Agroecological transformations: pollinators, people, and power

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As someone who studies landscapes and land management, land and its history are integral parts of what I think and learn about every day. A critical part of the history of the land on which I've lived and studied over the past five years is that this land is the homeland of the Ho-Chunk Nation, a land they have called Teejop since time immemorial. In 1832 the Ho-Chunk were forced to cede this territory, which, along with additional parcels of Indigenous land seized under the Morill Act, helped build the wealth of University from which I now benefit. While this statement acknowledges a part of history, it is also a matter of the present. These wrongs are perpetuated today through science and institutions which continue to privilege Western scientific practices and appropriate Indigenous science and ecological knowledge. Throughout graduate school I have challenged myself to think about how these legacies of colonialism impact the work I do and the issues I care about. Moving forward, I am committed to continuing to support Indigenous sovereignty, to reflect on my role in perpetuating colonialism, and to seek additional ways to address it. I challenge my readers to do the same.

Table of Contents:

Abstract

There is growing recognition that the dominant agricultural system is not working for people or for the environment and that there is an urgent need for transformation. This dissertation explores one aspect of what that transformation could look like and how to make it happen. The first two chapters focus on the effects of diversified agroecological landscapes as an alternative to large-scale monocultures. Chapter 1 focuses on the impact of increasing flower availability in crop field edges, a common strategy for supporting wild bee conservation and crop pollination. In one of the two years of the study, we found positive effects of increasing flower availability in crop field edges independent of the amount of natural area in surrounding landscapes. We also found that leaving existing flowers (i.e., not removing them via herbicide or mowing) may matter more than planting flowers for increasing local wild bee abundance, richness, and crop pollination. Adding additional flowers was found to improve the nesting success of stem-nesting bees. Chapter 2 details an R package we built to quantify the impact of landscape-scale variables on local responses. This package was developed to evaluate the impact of non-crop habitat on wild bees in Chapter 1, but it can also be used to understand the impact of other landscape-scale variables on a range of responses. The third chapter addresses bigger-picture questions of how to alter socio-political structures in ways that enable transformational change toward diversified agricultural systems (such as those explored in Chapter 1) and empower farmers, communities, and the environment. To explore these questions, we conducted 127 interviews and 3 participatory workshops with farmers and other members of the agricultural community in the Midwestern United States and evaluated what is needed to make such change in the Midwest region. Based on the interviews and workshops, we found that if the goal is to achieve transformational change, more effort within the Midwest sustainable agriculture movement should shift toward providing social supports for farmers and farmworkers, addressing land and capital consolidation, and altering social norms around the type of agriculture that is valued. Through researching questions aimed at helping farmers establish agroecological management practices and understanding the changes to socio-political structures needed to support them, this dissertation illuminates some of the elements necessary to make transformational change.

Introduction

There is growing recognition that the dominant agricultural system is not working for many people, and that there is an urgent need for transformation (HLPE 2019; IPES 2021). Today, agriculture is one of the leading causes of degradation to soil, water, and biodiversity as well as a leading contributor to climate change (Altieri, 2009; Rasmussen et al., 2018). Likewise, the dominant food system is rife with systemic problems from struggling rural communities, to rampant hunger and obesity, to labor exploitation and systemic racism (Horst & Marion, 2019; Lappe 1998). However, this version of the food system is a relatively recent invention, and there are examples of food systems around the world that do a far better job of supporting sustainable livelihoods for farmers as well as healthy communities and environments (Altieri & Toledo, 2011; Marrero & Mattei, 2022; Xolocotzi, 1985). Agroecology, the broad focus of my research, looks to these alternatives and provides a means of reimagining the way our food system is structured so that it supports these aims.

