$1,688	$96,491
threshold=2	N, H, R	296,597	$95,109	$1,308	$93,801
threshold=3	N, H, R	292,721	$93,824	$1,074	$92,750
threshold=4	N, H, R	306,900	$98,618	$1,074	$97,544
threshold=5	N, H, R	299,942	$96,199	$1,074	$95,125

N: neonic spray; H: habitat; R: renting honeybees

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Results w pesticide drift externality

	Optimal Combination Strategies	Yield (lbs/acre), 5 years	Revenue ($/acre), 5years	Cost ($/acre), 5 years	Profit ($/acre), 5 years
Calendar Spray	N, R	233,979	$74,581	$2,808	$71,773
IPM					
threshold=1	N	235,013	$75,382	$1,229	$74,153
threshold=2	N	236,257	$75,769	$848	$74,921
threshold=3	N	237,262	$76,103	$615	$75,487
threshold=4	N	240,150	$77,075	$615	$76,460
threshold=5	N	239,471	$76,952	$615	$76,337
IPPM					
threshold=1	N, H, R	247,529	$79,143	$1,688	$77,455
threshold=2	N, H, R	248,414	$79,609	$1,308	$78,301
threshold=3	N, H, R	249,085	$79,811	$1,074	$78,736
threshold=4	N, H, R	249,973	$80,101	$1,074	$79,027
threshold=5	N, H, R	252,323	$80,974	$1,074	$79,900

N: neonic spray; H: habitat; R: renting honeybees

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Summary of optimal strategies

	Calendar	IPM	IPPM
Neighbor (Externalities)	Neonics + Renting Commercial Bees	Neonics (Threshold=4)	Neonics + Renting Commercial Bees +Setting Habitat (Threshold=5)
No Neighbor (No Externalities)	Neonics + Renting Commercial Bees +Setting Habitat	Neonics (Threshold=4)	Neonics + Renting Commercial Bees +Setting Habitat (Threshold=4)

- When externality exists, threshold is higher when doing IPPM comparing to IPM ➔ farmers care more about pollinators conservation and have higher tolerance for pests
- When farmers adopt IPPM, threshold is higher when externality exists ➔ there is more damage from outside, farmers want to mitigate neonics damage and therefore less likely to spray neonics

Yield(Calendar)<Yield(IPM)<Yield(IPPM)

Profits (Calendar)<Profits(IPM)<Profits(IPPM)

➔ More Neonics, yields are lower

- Pollinator diversity matters
- Traditional threshold maybe too high for either IPM or IPPM

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On-going work and future steps:

- Examining higher thresholds for IPPM in the case of neonic drift;
- Compare model results with those of a choice experiment, we conducted in 2018-2019, where farmers make hypothetical pest and pollinator management decisions.
- Solving the problem from a social planner's perspective:
  - Allow corn farmers to choose between treated and non-treated seeds;
  - Examine if externality exists when corn farmers have the option of using non-treated seeds.
  - Especially that recent experimental evidence suggest that neonicotinoid seed treatments provide negligible yield benefit (Krupke et al.2017)

Thank you!

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United States Department of Agriculture
National Institute of Food and Agriculture

USDA Specialty Crop Research Initiative (SCRI)
“Navigating the trade-off between pest management & pollinator conservation in cucurbits”

Dana Bauer; Christian Krupke, Ian Kaplan, Laura Ingwell

Clark University
University of New Hampshire
Purdue University
Michigan State University
The Ohio State University

Appendix

$$y=[\underbrace{Y_{max}}_{\text{Maximum possible yield}}(\underbrace{1-m^{WB}(PS_t^{WB})}_{\text{Yield loss due to neoncic effect on WB}})(\underbrace{1-m^{CB}(PS_t^{CB})}_{\text{Yield loss due to neonic effect on CB}})][1-\underbrace{b(N,threshold)}_{\text{Pest damage b is reduced through neonic application}}]$$

$$\frac{\partial b}{\partial N} < 0$$

Total Yield Level	Yield loss due to neonic effect on CB	Yield loss due to neonic effect on CB
High	0	0
Moderate	0<yM<1	0<ym<1
Low	0<yL<1	0<yl<1

$\frac{\partial m}{\partial PS} < 0$, pollinators mitigation strategies limit yield loss

