Quantifying landscape level threats from pesticide use to honey bees in the Prairie Pothole Region

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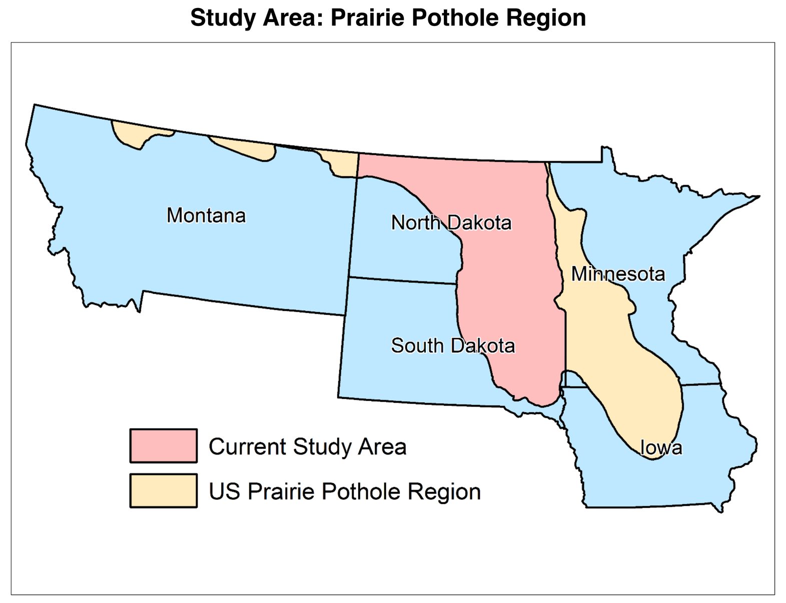
Introduction

Land use change of grasslands and pesticide applications have significantly impacted honey bee colonies in the US; grasslands containing pollen and nectar resources have decreased and pesticides known to cause lethal and sub-lethal effects to honey bees have followed conversion to cropland. Insect pollination represents $16 billion annually to the US economy; and of that sum, 75% originates from honey bee production. This includes the pollination of fruits, nuts, seeds, oils and fibers. The Northern Great Plains (NGP) region of the US supports over 40% of US honey stocks. However, land use change in the NGP from grassland to biofuel crops has significantly decreased the available forage for bees. Conservation Reserve Program (CRP) land decreased by close to 50% while losing over 1.5 million acres since its peak in 2007. Following the conversion of grassland has followed row crops treated with various insecticides at different concentrations known to impact colony performance. This is a spatial analysis of where these trends have occurred.

Study Area: Prairie Pothole Region



Prairie Pothole Region (PPR) hosts above average biodiversity such as pollinators and birds due to wetlands and marginal soils not suitable for crop production.

Objectives and Questions

Objective 1. Quantify key insecticide use around registered apiaries in North and South Dakota found in the PPR within 1 and 2km buffers of apiaries

- **Question 1:** From 2006-2014/2015, of eight insecticide uses on corn, soybeans and wheat at 1 and 2km buffers around registered apiaries, which show increasing or decreasing trends? (Have pyrethroid use and organophosphate use changed with the adaption of neonicotinoids?)

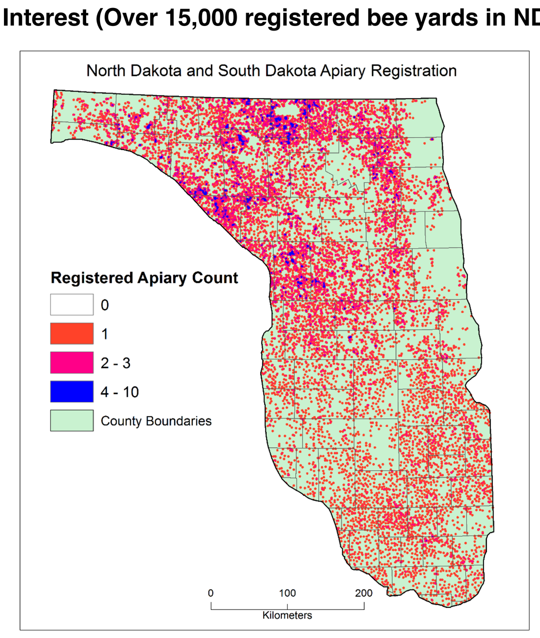
Objective 2. Understand where and how grassland and CRP quality could be impacted by insecticide use along cropland margins

- **Question 1:** Where in the PPR did registered apiaries experience the most relative degradation due to additional pesticide use?
- **Question 2:** Did the mean habitat quality per acre of CRP change from 2006 to 2014?

