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Using GIS To Evaluate Habitat Connectivity Among The Pollinator Conservation Reserve Program Pollinator Habitat (CP-42) Restorations In Northeast Iowa

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USING GIS TO EVALUATE HABITAT CONNECTIVITY AMONG THE POLLINATOR CONSERVATION RESERVE PROGRAM POLLINATOR HABITAT (CP-42) RESTORATIONS IN NORTHEAST IOWA

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Abstract

The Conservation Reserve Program pollinator habitat conservation practice (CP-42) allows farmers to turn their land, once used for agriculture, into restored prairie to provide floral sources and habitat for wild pollinators. In order for these sites to be fully effective, they must be accessible to native bees and other pollinator species. To understand the movement of native bees and how these corridors are being used to establish new bee communities in these restored sites, we must understand the landscape around them. The vegetation and native bee communities were surveyed at nineteen CP-42 sites in 2018 and 2019. Landscape and land-use data, derived from the USDA CroplandCROS data layers, were analyzed using ArcGIS software to delineate and quantify potential pollinator habitat in 1km buffers surrounding each CP-42 site. Paired with the collected bee data, statistical analysis was run using the computer software R to compare the percent of each land cover class and the richness and abundance of the native bee communities per site. Our data showed less correlation between the richness and density of native bee species and the surrounding landscape variables, compared to the strong correlation between the floral resources within the restored habitat. This tells us that the floral resources that comprise the restorations are important to establishing and maintaining a rich and abundant bee community.

Keywords: ArcGIS, CRP - 42, bee richness, land usage, landscape

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Introduction

Purpose

The Conservation Reserve Program is a program that takes land out of agricultural production to provide benefits to the ecosystem. A CP-42 restoration is a part of the larger CRP program that focuses on the enhancement of pollinator habitat and is one of many available practices under the overarching CRP program. As a part of the CP-42 program, the federal government pays farmers to turn their agricultural land into restored prairie habitat. Through this NASA research project, we examined 19 CP-42 sites to understand the habitat connectivity between these restored habitats and other natural habitats in the landscape, and to determine how native bee species travel between habitats to colonize the restored CP-42 sites. These data helped us understand how habitat fragmentation, connectivity, and isolation all play a role in the movement of native pollinators from their native habitats to restored habitats. We examined how the quality and quantity of these habitat patches within the surrounding landscape affect the movement of native bees to the CP-42 sites and the richness and density of these native bee communities. This research can advance our understanding of local and landscape characteristics that promote colonization by native bees and ways we can improve the movement of bees and other native pollinators to these areas.

Literature Review

A few previous studies looked at habitat connectivity and how this plays a role in the dispersion of native bee communities. In McGarigal et al. (2009), the authors discussed the patch mosaic paradigm in which landscapes are conceptualized and analyzed as a mosaic of small patches of habitat. The authors also discussed surface metrology which is used to model landscapes in continuous rather than finite space. The authors described a “landscape gradient model” in which the landscape is looked at based on continuous differences that occur within the habitat versus assuming the habitat functions only one way internally.

Vasiliev and Greenwood (2023) examined the role that landscape connectivity plays in the biodiversity of pollinator communities. They discussed past studies that found that biodiversity within the native bee communities determines the size, quality, and the resiliency of the services that pollinators can provide. They argued that habitat fragmentation is often ignored when looking at factors driving pollinator declines. Vasiliev and Greenwood also argued that sensitivity to habitat isolation might be linked to how mobile a bee species is. For example, a species that travels farther to forage might struggle more than a species with a smaller foraging range. Traits like size and mobility likely increase the sensitivity to issues such as habitat loss and fragmentation. They also discussed how the quality of habitat is just as important as the abundance of available habitat. This concurred with Mola et. al (2021) in which the authors discussed how, due to the long flight season of bumblebees, different land cover types are needed at different points in the season. Native bee species require habitat that provides suitable floral resources for feeding during the summer months as well as abundant grassland and forest for nesting and overwintering. They argued that just because available habitat might be continuous across the landscape that does not mean that it is usable or of high quality.

Similarly, Kennedy et al. (2013) looked at landscape configuration and composition, as well as the management of nearby farmland, to determine its effects on the abundance and richness of the bee community. Similar to the previous study, they found that bee abundance and richness were higher if more high-quality habitats surrounded the farmland. The researchers also concluded that the configuration of the landscape plays little role in the abundance and richness of the bee communities. Rather, a diverse and robust bee community requires an abundance of high-quality habitat locally accessible to them. The authors discussed how the loss of suitable habitat is a big factor in the decline of bee species as more agricultural landscapes can cause the loss of needed habitats. Kennedy et al. shared insights on the idea that social bees tended to be more affected by the landscape than solitary bees, stating that “social bees may see the landscape at larger spatial scales and more sensitive to landscape-level habitat structure” (Kennedy et al., 2013, p.13). They concluded by discussing how an increase in natural habitat in the area and around farm fields can help increase the diversity of the native pollinator communities that call the area home.

Haddad et al. (2017) disagreed with the “Habitat amount hypothesis” which states that the amount of habitat available is the main factor that drives species richness decline. Rather, they described how abundance and fragmentation must be looked at with equal importance when it comes to identifying factors causing the decline of native bee populations. They argued that the effects of habitat fragmentation on the ecosystem will only increase over time and thus must be looked at as a factor in the loss of species richness.