Agroecology is an approach to agriculture that mimics nature, honors traditional farming practices and local knowledge, and prioritizes the agency of farmers and rural communities (Anderson et al. 2020). As a farming practice, agroecology has been around for millennia. However, over the course of the 20th century, agroecology has also been articulated as a scientific field (based on the application of ecological principles to agriculture) and as a social movement. Agroecology's conceptions as a science and a movement have sometimes been separated. More recently, however, there has been an effort to merge these visions in academic literature, defining agroecology as a science, a practice, and a movement (Wezel et al., 2009). Moreover, Rivera Ferre (2018) emphasize that these aspects are never truly separate. While people sometimes discuss only the scientific aspects of agroecology, the science and practice of agriculture is always informed by the socio-political context in which it exists, and therefore these aspects can never be truly separate from agroecology's broader conception as a movement (Rivera-Ferre, 2018).

I became interested in pollinator conservation, the focus of the first chapter of this dissertation, as a means of illuminating the consequences of the dominant agricultural system and exploring some of the solutions. All of the leading causes of pollinator declines, pesticides, disease, loss of habitat, and climate change, can be linked to some degree to today's dominant agricultural system, specifically the way this system incentivizes the global expansion of large-scale, intensive monoculture agriculture (Angelo, 2010.; Bruckner, 2016; Socolar et al., 2021; Wang & Ortiz-Bobea, 2019). Many socio-political structures incentivize monocultural expansion. For example, in the U.S. context, crop insurance payments, which offset profit and yield losses in corn and soy production, have encouraged farmers to put more and more acreage into these two crops (USDA ERS 2021). Beyond pollinators, monocultures are tied to many other problems including creating a greater need for purchased inputs like pesticides (Meehan et al., 2011; Wu, 1999), making it so many farmers need to expand and increase production to afford their operating costs (Levins and Cochrane 1996). This in turn fuels farm consolidation, leading to rural depopulation and community declines. Likewise, the increased use of agrochemicals makes work environments increasingly dangerous for farmworkers, a highly exploited population within the agricultural system (Reeves & Schafer, 2003). Thus, the root causes of issues for pollinators are connected to many of the issues for people within our agricultural system, and pollinators can therefore act a lens through which to view alternatives.

If our systems of food systems governance were transformed to support holistically managed, diversified agroecological landscapes rather than large-scale intensive monocultures, it could solve many of the problems the current system causes for both pollinators and for people (Hill et al., 2019; Kremen et al., 2012). Such diversified farming systems can be defined as socio-ecological systems that:

> "…intentionally [include] functional biodiversity at multiple spatial and/or temporal scales, through practices developed via traditional and/or agroecological scientific knowledge [and that] enable ecological diversification through the social institutions, practices, and governance processes that collectively manage food production and biodiversity" (Kremen et al. 2012).

Farming practices that could be a part of these systems include those that support diversification at a field-scale, such as polycultures, crop rotations, crop genetic diversity, and integrated crop-livestock systems, as well as off-field and landscape-scale diversification practices such as establishing flower plantings or hedgerows established along crop field edges and integrating corridors of non-crop habitat into agricultural landscapes (Kremen et al. 2012). The first two chapters of my dissertation fit within this broader context of research on diversified agroecological landscapes. The first chapter focuses on the efficacy of field edge flower plantings, an increasingly common strategy both for diversifying agricultural systems and supporting pollinators. My second chapter builds on the first through elaborating on an analytical tool I developed to accomplish the research in the first chapter, but that can also be used more broadly to assess the impact of features of agricultural (or other) landscapes on localized environmental responses. I apply this tool in the context of my research to evaluate the impact of non-crop habitat (i.e. diversified landscapes) on pollinators, however it could also be used to determine the effect of other landscape-scale features such as how the amount of monocultural crops in the landscape impact water quality in specific locations.

While this research fits within the framework of diversified agroecological systems, it focuses on specific management practices rather than on the broader socio-political structures (such as crop insurance policy) that maintain our current agricultural system. Such research is important for supporting framers on the ground (e.g., helping them establish effective management practices) and helping them implement specific agroecological practices can lay the groundwork for broader changes through establishing social norms around the types of agriculture that are viable and accepted within different communities (Gliessman, 2019; Mier y Terán Giménez Cacho et al., 2018). However, without *also* altering the socio-political structures that dictate the way agricultural landscapes are structured, the research in Chapters 1 and 2 will likely do little to enable transformative change from a system dominated by large-scale monocultures to diversified agroecological landscapes. Therefore, in my last chapter (Chapter 3), I address this broader context, exploring the transformative potential of a variety of change strategies that could promote transformation at the level of the agricultural system.