Objective 3. How will the total individual habitat quality of 15,000 registered apiaries respond under randomly and strategically reallocated CRP acres within 1mile of apiary sites?

- **Question 1:** Under scenarios of reallocated CRP acres to be placed within registered apiaries, is there a difference between total habitat quality with randomly distributed acres vs. strategically distributed acres?

Regions of Interest (Over 15,000 registered bee yards in ND and SD PPR)

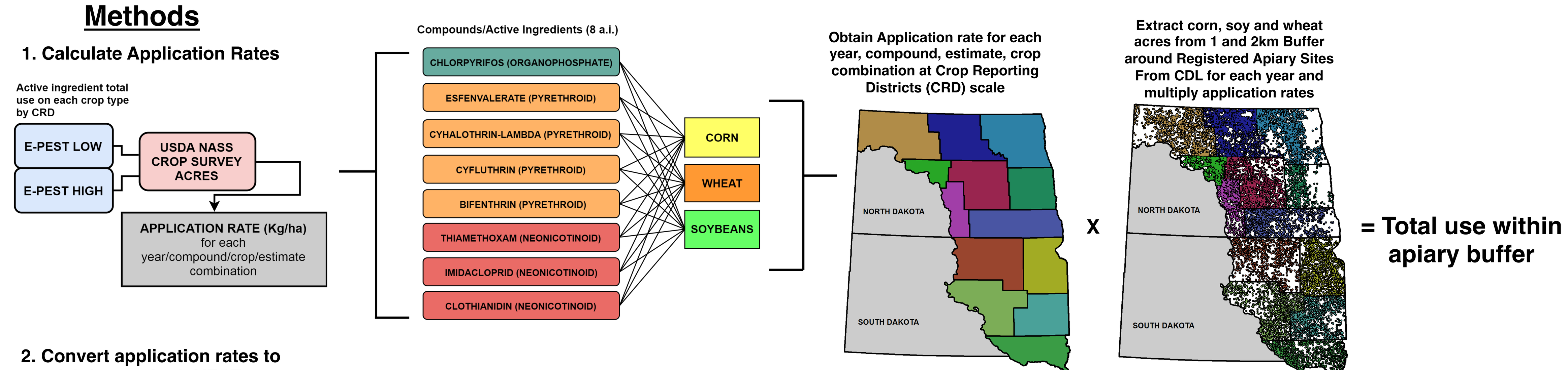


Data 2006-2014/2015

1. Pesticide Use: USGS E-PEST individual compound estimates per county/year combination are based on proprietary surveys. State level per crop-type and county level total estimates are merged to create quantity (kg) per **CROP REPORTING DISTRICT** on corn, soybeans and wheat. Higher uncertainty would be expected with other crops due to grouped reported quantities and fewer overall acres reported by USDA NASS. Neonicotinoid use stops at 2014. All other insecticides continue through 2015.
2) Pesticides selected: Identified by Goka & Bayo (2014) as commonly occurring in colonies at harmful concentrations globally, as well as commonly used on corn, soybeans or wheat in the PPR during the 2006-2014/2015 time period.
3) County crop acres: USDA NASS estimates for corn, soybeans and wheat. Agricultural districts were grouped when counties were not reported individually.
4) Spatial location of crops: NASS Cropland Data Layer (30x30 annual classified cropland product) **Corn, soybeans, wheat, grassland, forest, and wetland** were extracted from each year) (see figure right). 2006 was resampled to 30x30m.
5) Apiary registration: Points represent where beekeepers could potentially place their colonies given at quarter section accuracy. Registration includes sites up to 2014/2015 registration.