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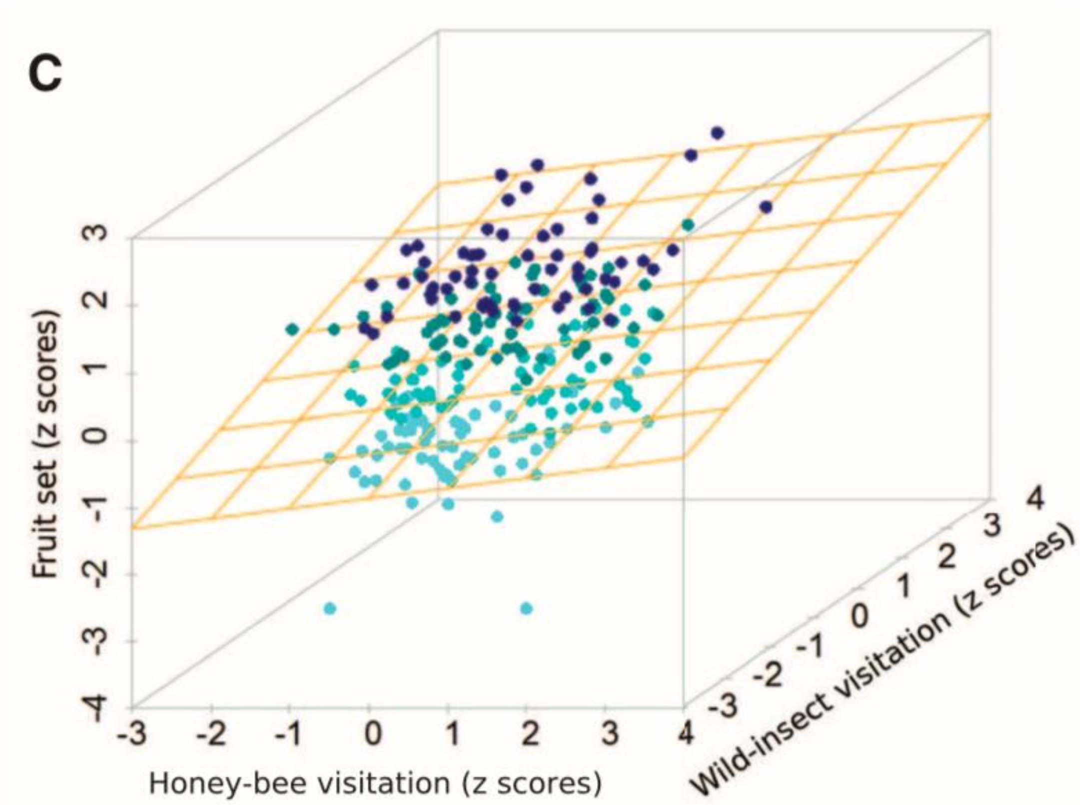
Garibaldi et al. (2013)

- Pollination by managed by honey bees supplemented, rather than substituted for, pollination by wild insects.



- Other evidences show wild bees enhance the pollination productivity of honey bees
  - Greenleaf et al., 2006; Brittain et al., 2013; Carvalheiro et al., 2001; Greenleaf and Kremen, 2006, Klein et al., 2003; Hoehn et al., 2008

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Ecological-Economic Model

Economic objective: maximizing profits that revenue minus costs

$$max_{\{N,H,R\}}\pi(t) = \sum_{t=0}^{T} \rho^{t}[py\left(PS_t^{WB}, PS_t^{CB}, N\right) - C(N,H,R,y)]$$

Ecological constraints: pollinator dynamics (decline and mitigation)

$s.t.\ \ PS_t^{WB} = f_n(F_t^{WB}(F_{t-1}^{WB}, N, H)\ )$ wild pollinator (WB) pollination service (PS) dynamics

$PS_t^{CB} = f_n\left(F_t^{CB}(F_{t-1}^{CB}, N, R), F_t^{WB}(F_{t-1}^{WB}, N, H)\right)$commercial pollinator (CB) pollination service (PS) dynamic

Where crop yield: $y=[Y_{max}(1 - m\ (PS_t^{WB}, PS_t^{CB})][1-b(N(threshold))]$

PS: Pollination Services
F: Number of effective foragers
N: Spraying Neonicotinoids
H: Setting Habitat
R: Renting Commercial Bees