Kaul and Wilsey (2021) described the different models with which a restoration can be examined, looking specifically at the establishment of vegetation at restoration sites. They proposed the deterministic model in which “communities assemble towards a predictable and consistent community composition and diversity over time as determined by local environmental conditions” (Kaul & Wilsey, 2021). In other words, the communities within a restoration predictably move towards a specific composition based on the environmental conditions around them. Alternatively, they also proposed the Stochastic/alternate state model in which “factors that are somewhat random set the trajectory of community development” (Kaul & Wilsey, 2021).

This idea states that communities develop as a result of random variables. Based on observations they made in restored and remnant prairies, Kaul and Wilsey concluded wild bee communities in restorations follow the stochastic model as the factors that affect them are highly variable.

In summary, there is not a unified theory on the impact of habitat diversity/abundance on the richness and diversity of pollinator communities after habitat restoration. We had the opportunity to use our wild bee data collected from newly restored prairie habitats to provide empirical evidence to test how the habitat abundance and degree of fragmentation around the restored prairie habitat affected the community assembly of wild bee pollinators in a landscape predominantly occupied by agricultural row crops.

Research Questions

1. How does the landscape surrounding a prairie restoration affect the establishment of its bee community?
2. Are natural landscape covers (i.e. forests, wetlands, etc.) better suited to supporting native bee species than agricultural landscape covers (i.e. corn, soybeans, etc.)?
3. How does overall habitat quality affect the richness and density of native bee communities?

Hypothesis

Sites with proximity to high-quality landscape patches (i.e. forests, wetlands, etc.) will have a higher richness and density of their bee communities than those sites with greater proximity to low-quality landscape patches (i.e. corn, soybeans, etc.)

Methods

Study sites and survey methods

Nineteen pollinator habitat (CP-42) Conservation Reserve Program (CRP) sites of varying size and all within a 1-hour driving distance from Cedar Falls were previously surveyed in the months of June, July, and August 2018 and 2019 for wild bee pollinator diversity and density (Fig. 1). Bees were hand-netted by four surveyors in four randomly chosen quadrants for 15-minute intervals. Each quadrant covered one-quarter of a hectare (50 m $\times$ 50 m). When a bee was caught, timers were paused and the bee was put in an ethyl acetate kill jar. Bumblebees were put in tubes of alcohol for preservation and future testing. Timers were resumed after the bee was transferred. In the lab, bees were later identified to the species level.

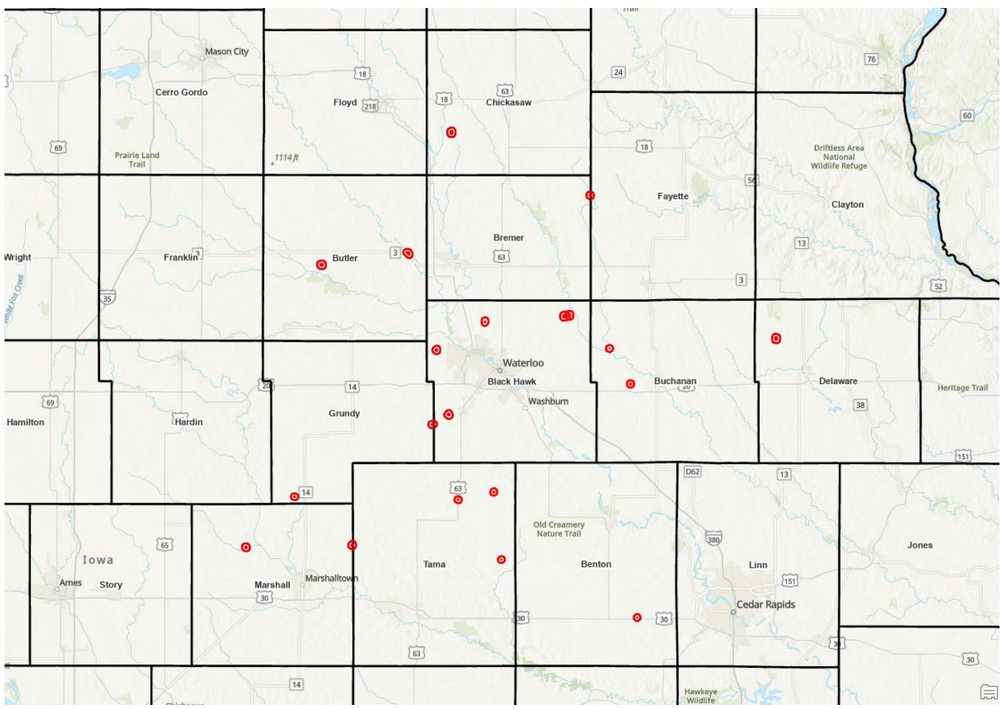

Fig. 1| Map of the 19 CP-42 sites examined and their locations throughout Northeast Iowa