Methods

1. Calculate Application Rates



2. Convert application rates to spatial threats for InVEST Habitat Quality with methods from EPA BeeREX model

Application rate (kg/ha) * 98 / 1000 = Potential "Bee application"

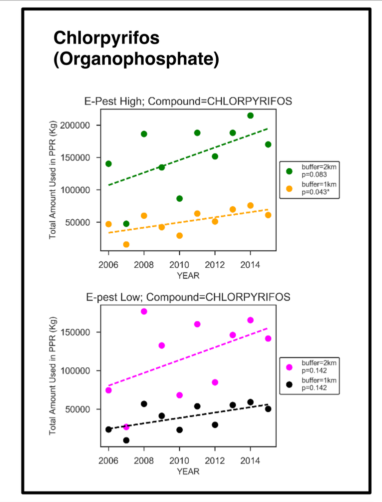
(For dietary exposure, the method includes upper bound for tall grass used in the model (98μg) as to represent pesticide concentrations in pollen and nectar of flowers directly sprayed by pesticide.

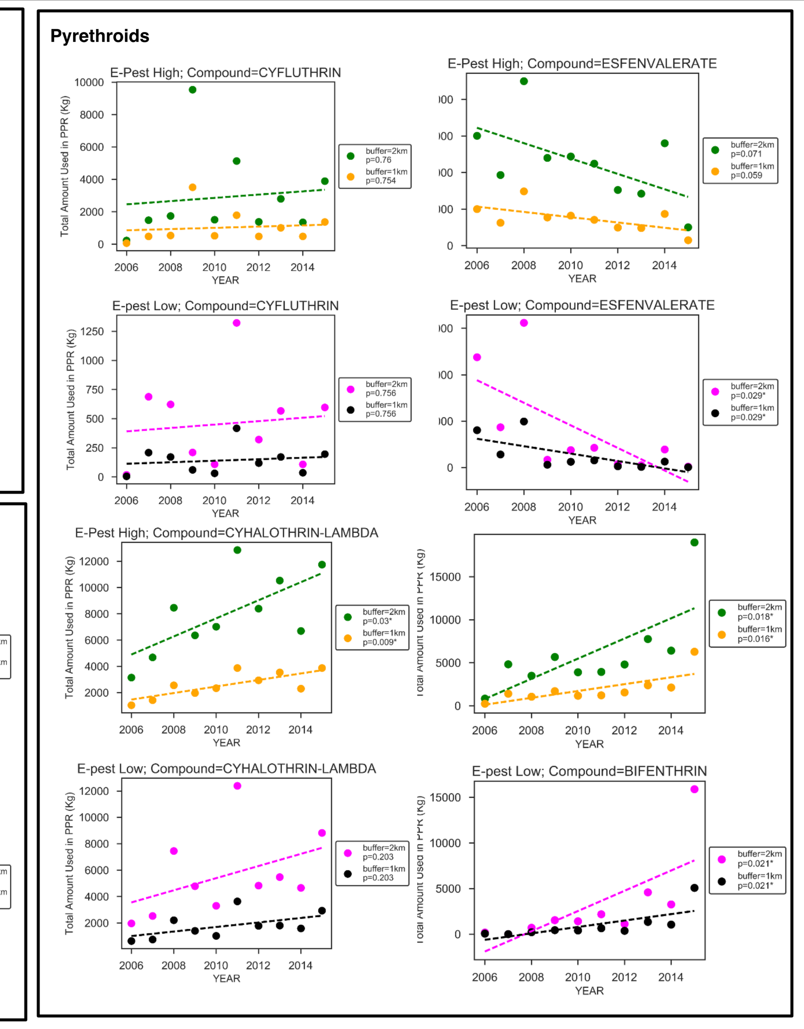
Result (μg) * 2.4 / LD50 acute contact
Upper bound exposure value proposed by Koch and Weisser (1997)