Taken together, this dissertation explores several different facets of agricultural systems transformation. The first two chapters assess technical strategies for supporting farmers and understanding the ecological impacts of different agricultural management practices. In this way, they focus primarily on the science and practice of agroecology. However, I agree strongly with Rivera Ferre (2018) that the science and practice of agroecology can never be separated from the socio-political contexts in which they exist. As I emphasize at the end of my first chapter, the research questions that are asked are influenced by research funding and policy incentives which disproportionately support diversification practices that can be integrated along the margins of crop fields rather than making fundamental changes to agricultural management itself (O'Brien, 1993). Just as broader socio-political structures maintain the current agricultural system, they also influence the research that is conducted in ways that may limit its transformative potential (O'Brien, 1993). In my third chapter I focus more directly on these broader socio-political structures, assessing how agroecology as a movement can support transformative change. If the movement is successful, it should also provide more direct support for agroecological research and management practices, facilitating a more wide-spread transformation toward diversified agroecological systems.

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Chapter 1

Field edge flower plantings have variable effects on wild bee nesting and crop pollination independent of the surrounding landscape

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[1]EL conceived of the project, developed the methods, collected the data, and wrote the manuscript

[2]CG assisted with the conceptualization of project, development of experimental design and sampling, consulted on analyses, reviewed multiple drafts of the manuscript, and provided funding

[3]RG assisted with conceptualization of the project, development of experimental design and sampling, connected EL with the farmers who provided space on their farms for the data collection, provided funding

Abstract

To mitigate the effects of habitat loss on bee conservation and crop pollination, farmers are often encouraged to plant flowers along the edges of crop fields. However, it is unclear where and to what degree field edge flower plantings can achieve these aims. Some have suggested that flower plantings may be less effective if they are established in landscapes with either very low or very high amounts of non-crop habitat. Moreover, while field edge flower plantings often increase the abundance and richness of bees in field edges, it is unclear whether this improves bee nesting success (thereby increasing bee populations over time) or crop pollination. In this study we examined how field edge flower plantings and the landscape context in which they are established impact wild bee conservation and crop pollination. Across two years we planted flower plantings (0.1-0.5ha) along the edges of 17 out of 34 commercial cucumber crop fields arranged across a landscape complexity gradient. We then measured wild bee abundance, richness, and crop pollination in field edges and crop fields as well as the nesting success of stem-nesting bees. We found that the amount of non-crop plantings in the landscape did not to influence the effect that flower plantings have on bee abundance, richness, nesting, or crop pollination. Rather, flower plantings and landscape-scale habitat had independent, positive effects on all these response metrics, at least in one of the two years. We also found that managing field edges in a way that maintains naturally occurring flowers may matter as much or more than establishing flower plantings for short-term increases in bee abundance and richness. However, flower plantings may improve bee nesting success, the outcome that is more important for both bee conservation and sustained crop pollination.

Introduction

Habitat loss, particularly loss of floral resources, is one of the leading causes of bee declines in agricultural landscapes (Brown & Paxton, 2009; Goulson et al., 2015). This loss of habitat is driven largely by policies and economic incentives that promote the expansion of large-scale monoculture agriculture (Lark et al., 2015; Otto et al., 2016). On a landscape scale, these incentives have resulted in larger farms and crop fields, leading to a loss of habitat that once existed on and around farm and field margins. Within crop fields, monocultures create vast landscapes of single crops that are either not insect pollinated or that bloom for short time periods, limiting flower availability and creating inconsistency in food availability.

Research has shown that increasing the amount of non-crop habitat both in farm landscapes and on the edges of crop fields can increase bee abundance and richness (Albrecht et al., 2020; Dainese et al., 2019; Lowe et al., 2021; Ricketts et al., 2008) Because of this, farmers are often encouraged to establish flower plantings on crop field edges (Sidhu & Joshi, 2016). However, a number of questions remain as to where and to what degree these types of flower plantings are effective (Lowe et al., 2021).