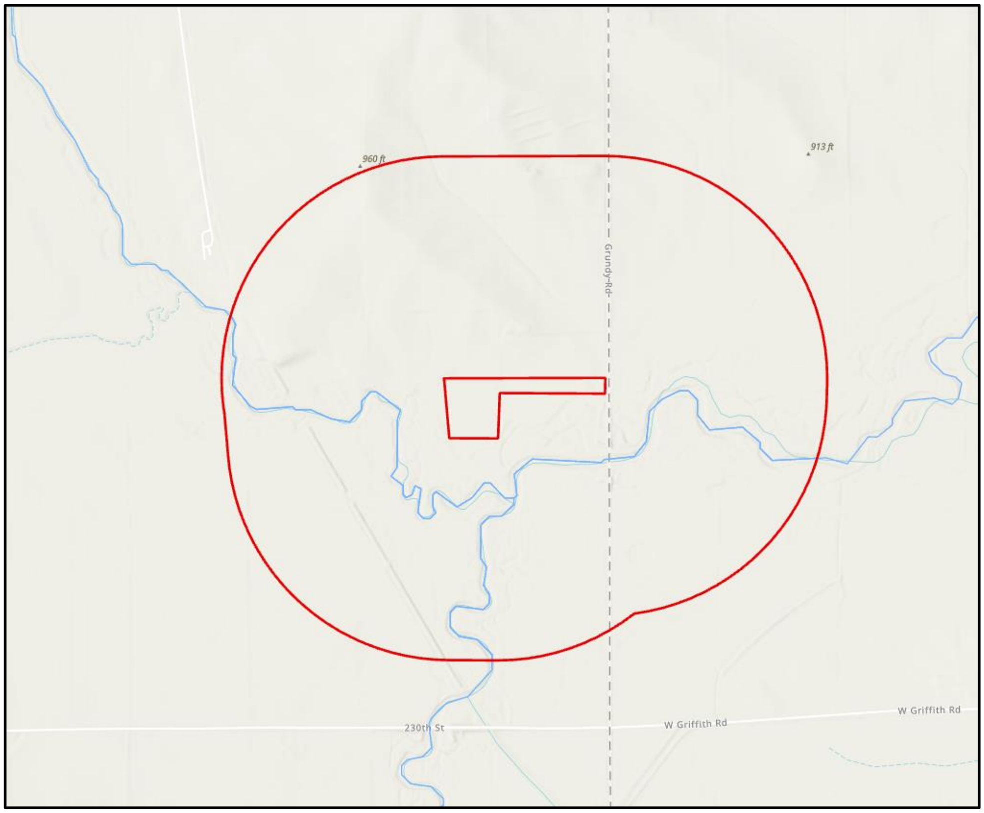

Fig. 2| Example of site with 1-km buffer mapped in ArcGIS

Land-use data

The sites were plotted using shapefiles created by Katie Sinnott a former University of Northern Iowa student. Land-use data was taken from the CroplandCROS data layers from the USDA (USDA, 2024). The mapping software ArcGIS Pro was used to create a 1 km buffer around each site (Fig.2). This buffer was then used to clip the land-use data within the buffer zone and a count for each land-use classification was taken which was used to calculate the percent of each land class within the buffer zone (Fig.3).

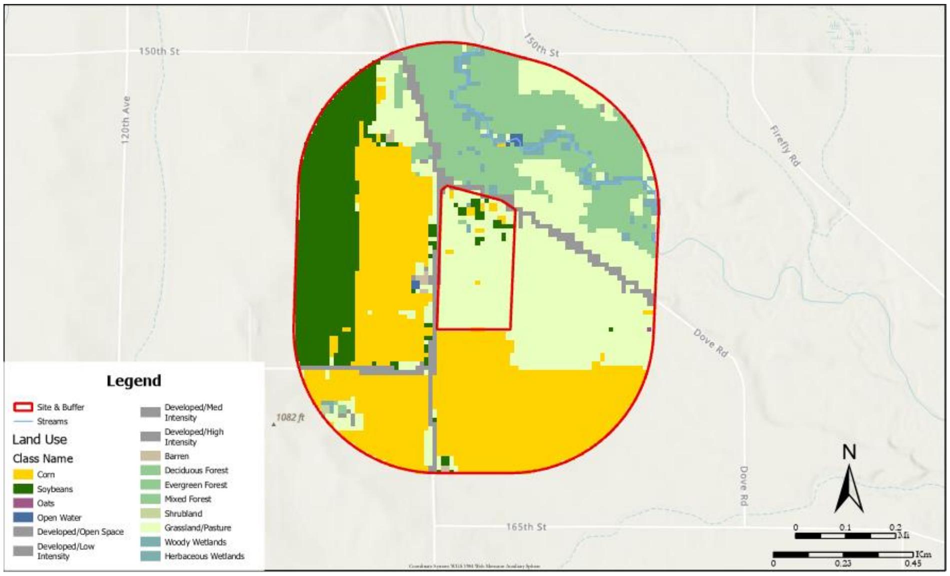

Fig. 3| Example of site with clipped land-use layers

For each site, the percent cover of corn, soybeans, alfalfa, open water, developed space, forest, grassland/pasture, woody wetlands, herbaceous wetlands, and stream length were examined. The land-cover classes "deciduous forest," "evergreen forest," and "mixed forest" as well as the classes "developed/open space," "developed/low," "developed/med," and "developed/high" were combined into the general "Forest" and "Dev. Space" categories respectively.