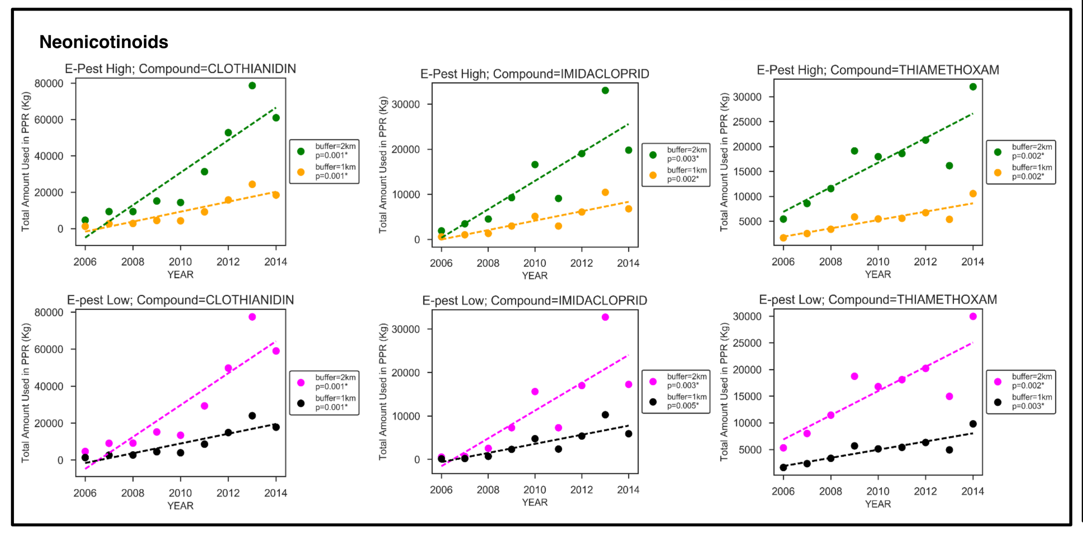
Risk Quotient

OBJECTIVE 1.Total Use Quantity Results
Reporting trends for eight insecticide at E-PEST LOW and HIGH total use (kg) within 1 and 2 km buffers from registered apiaries in the PPR.

-6/8 show increasing trends including neonicotinoids and chlorpyrifos (highest risk quotients)
-Esfenvalerate and Cyfluthrin showing negative or no trend.
Significance obtained from linear regression where independent variable is year (from 2006-2015 for non-neonicotinoids and 2006-2014 for neonicotinoids). Significant level* < 0.05.