Where field edge flower plantings are most effective may depend on the amount of existing non-crop or “natural” habitat in the surrounding landscape. One of the most cited theories that explains how landscape context might modulate the effect of habitat restorations is the Intermediate Landscape Complexity Hypothesis (ICH) (Tscharntke et al., 2005). This hypothesis predicts that restorations will be most effective in landscapes with an “intermediate” amount of existing non-crop habitat as areas with little habitat have low source populations of bees, and landscapes with large amounts of habitat may already contain sufficient floral resources. Evidence for the ICH is mixed. Syntheses examining the effects of non-crop habitat on field edge restorations have found evidence for the ICH (Batáry et al., 2011; Lowe et al., 2021; Scheper et al., 2013), while others have found no relationship between restoration effectiveness and landscape context (Albrecht et al., 2020). Some experiments have assessed the ICH for habitat restorations more broadly, however, experiments that test the ICH for field edge flower plantings remain limited (Grab et al., 2018; Scheper et al., 2013).

The purpose of field edge flower plantings is to support bee conservation and to improve pollination in adjacent crop fields (Vaughan et al. 2015, Sidhu and Joshi 2016, USDA Conservation Stewardship Program practices 327 and 386). To support bee conservation, flower plantings must increase the bee populations over time. Studies that investigate the effects of flower plantings often use bee abundance as a proxy for population growth, and have found that plantings are effective in terms of increasing bee abundance and richness in crop field edges. However, increases in abundance may simply reflect an increase in local abundance caused by bees visiting the restoration from the surrounding landscape (Kremen et al., 2007). A few recent studies have addressed this issue by measuring more direct metrics of population growth. These include colonization and persistence (M'Gonigle et al., 2015), body size (as a proxy for immune function and fitness) (Grab et al., 2019), and nesting or reproductive success (Bommarco et al., 2021; Ganser et al., 2021; Geppert et al., 2020; Holland et al., 2015; Klatt et al., 2020; Wood et al., 2015). All of these have found positive effects of restorations, although more research is needed to confirm these results.

Empirical evidence for the influence of plantings on crop pollination is also limited (Albrecht et al., 2020; Lowe et al., 2021). While many studies evaluate pollinator abundance or richness within restorations themselves, a relatively small proportion measure crop pollination directly via assessing crop flower visitation, crop yields, or fruit quality (Lowe et al., 2021). Thus, studies evaluating crop pollination more directly are needed.

We designed this study to examine how field edge flower plantings and the landscape context in which they are established, impact wild bee conservation and crop pollination. To do this, we established flower plantings along the edges of half of a set of cucumber crop fields arranged across a landscape complexity gradient. We measured the impact of flower plantings on wild bee conservation outcomes by assessing both the nesting success of stem-nesting bees and bee abundance and morpho-group richness in field edges. To evaluate the impact of flower plantings on crop pollination we assessed the abundance and morpho-group richness of wild bees visiting cucumber flowers and cucumber yields. In accordance with past research, we hypothesized that both flower plantings and the amount of landscape-scale habitat would positively impact all of our response metrics including nesting success and crop yields. Based on the predictions of the ICH, we expected that flower plantings would influence these responses most in areas surrounded by an intermediate amount of existing non-crop habitat

Methods

Site locations and crop choice

This project took place in the summers of 2018 and 2019 in Central Wisconsin, USA, a sandy region dominated by intensive rotational vegetable production. Crops in this region are mostly grown conventionally in large monocultures. At scale of this region, however, vegetable production is diversified, with crops including corn (sweet and feed), soybeans, peas, beans, cucumbers, carrots, and potatoes. We chose pickling cucumber, *Cucumis sativus* (L.), as the focal crop for this project because it is highly pollinator-dependent and prevalent in Wisconsin. In 2018 we studied 18 cucumber fields (19-151 acres) and adjacent field corners with flower habitat plantings from late June – early September. In 2019 we studied 16 sites (20-223 acres) from mid-July—late August (Table A1). Study periods corresponded with the period of cucumber bloom in this region across the two years. All fields were managed by one of two farmers who used similar conventional agronomic practices.