Statistical analysis

The computer program R was used to do statistical analysis. Each land-cover class per site was analyzed against the richness and density of the bee species for each site by linear regression. A P-value<0.05 was used to determine a significant relationship, and a P-value between 0.05 and 0.1 was considered a marginally significant linear relationship. Linear regression plots were then created for each land class and used to describe the relationship between the land cover class and the bee community for each site. For this project, bee richness is the number of bee species documented at each site, and bee density is the abundance of bees per hectare documented at each site.

Results

We found a negative correlation between the percent corn and bee richness ($p = 0.161$) and bee density ($p = 0.362$) at a site; although neither linear regression yielded a significant correlation, the trend was very clear (Fig. 4 & 5).

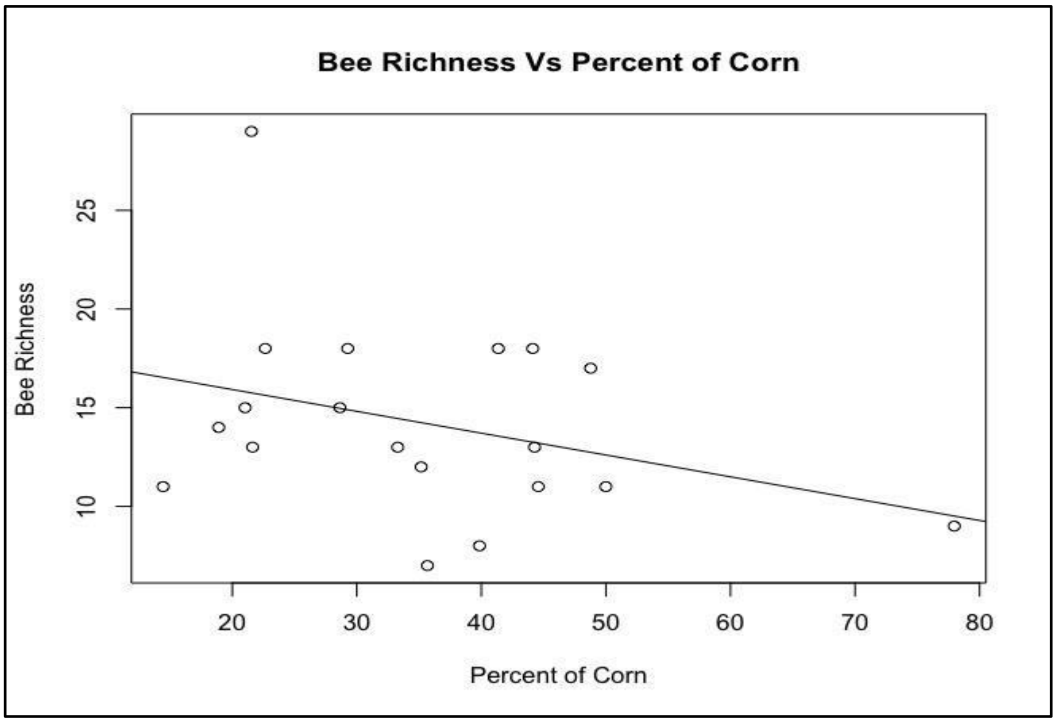

Fig. 4| Linear Regression showing the correlation between bee richness and percent corn cover for the 19 sites

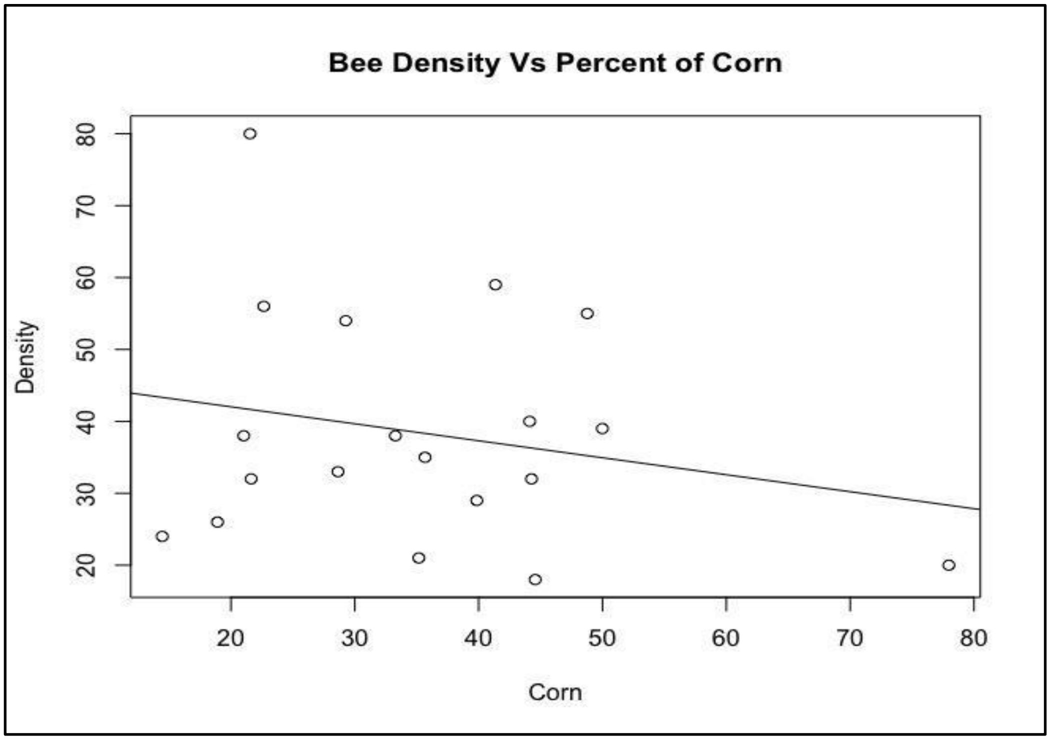

Fig. 5| Linear Regression showing the correlation between bee density and percent corn cover for the 19 sites

Similarly, we did not find a significant correlation between the bee richness and density with other land-use categories. The only marginally significant correlation was between bee richness and stream length ($p = 0.065$). The percent of open water ($p = 0.020$) was found to have a significant positive correlation with the richness of the bee community within sites (Fig. 7). The *p* - values for the remaining land classes can be viewed in Table 1 in the Appendix.