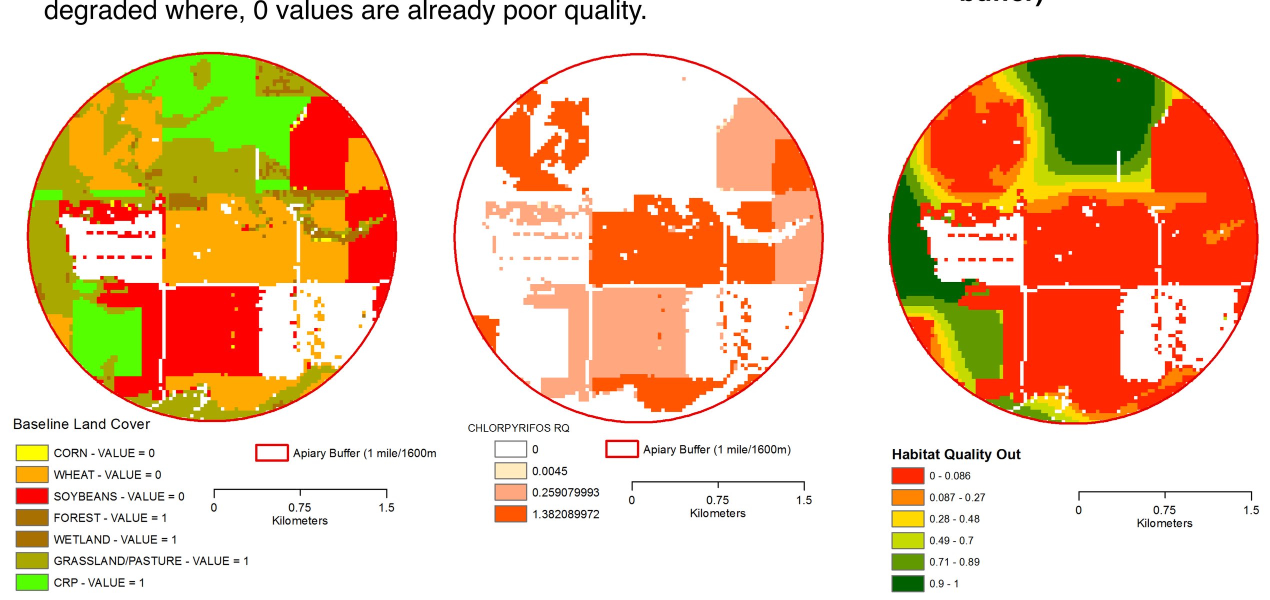


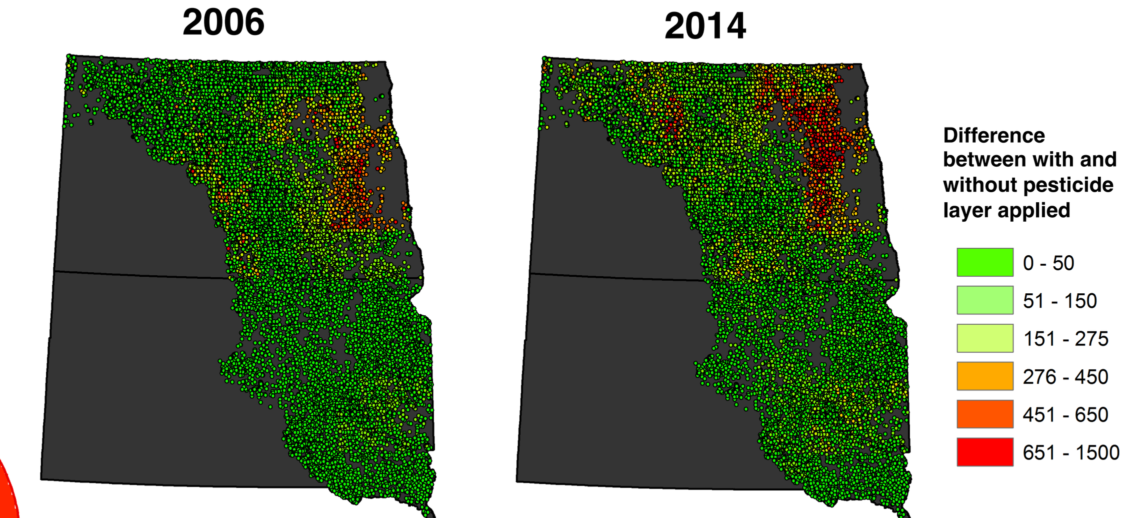
3. Plotting threats spatially with InVEST Habitat Quality Model

Model Requirements (example)

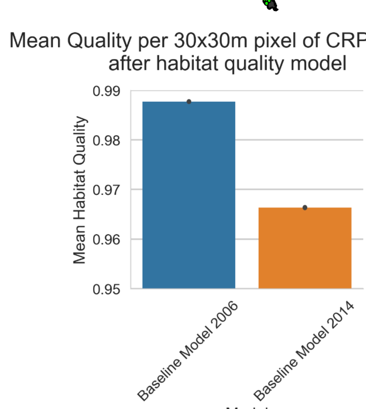
- Baseline Layer (CDL merged with CRP 2006 and 2014)
- Weighted Threat Layers for each pesticide
  - Each pixel represents risk quotient on each crop type
- Threat weight and sensitivity (weights already captures with rasters and for sensitivity, if == natural land cover, sensitivity = 1, if == cropland, sensitivity = 0) where land covers with value of 1 can be degraded where, 0 values are already poor quality.

4. (right) Model outputs with and without pesticide layer applied for each apiary site (habitat quality summed for all pixels within 1 mile buffer)





5. (right) Difference in CRP quality from 2006 – 2014
Change in quality suggests the same acre of CRP in 2006 was providing on average 2.5% better quality due to multiple factors such as less fragmentation and fewer margins with cropland.