Landscape characterization

The study region spans a landscape gradient from an agriculturally-dominated region in the West to agricultural fields interspersed with a mosaic of woods, old fields, and grasslands in the East. To characterize wild bee habitat in the landscape surrounding our field sites, we used a combination of QGis (QGIS Development Team, version 3.60; QGIS Geographic Information System, Open Source Geospatial Foundation, http://qgis.osgeo.org) and R Studio with the Wiscland 2 datalayer (WDNR). We classified the "grassland," "forest," "wetland," and "barren" habitat types as non-crop habitat (i.e., bee habitat, Koh et al., 2016). Because experimental field corners were occasionally mis-classified as part of the crop field we hand-digitized all corners as grassland. Field sites were selected to span this habitat gradient and varied from 13% - 70% non-crop habitat within 1,500 m of individual study sites (Figure 1; Appendix A). Because cucumber was rotated each year, we used different field sites in the two years of the study (so that our experimental field corners were always adjacent to a cucumber field). The landscape gradient was consistent across both years even with a different set of field sites.

Field corner flower plantings

All cucumber fields were irrigated with central-pivot irrigation, creating fallow field corners of 1-2 acres (Figure A1). We established flower plantings in the field corners of half of the sites each year. To ensure that sites with and without flower plantings were distributed across the full landscape gradient, we binned sites into 3 groups based on the amount of surrounding non-crop habitat within 1500m, and randomly selected half the fields in each group to receive a restoration. Restorations varied in area based on the size of the field corner and ranged from ~0.12 to 0.5 ha in 2018 and ~0.12 to 0.4 ha in 2019. Restorations were set back from the field edge by 15m to buffer from fungicide spray drift. We selected a mix of annual and perennial flower species that were documented to bloom robustly in their first year after planting, and that together would bloom from spring through fall (Table B1). Because farmers did not know the location of their crop fields until spring, planting occurred in mid-May of 2018 and in late April of 2019 based on snow melt.

Bee visitation Surveys

At each site, we surveyed cucumber fields and adjacent field corners for both bees and flowers 3-4 times within the ~2 weeks that cucumbers were in bloom. Because cucumber fields were planted at different times over the course of the season, this meant that each individual site was visited at a different time throughout the summer. All observations took place between 7 am and 4 pm. During survey periods wind speeds averaged < 1.8 m/s, temperature was no less than 21°C and all days were sunny enough to see a shadow.

We assessed the abundance and richness of bees in both cucumber fields and field corners. In field corners we observed bees for 5 mins at each of 6, 1x1m sampling stations located every 5m along two randomly placed 25m transects (60 mins total observation per visit). If the sampling station on the transect did not contain flowers, observers walked perpendicular to the transect until they encountered a 1x1 m patch with at least one flower. Transect location was re-randomized each visit. In planted corners, one transect was located within the restoration and one outside it (flower plantings did not fill the entire field corner). For the collection of richness data, we conducted an additional 15-minute meandering survey where observers wandered the whole corner, prioritizing observations at dense patches of attractive flowers. The purpose of this survey was to more accurately characterize corners where the randomly placed transects may not have crossed the most attractive flower patches. Each time a bee was observed visiting a flower, the flower species was recorded.

In cucumber fields, we surveyed bees along two transects, one originating from and running perpendicular to the edge of the non-crop corner, and one at the field center. Along both transects we surveyed as close to 10 flowers as possible in 2018 (mean = 8.4, SD=2.3) and exactly 10 (gently moving vegetation if necessary) at each sampling station in 2019. The field edge transect had 7 sampling stations (at 1m, 2m, 4m, 8m, 16m, 32m, and 64m from the corner) each of which was surveyed for two

5-minute periods (70 mins total per visit). The field center transect had 6 sampling stations located 5m apart, each of which was surveyed for a single 5-minute period (30 mins total per visit).