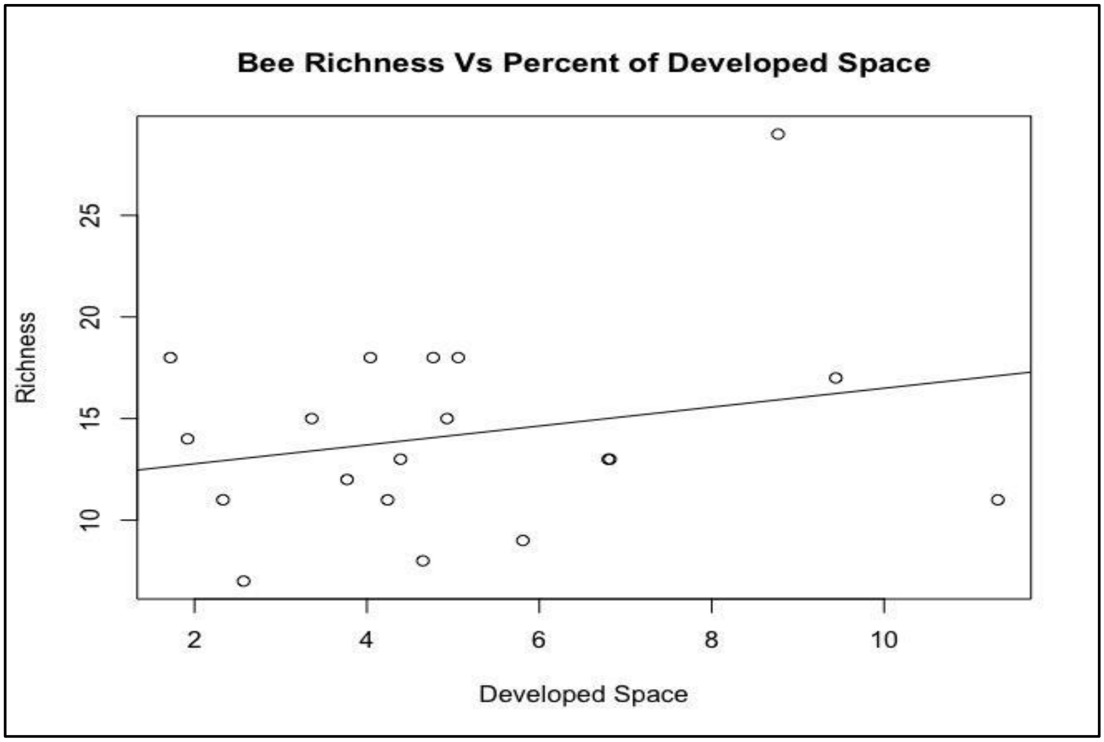

Fig. 6| Linear Regression showing the correlation between bee richness and percent developed space for the 19 sites