Ymax: Maximum Level of Yield w/o Pests

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$$y=[\underbrace{Y_{max}}_{\text{Maximum possible yield}}(1-\underbrace{m\,(PS_t^{WB},PS_t^{CB})}_{\text{Yield reduction due to NNI effect on WB and CB}}][1-\underbrace{b(\mathrm{N}\ (\mathrm{threshold}))}_{\text{Pest damage b is reduced through NNI application}}]$$

$$\frac{\partial b}{\partial N}<0,\qquad \frac{\partial N}{\partial threshold}<0$$

Total Yield Level	F_t^{WB} (Z-score)	F_t^{CB} (Z-score)	Yield
High	100% (4)	100% (4)	Ymax
Moderate	100% (4)	50% (0)	y1
	100% (4)	0 (-3)	y2
	50% (0)	100% (4)	y3
	50% (0)	50% (0)	y4
	50% (0)	0 (-3)	y5
	0(-3)	100% (4)	y6
	0(-3)	50% (0)	y7
Low	0(-3)	0 (-3)	Ymin

$$\frac{\partial m}{\partial PS}<0$$

$$\mathrm{m}(PS_t^{WB},PS_t^{CB})=\frac{Y_{max}-yi}{Y_{max}-Y_{min}}$$

Thank you! Questions?

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Parameters

Strategy

Strategy Transitions					
R_recover	**Para1**	Percentage or portion of the farm's pollination services that recover from a moderate to a high level as a result of renting commercial bees	41	%	Walters et al. 2006
H_recover	**Para2**	Percentage or portion of the farm's pollination services that recover from a moderate to a high level as a result of setting aside marginal land for pollinator habitat	12.5	%	Holzschuh et al. 2012

Parameters

Yield

Yield					
Ymax	**Para3**	Maximum attainable yield when there are no pests	1166.42	lbs/acre	USDA (after calibrating)
ym	**Para4**	NNI short-term (48 hours) effect on yields through effect on commercial bees	35.87	%	Garbaldi et al. (2013), Wood & Goulson. (2017)
yl	**Para5**	NNI long-term (8 weeks) effect on yields through effect on commercial bees	46.63	%	Garbaldi et al. (2013), Wood & Goulson. (2017)
yM	**Para6**	NNI hort-term (48 hours) effect on yields through effect on wild bees	8.97	%	Garbaldi et al. (2013), Wood & Goulson. (2017)
yL	**Para7**	NNI long-term (8 weeks) effect on yields through effect on wildl bees	35.87	%	Garbaldi et al. (2013), Wood & Goulson. (2017)

Parameters

Yield (cont)

Yield					
tran	**Para8**	Rate of decline of yield as a result of bees exposure to NNI (*deacrease as distance to corn edge increases, increases when NNI sprays*)	F(d, N)*	Day^{-1}	Krupke et al. (2017), Spurgeon. (2016)
habitat	**Para9**	Recommended proportion of unproductive land to be set aside for pollinator habitat so that bees recover from the lowest to the moderate level	10	%	Hladik et al. (2017)
r	**Para10**	Rate of growth of cucumber beetles pollination as a function of temperature	F(T)**	Day^{-1}	Ellers-KirK et al.(2006)
threshold	**Para11**	Threshold to Spray neonicotinoids based on IPPM Strategies	1,2,3,4,5	#/pl	SCRI Project
damage	**Para12**	Crop (per plant) susceptibility to pest (cucumber beetles: as function of different thresholds)	F(threshold)	%	Brust et al. (1999)
time	**Para13**	Growing season (from planting seedling till harvest)	92	days	

$*\frac{\partial F(d,N)}{\partial d} < 0,\ \text{and}\ \frac{\partial F(d,N)}{\partial N} > 0$ (Source: Author's Estimation).

$**F(T) = e^{0.106*T} - e^{0.106*36.972-\frac{36.972-T}{4.14}}$ (After Calibration).