For bee richness data use used a “morphospecies” approach where we identified the most distinctive bee groups to genus or species and the less distinctive ones to morpho-groups. *Megachile, Mellisodes, Hylaeus, Osmia, Nomada,* and *Sphecodes,* were identified to genus, and *Bombus* were identified to species with a few exceptions in which two difficult to distinguish species were combined into a single category. These included *B. pensylvanicus/B. auricomus*, *B. fervidus*/*B. borealis* which were combined respectively, and *B. ternarius/B. rufocinctus* which were combined in 2018 only. One distinctive orange species of *Lasioglossum, Lasioglossum (Dialictus) vierecki* was also identified to species, although this identification was based on a single voucher specimen. Bees not included in the groups above were assessed to morpho-group. These morpho-groups included: ‘dark,’ ‘dark with abdominal stripes,’ ‘green,’ and ‘green with abdominal stripes’ which were further subdivided into size categories: ‘small’ (<7-9 mm), ‘medium’ (10-13mm), ‘large’ (≥14mm). A ‘tiny’ (≤7 mm) category was added in 2019, redefining the ‘small’ category as 8-9mm. Finally, a small number of distinctive dark green metallic bees were seen in field corners in 2018 only. Since this bee was clearly different from other categories, it was added as its own ‘dark green metallic bee’ morpho-group. This led to a total of 29 groups in 2018 and 31 groups in 2019 from which bee “richness” was calculated. All data collectors went through rigorous training and testing procedures to ensure accuracy of morpho group IDs and inter-observer reliability (Appendix C).

Floral surveys and index

To describe floral resources in the field corners we conducted floral surveys along the same 25m transects used for bee surveys during each visit to a site. We used a modified belt transect method to estimate floral species richness and cover. Flower species were recorded if they fell within a 1x1m quadrat laid on alternating sides of the transect each meter (25 quadrats per transect). We used continuous measures of flowers, rather than the categorical “flower planting” vs. “control” because all field corners, including un-enhanced controls, had flowers present, and not all flower enhancements were equally successful in this first year of the study. A continuous measure of flower availability and quality thus captured more of the variation among field corners between sites. Because floral surveys were conducted during site visits, floral resources reflect what was blooming at the time bee data was collected, but do not account for an early-season decrease in floral abundance at planted sites due to herbicide treatment before seeding.

Since bees are influenced not only by flower abundance or richness in the field corners but also by the quality (i.e., desirability or attractiveness) of the flowers present we developed a “floral index” that captures both the quantity and quality of field corner flowers (Appendix B). The index was calculated as the sum of floral cover (C) and a preference score (P_i) for each flower species based on observed bee foraging data (FQI = P_i + C). Floral cover was measured as the proportion of quadrats across all visits to each field site that contained flowers. The floral preference score was calculated based on the Chesson Foraging Index (Chesson, 1983; Sam et al., 2017) and was calculated separately for each flower species using data from all field sites as:

$$P_i = \frac{r_i/n_i}{\sum_{j=1}^{m} r_j/n_j}, \; i=1, \ldots, m$$

where r_i is the number of bee visits to flower species *i*, n_i is the number of times species *i* appeared in flower sampling stations, and $\sum_{j=1}^{m} r_j/n_j$ is the sum of the numerator calculations for all species. The data used to calculate bee preferences included the total number of bee visits across both transect and meander observations at all field sites, meaning that bee data and floral data were semi-independent measures. Preference scores were summed for all the flower species at each field site, thereby accounting for differences in floral richness as well.

Solitary bee nesting success

To measure solitary bee nesting success, we established 8 nest tubes at each field site in early June. Nest tubes faced Southeast to maximize sun exposure (Stubbs et al., 1994). Each box was composed of 120 cardboard straws with an equal number of straws of four widths, 3.5, 5.5, 7.5, 10mm (all 150mm in length). Straws were bundled within sections of PVC pipes ("nest tubes") and set at least 1.4m above the ground on metal t-posts (Appendix A). Nest boxes were set up at all sites in both years, but in 2019 7 of the 16 nest tubes were accidentally removed by the grower. The sites at which nest tubes remained were representative of the full data set in terms of the distribution of the landscape gradient, the floral index scores, and the size of the corners. Nest tubes were left in the field until the end of February and mid-March (after overwintering in the field) and were stored between 1-4°C in the laboratory until early June. At this time, all straws were examined and classified as empty or occupied. They were then left at room temperature for bees to emerge. Individuals that emerged were sorted into species-level groups. A subset of each group was later identified to the species-level, except for one type of wasp in each year that was identified only to family (Appendix C).