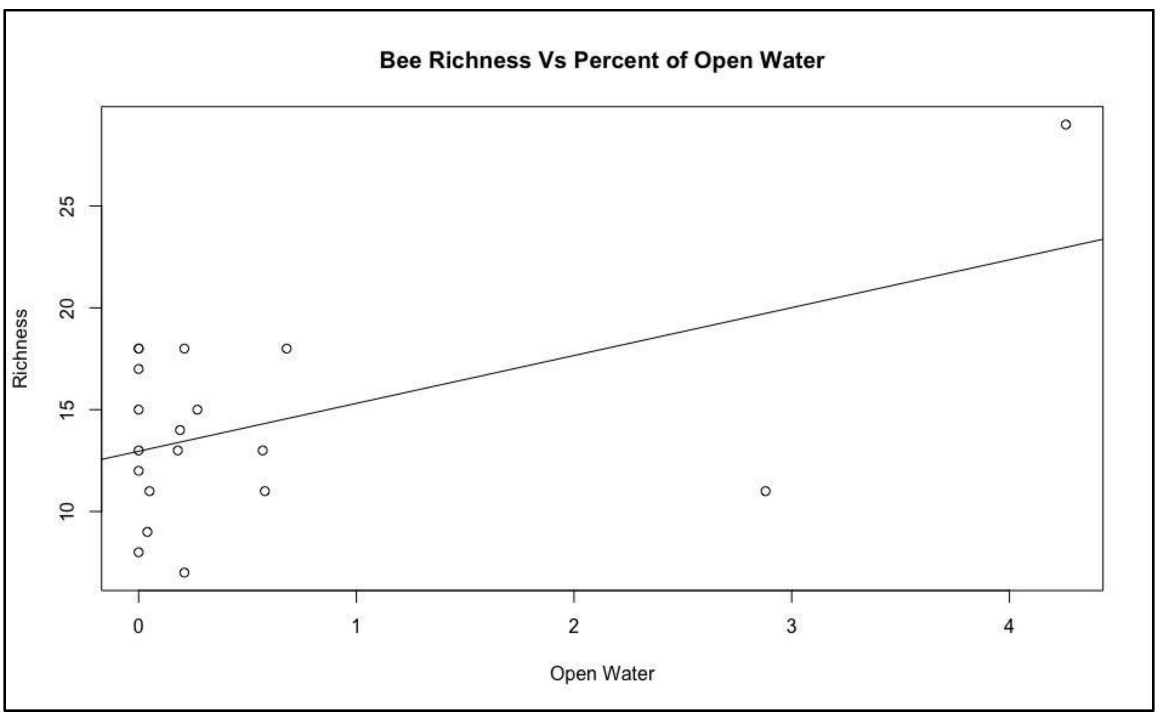

Fig. 7| Linear Regression showing the correlation between bee richness and percent open water for the 19 sites

Discussion

Through our analysis of the sites, we found that the surrounding landscape composition had no significant effect on the richness or density of the bee communities of the CP-42 sites. The negative correlation trend seen with the corn tells us that corn is not a suitable habitat for bee communities to establish. Areas with more landscape devoted to corn cover will likely see a decrease in the richness and abundance of the bee communities within restorations. While the percentage of open water in that area didn't affect the density of the bee community, the significant positive correlation between open water and bee richness indicates the importance that water resources play in the support and establishment of a rich bee community (p=0.020). However, due to the limited number of sites in this study with open water within the buffer, the positive significance may be driven by a few sites (Fig. 7) and requires further investigation with a larger sample size. The positive correlation is also seen in the stream length association with the bee richness, which shows us that the larger stream length did seem to have a marginally significant positive effect on the richness of the bee species within a site (*p*=0.065, Fig. 8).

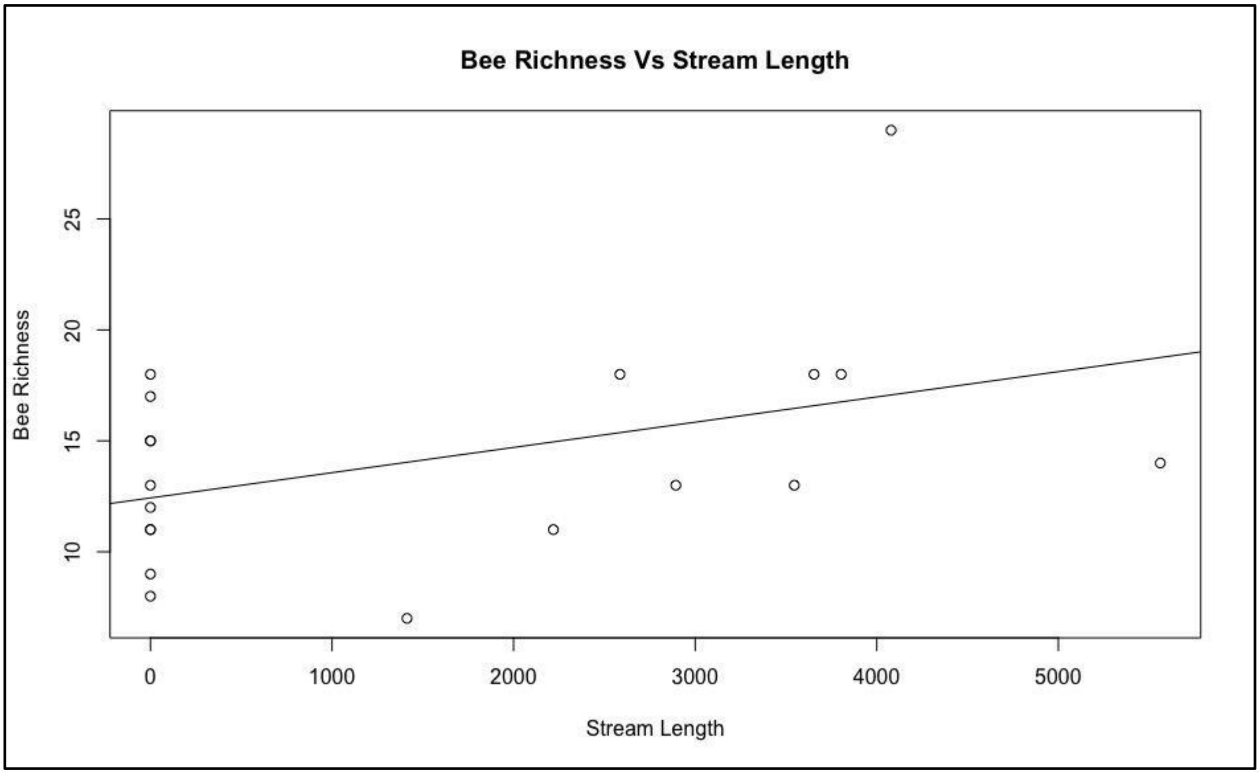

Fig. 8| Linear regression showing the correlation between bee richness and stream length for the 19 sites

Although we did not have a large number of study sites with open water or streams to make a definitive conclusion, our results concurred with previous studies that showed a strong positive association between wild bee communities and wetland covers in agricultural landscapes (Cohen *et al*. 2023). There was a strong overlap between bee species at sites with open water and sites without and a larger overlap between sites with streams and without streams (Fig. 9 & 10). The sites that contained open water were sites 1, 4, 5, 6, 7, 8, 9, 10, 12,14, 16, and 18. The sites that contained streams were sites 1, 2, 5, 7, 8, 9, 12, 13, and 16. Sites that contain open water/streams might have some wild bee species that are associated with water that the sites without streams/open water do not have, thus leading to the positive trend observed (Fig. 7 & 8).