Scenarios on 2014 Landscape and Results

MODEL SCENARIOS TO REALLOCATE CRP WITHIN ONE MILE OF APIARY BUFFERS

RANDOMIZED	LARGEST CRP POLYGONS FILLED	LARGEST CRP AND MOST OVERLAP FILLED

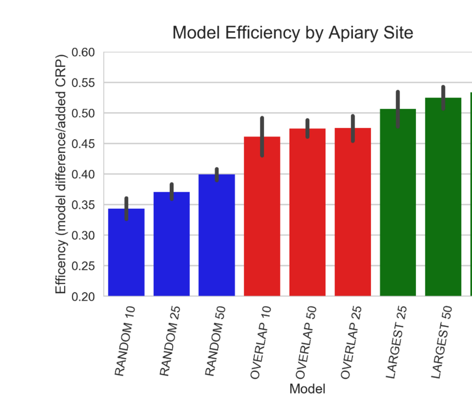
EACH AT 10%, 25% AND 50% OF AVAILABLE CAP (ACRES NOT WITHIN CURRENT APIARY BUFFER IN 2014)

There were ~1,800,000 acres of CRP within the study region in 2014.
-Of those 2014 polygons, ~454,000 acres of polygons had centroids **NOT** within 2.5km of apiary sites. That is ~24% of all CRP in 2014.
Purpose: Redistribute 10% and 25% and 50% of those under three scenarios and compare habitat quality benefits considering land use and decreased pesticide exposure.
TOTAL CAP = ~454,000 (obtained from the 24% not within buffers)
9 Total Scenarios: 10% (45,400 acres), **25%** (113,000 acres), **50%** (227,000 acres)
Where to put them? - In available polygons that were CRP in 2006 but were not in 2014
1) Random scenario -> polygons sorted and randomized, filled until each cap met.
2) Largest polygons scenario -> sort available polygons by size and fill until cap met.
3) Overlap Buffer scenario -> Sort polygons by area of overlapping apiary buffers and fill until cap met.
Habitat suitability models are run again with modified land covers and threat layers.

Measuring model efficiency

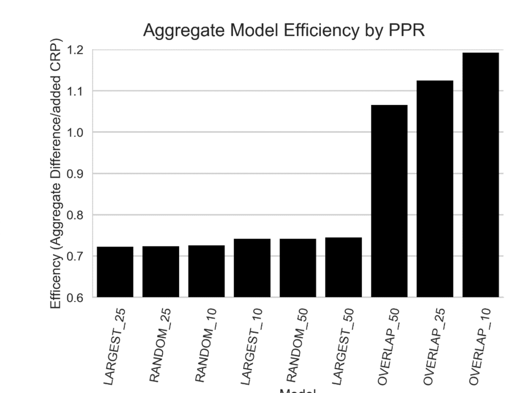
1.Look at Efficiency per apiary site (so some changes inside apiaries are counted multiple times) (favors **LARGER** model)

When the largest polygons were filled, this increased the quality per unit of CRP by decreasing cropland margins.



2 Aggregate all changes within each apiary site and divide by overall additional CRP acres

As expected, models favoring overlap would on average provide the most benefit considering additive effects.



Conclusion

1. Measuring the total use of eight insecticides within 1 and 2km buffers suggests that neonicotinoid use has not significantly reduce the total amount of other key insecticides (pyrethroids/chlorpyrifos) at the apiary level in the PPR from 2006-2014. Whether it be rises in application rate or corn, soybean and wheat acre changes, land important for apiaries is experiencing increasing trends on 6/8 insecticides selected.
2. When spatially distributing threats, chlorpyrifos use in eastern North Dakota seems to drive a majority of additional degradation on top of land use when considering models with and without threat (pesticide) layers.
3. While the number of CRP acres decreased by close to 50% from 2006 to 2014, the mean quality per CRP acre also decreased, suggesting fewer regions where pesticide application and drift are absent.
4. If trying to improve quality of forage for the highest number of registered apiary sites, scenarios suggest that there may be significant differences between randomly placing (inside buffers) CRP and strategically locating CRP to meet multiple registered apiaries and provide a refuge from crop margins where spray drift is likely. By targeting larger swaths of CRP, margins will also decrease leading to mitigated threats.

References

NASS Quick Stats

Sanchez-Bayo, F., & Goka, K. (2014). Pesticide residues and bees - A risk assessment. *PLoS ONE*, *9*(4).

Koch, H., & P. Weisser. (1997) Exposure of honey bees during pesticide application under field conditions. *Apidologie* 28, no. 6 439-447.

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