"Nesting success" was calculated as the total number of bees that emerged from all the nest boxes at a site divided by the total number of occupied nest straws at each site, a metric that combines adult performance and larval/pupal survivorship. Bee emergence values may be an underestimate of bee nesting success as both bees and wasps (mostly the solitary vespid *Ancistrocerus antilope*) nested in our nest boxes. In 2018 93% of what emerged from the nest straws was bees while in 2019 only 33% of what emerged was bees. While it is possible that unsuccessful *Ancistrocerus* nests at some sites may have skewed our data (increasing the denominator), it seems unlikely as wasps appear to have been concentrated primarily at just a few sites.

Yield assessment

To measure the yield of the cucumber crop, we estimated the number of cucumbers per m2 within each crop field, excluding fruits that were too small (<2cm diameter) or crooked as these were unmarketable. We counted the number of cucumbers in 1x1m plots at the end of the field-edge bee survey transect (6 plots in 2018, 4 plots in 2019) and in the field center (18 plots in 2018, 4 plots in 2019). All plots were averaged in analyses to get the average number of cucumbers per square meter in each field. We used count data rather than weight as this is a better metric of pollination.

Statistical Analyses:

<u>Response variables:</u>

To test the effects of landscape-scale habitat and field corner flowers we focused on six different bee response metrics. In field corners we measured bee abundance, richness, and nesting success, and in crop fields we examined the abundance and richness of bees visiting cucumber flowers and crop yield. Bee abundance data was summed across sampling dates at each site. To account for unequal sampling effort across sites, bee abundance in field corners was calculated as the number of bees per sampling location (each of which was observed for 5 mins). Bee abundance in crop fields was calculated as (number of bees/sampling location)/number of cucumber flowers examined. To account for differences in sampling effort bee data was rarified using the 'iNEXT' package in R (Hsieh et al. 2020).

Models & predictor variables:

To run any analysis on the effect of landscape, it is necessary to determine the appropriate spatial scale at which to evaluate the effect of the landscape variable. While there are well-established methods for this, these methods are subject to theoretical and statistical problems (Aue et al., 2012; Chandler & Hepinstall-Cymerman, 2016; Miguet et al., 2017; Stuber & Gruber, 2020). The most common methods all rely on *a-priori* assumptions about the relevant scale, which are often incorrect or too limited to accurately predict the true scale of effect (Jackson & Fahrig, 2015; Lowe et al. 2022). They are also subject to statistical issues that can increase type I error rates (Miguet et al., 2016; Lowe et al. 2022). To address these problems, we ran multiple linear regressions using 'scalescape' in R (Lowe et al. 2022). 'Scalescape' uses a distance-weighted model optimization approach to find the best spatial scale for the landscape predictor variables. This approach avoids *a priori* assumptions and produces more accurate p-values via bootstrapping. 'Scalescape' produces an aggregate p-value for all landscape variables in a model and likelihood ratio tests are used to get p-values for individual landscape terms (Appendix D).

We constructed a separate polynomial model for each year that contained landscape-scale non-crop habitat and non-crop habitat^2 (to account for the hump-shaped relationship of bee responses as predicted by the ICH), field corner flower index, and the interaction between landscape-scale non-crop habitat and field corner flowers. Temperature (averaged across sampling dates at each field site) was also included as a factor in models for bee responses as the short duration of sampling periods meant that temperatures sometimes ranged widely across site locations. The temperature term was never significant at $\alpha=0.05$ and is only shown in supplemental data in Appendix D. We did not include temperature in the yield or nesting models as these response metrics represented season-long measures that were likely the same on average across the study region.

We also ran a linear model with a subset of variables from the full model. This included landscape-scale non-crop habitat and the field corner flower index, as well as temperature in models for bee responses. We ran this smaller model both because the full model was large for the sample size of this study and because we wished to produce a p-value for non-crop habitat alone which was not possible with likelihood ratio tests of the full model (Appendix A).