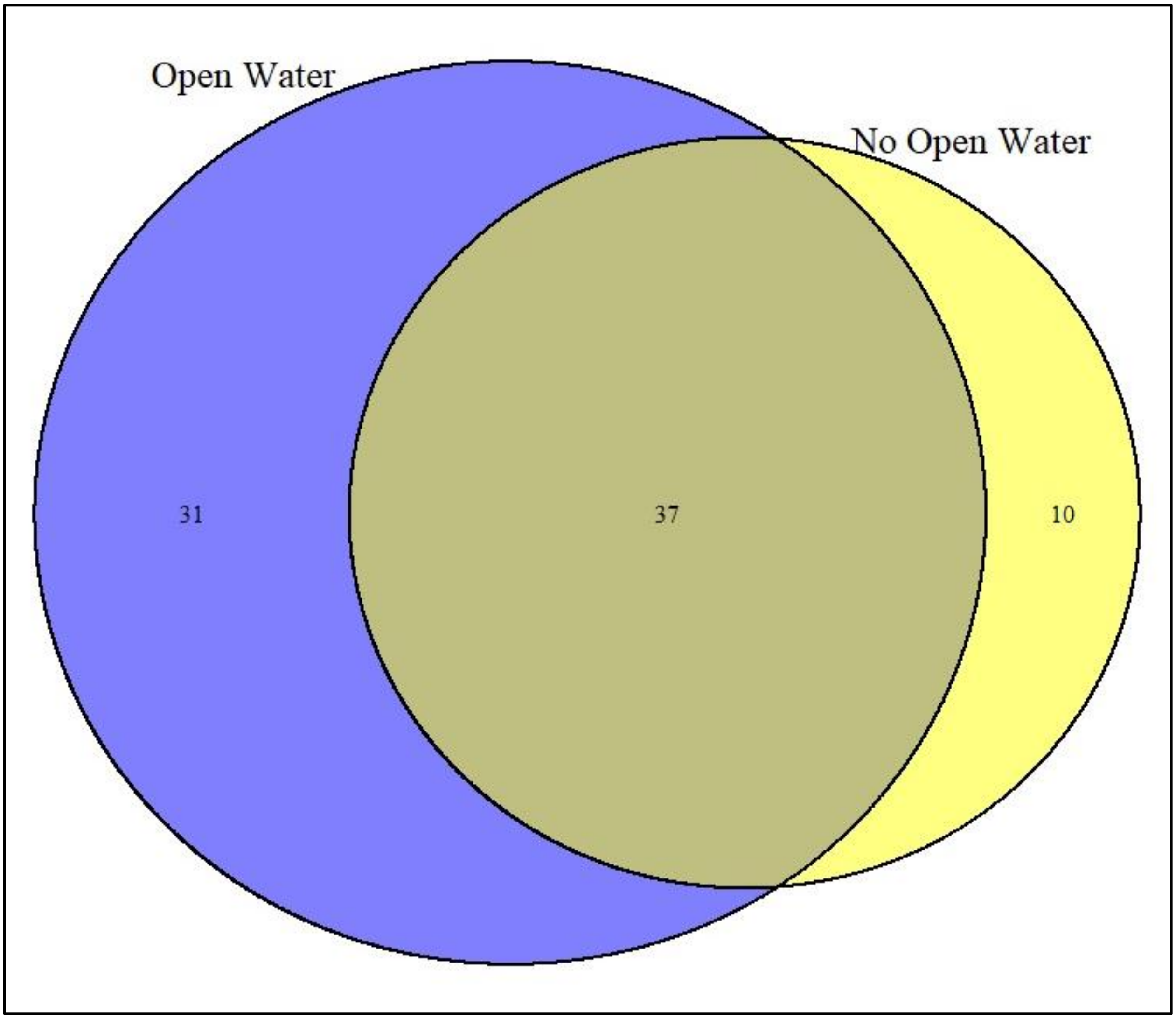

Fig. 9| Venn diagram showing the species overlap in sites with open water vs sites without open water