$***F(threshold) = 0.491*threshold^2 - 0.670*threshold + 0.089.$

Parameters

Economics

Economics					
p	**Para14**	National seasonal retail price of watermelon, 2017, Indiana	0.35	$/lb	AgMRC
Rho	**Para15**	Discount factor	0.999866337	Day^-1	Assume Equivalent to 5% per year
Cy	**Para16**	Harvesting and marketing cost, 2013, Indiana	7.143	$/lb	Vegemelon****
Cs	**Para17**	Cost of pesticides, 2013, Indiana	136.3	$/acre	Vegemelon****
Cc	**Para18**	Cost of renting commercial bees, 2013, Indiana	75	$/acre	Vegemelon****
Ch	**Para19**	Cost of setting habitat, 2018, Indiana	1192.39	$/acre	USDA

****Vegemelon is 2013 Indiana Melon Budget

Sensitivity Analysis

Rank Average of Sensitivity

Parameter	Yield Range (max%-min%)	Profit Range (max%-min%)	Rank
NNI short-term (48 hours) effect on yields through effect on commercial bees (**ym**)	1.28%	1.53%	5
NNI long-term (8 weeks) effect on yields through effect on commercial bees (**yl**)	20.73%	22.46%	1
NNI hort-term (48 hours) effect on yields through effect on wild bees (**yM**)	0.43%	0.52%	6
NNI long-term (8 weeks) effect on yields through effect on wildl bees (**yL**)	16.28%	17.61%	3
Rate of decline of yield as a result of bees exposure to NNI (*deacrease as distance to corn edge increases, increases when NNI sprays*) (**tran**)	2.94%	3.29%	4
Crop (per plant) susceptibility to pest (cucumber beetles: as function of different thresholds) (**damage**)	16.75%	16.79%	2

No Neighbor w/ Calendar Spray

	No Neonics + No Mitigation Policy	Neonics + No Mitigation Policy	Neonics + Renting Comm	Neonics + Habitat	Neonics + Habitat +Renting Comm
Yield (lbs/acre), 5years	376,615	249,793	263,199	254,225	277,783
Revenue ($/acre), 5years	$119,689	$79,858	$84,204	$81,376	$88,989
Cost ($/acre), 5years	$ -	$2,468	$2,808	$2,587	$2,927
Profit ($/acre), 5years	$119,689	$77,390	$81,396	$78,789	$86,062

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No Neighbor w/ IPPM (threshold = 1)

	No Neonics + No Mitigation Policy	Neonics + No Mitigation Policy	Neonics + Renting Comm	Neonics + Habitat	Neonics + Habitat +Renting Comm
Yield (lbs/acre), 5years	376,615	259,607	289,834	269,134	306,046
Revenue ($/acre), 5years	$119,689	$83,379	$93,040	$86,503	$98,179
Cost ($/acre), 5years	$ -	$1,229	$1,569	$1,348	$1,688
Profit ($/acre), 5years	$119,689	$82,150	$91,471	$85,155	$96,491

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No Neighbor w/ IPPM (threshold = 2)

	No Neonics + No Mitigation Policy	Neonics + No Mitigation Policy	Neonics + Renting Comm	Neonics + Habitat	Neonics + Habitat +Renting Comm
Yield (lbs/acre), 5years	376,615	268,747	292,878	273,006	296,597
Revenue ($/acre), 5years	$119,689	$86,422	$93,815	$87,939	$95,109
Cost ($/acre), 5years	$ -	$848	$1,188	$968	$1,308
Profit ($/acre), 5years	$119,689	$85,574	$92,626	$86,971	$93,801

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No Neighbor w/ IPPM (threshold = 3)

	No Neonics + No Mitigation Policy	Neonics + No Mitigation Policy	Neonics + Renting Comm	Neonics + Habitat	Neonics + Habitat +Renting Comm
Yield (lbs/acre), 5years	376,615	268,502	292,272	286,764	292,721
Revenue ($/acre), 5years	$119,689	$86,320	$93,647	$92,528	$93,824
Cost ($/acre), 5years	$ -	$615	$955	$734	$1,074
Profit ($/acre), 5years	$119,689	$85,705	$92,692	$91,794	$92,750

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No Neighbor w/ IPPM (threshold = 4)

	No Neonics + No Mitigation Policy	Neonics + No Mitigation Policy	Neonics + Renting Comm	Neonics + Habitat	Neonics + Habitat +Renting Comm
Yield (lbs/acre), 5years	376,615	277,133	292,143	268,886	306,900
Revenue ($/acre), 5years	$119,689	$89,360	$93,607	$86,556	$98,618
Cost ($/acre), 5years	$ -	$615	$955	$734	$1,074
Profit ($/acre), 5years	$119,689	$88,745	$92,652	$85,822	$97,544

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No Neighbor w/ IPPM (threshold = 5)

	No Neonics + No Mitigation Policy	Neonics + No Mitigation Policy	Neonics + Renting Comm	Neonics + Habitat	Neonics + Habitat +Renting Comm
Yield (lbs/acre), 5years	376,615	272,629	296,252	273,817	299,942
Revenue ($/acre), 5years	$119,689	$87,804	$95,132	$88,148	$96,199
Cost ($/acre), 5years	$ -	$615	$955	$734	$1,074
Profit ($/acre), 5years	$119,689	$87,190	$94,177	$87,414	$95,125

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Corn Neighbor w/ Calendar Spray

	No Neonics + No Mitigation Policy	Neonics + No Mitigation Policy	Neonics + Renting Comm	Neonics + Habitat	Neonics + Habitat +Renting Comm
Yield (lbs/acre), 5years	201,615	226,828	233,979	223,793	228,627
Revenue ($/acre), 5years	$64,597	$72,542	$74,581	$71,376	$72,928
Cost ($/acre), 5years	$ -	$2,468	$2,808	$2,587	$2,927
Profit ($/acre), 5years	$64,597	$70,074	$71,773	$68,789	$70,001

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Corn Neighbor w/ IPPM threshold=1

	No Neonics + No Mitigation Policy	Neonics + No Mitigation Policy	Neonics + Renting Comm	Neonics + Habitat	Neonics + Habitat +Renting Comm
Yield (lbs/acre), 5years	201,615	235,013	241,519	234,095	247,529
Revenue ($/acre), 5years	$64,597	$75,382	$77,222	$74,875	$79,143
Cost ($/acre), 5years	$ -	$1,229	$1,569	$1,348	$1,688
Profit ($/acre), 5years	$64,597	$74,153	$75,653	$73,527	$77,455

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Corn Neighbor w/ IPPM threshold=2

	No Neonics + No Mitigation Policy	Neonics + No Mitigation Policy	Neonics + Renting Comm	Neonics + Habitat	Neonics + Habitat +Renting Comm
Yield (lbs/acre), 5years	201,615	236,257	239,554	236,027	248,414
Revenue ($/acre), 5years	$64,597	$75,769	$76,671	$75,707	$79,609
Cost ($/acre), 5years	$ -	$848	$1,188	$968	$1,308
Profit ($/acre), 5years	$64,597	$74,921	$75,482	$74,739	$78,301

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Corn Neighbor w/ IPPM threshold=3

	No Neonics + No Mitigation Policy	Neonics + No Mitigation Policy	Neonics + Renting Comm	Neonics + Habitat	Neonics + Habitat +Renting Comm
Yield (lbs/acre), 5years	201,615	237,262	247,283	237,603	249,085
Revenue ($/acre), 5years	$64,597	$76,103	$79,176	$76,125	$79,811
Cost ($/acre), 5years	$ -	$615	$955	$734	$1,074
Profit ($/acre), 5years	$64,597	$75,487	$78,221	$75,390	$78,736

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Corn Neighbor w/ IPPM threshold=4

	No Neonics + No Mitigation Policy	Neonics + No Mitigation Policy	Neonics + Renting Comm	Neonics + Habitat	Neonics + Habitat +Renting Comm
Yield (lbs/acre), 5years	201,615	240,150	247,897	240,011	249,973
Revenue ($/acre), 5years	$64,597	$77,075	$79,443	$77,017	$80,101
Cost ($/acre), 5years	$ -	$615	$955	$734	$1,074
Profit ($/acre), 5years	$64,597	$76,460	$78,489	$76,283	$79,027

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Corn Neighbor w/ IPPM threshold=5

	No Neonics + No Mitigation Policy	Neonics + No Mitigation Policy	Neonics + Renting Comm	Neonics + Habitat	Neonics + Habitat +Renting Comm
Yield (lbs/acre), 5years	201,615	239,471	248,025	238,471	252,323
Revenue ($/acre), 5years	$64,597	$76,952	$79,604	$76,591	$80,974
Cost ($/acre), 5years	$ -	$615	$955	$734	$1,074
Profit ($/acre), 5years	$64,597	$76,337	$78,649	$75,857	$79,900

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