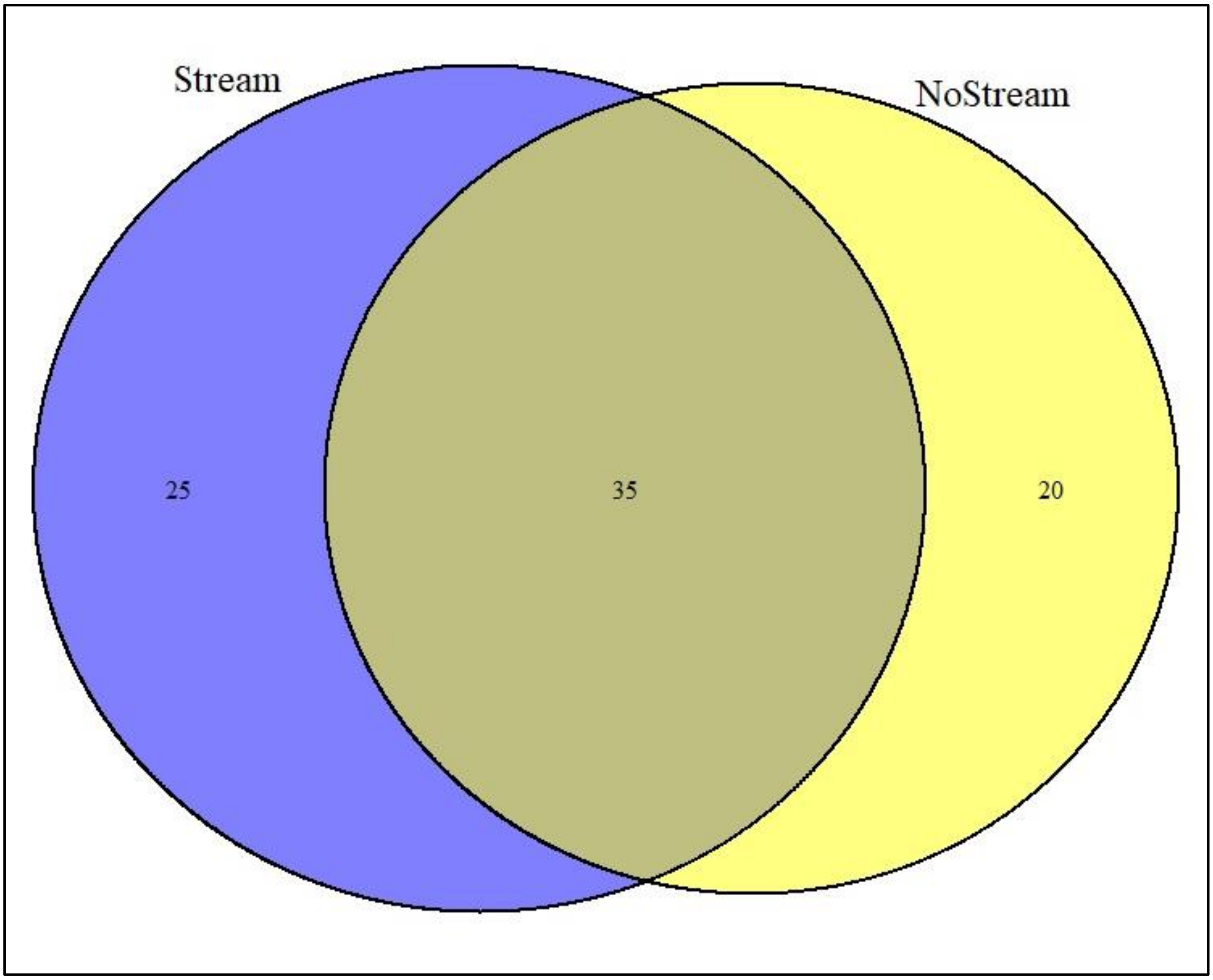

Fig. 10| Venn diagram showing species overlap at sites with streams vs sites without streams

The positive correlation trend between the richness and density of the bee community and the percentage of developed space is probably due to the way that the developed space is being used. Some of the developed space in the buffer around the CRP site was devoted to the homestead of the farmer who owns the land and there are often horticultural plants with floral resources that are planted around the homestead in the spring and summer months. Other developed surfaces are roads that can have roadside vegetation with forbs, either as a result of active roadside prairie planting or as naturalized vegetation from local propagule sources

(Quinlan et al. 2021). As a result, this positive correlation was likely due to the native bees in the area utilizing these planted flowers around the homestead, or in the roadside ditches.

Overall, our findings demonstrated that there is less correlation between the richness and density of native bee species and the surrounding landscape variables, compared to the strong correlation between the bee communities and the floral resources within the same restored CRP habitat (Wen at al. 2021). This emphasizes the importance of creating restorations that provide a variety of floral resources to support the bee communities that utilize them. Our findings suggest that the quality of the habitat itself (in this case the restoration) is more important than the quality of the surrounding area in supporting the native bee communities. Future research needs to be done to compare the effect of the surrounding landscape with the effect of the floral composition of the restoration sites and their effect on the native bee communities that utilize the site. Further examinations involving the expansion of the buffer to analyze a larger area around the sites would be beneficial to see if there is a more significant connection at a larger scale. Finally, though there was no consistent and complete record of roadside plantings throughout the counties of Northeast Iowa, adding in roadside planting data might be beneficial in mapping out the full habitat corridors between sites.

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Appendix

Land Cover Class	*p* - value Richness	*p* - value Density
Corn	0.161	0.362
Soybeans	0.526	0.238
Alfalfa	0.407	0.177
Grassland/pasture	0.705	0.764
Developed Space	0.317	0.558
Woody Wetlands	0.262	0.567
Herbaceous Wetlands	0.119	0.322
Forest	0.512	0.205
Open water	0.020	0.599
Stream Length	0.065	0.244

Table 1| *p* - values for all landscape cover classes generated by the linear regression analysis