Results

Establishment and attractiveness of floral restorations

In both years, the flower species planted in restorations had high preference scores meaning that, controlling for abundance, they were preferred by bees over most other flowers. Of the planted species that established, but all but 2 were within the top 20 flower species ranked by preference score (Table B2). Because of this, better restoration establishment in 2019 also likely led to the higher average floral index scores in 2019 as compared to 2018 (Figure 2).

In 2018, more than half of the planted sites (5/9) fell within the bottom half of sites ranked by floral index (Figure 2). This is likely because planted sites were herbicided prior to planting (while control sites were not), removing any naturally occurring flowers. At sites where planted flowers did not establish, this produced corners with lower quality floral resources than those that had not been planted. The sites that established well in 2018 had floral index scores equivalent to the high-end scores in 2019. However, floral index scores spanned a greater range in 2018 than in 2019 with eight sites in 2018 having lower floral index scores than any sites in 2019 (Figure 2).

In contrast, in 2019 planted corners almost always had higher flower index than control sites; all but two of the top sites were planted (Figure 2). Better establishment in 2019 is likely due to both changes made to the flower species in restorations and to better weather conditions. In 2018 a late spring delayed flower planting but a warm period shortly thereafter led to early cucumber bloom. This time for restorations to establish before sampling in 2018 as compared to 2019.

Bee Community

In total, 2,033 bees were observed on transect surveys over two years. Across all sites, there were more bees observed both in field corners and in-field in 2018 (corner: mean 0.43 ± 0.35 bees per sampling location, in-field: mean 0.02 ± 0.03 bees per sampling location) than 2019 (corner: mean 0.28 ± 0.10 bees per sampling location, in-field: mean 0.008 ± 0.006 bees per sampling location). Across the two years of the study, we observed all of the morphospecies we had defined except for *Nomada* (Table C1). The bee community in field corners skewed more strongly toward non-*Bombus* in 2018 than 2019 (82% non-*Bombus* in 2018, 59% non-*Bombus* in 2019) (Figure 3; Table C1). The proportion of *Bombus* to non-*Bombus* bees in crop fields was relatively consistent across years (61% non-*Bombus* in 2018, 69% non-*Bombus* in 2019) (Figure 3; Table C1).

Spatial scale of the landscape effect

To understand the impact of landscape-scale habitat, we first had to determine the spatial scale at which habitat in the landscape impacted our response variables. Estimates of the spatial scale of the landscape effect are less accurate when the significance of the landscape effect is low. Therefore, we focus only on scale estimates for models that have landscape variables with $p<0.30$ in the text (for all values, see Table D1). Because all landscape variables except for nesting were far from significant in 2019, the following spatial scale estimates reported are from 2018 unless otherwise specified. Estimates from 'scalescape' (Lowe et al. 2022) indicate that two-thirds of the effect of habitat in the landscape on bee abundance in field corners occurred within ~1900m of field sites (Figure 4; Table D1). In contrast, two-thirds of the effect of landscape-scale habitat on bee richness occurred within only 80m of the sampling sites (Figure 4; Table D1). These values were very similar to the spatial scale values from the polynomial model (Figure 4; Table D1). The spatial scale of the landscape effect for bees in crop fields was larger; two-thirds of the effect of landscape scale habitat on in-field bee abundance and richness occurred within ~3600m of sampling locations (Figure 4; Table D1). For crop yield this effect varied widely between the linear (~8,000m) and polynomial models (~40m) (Figure 4; Table D1), indicating that the model could not determine if the landscape was having a very local effect or a regional effect. Two-thirds of the landscape effect on nesting in 2019 was very small (35m), falling within the field corners of many sites (Figure 4; Table D1).

Interaction between landscape scale habitat and field edge flower plantings

Likelihood ratio tests of the landscape variables in the polynomial model indicate that the landscape effect was driven almost entirely by the main effect of landscape-scale habitat (rather than the squared or interaction terms). While the aggregate landscape term was significant for some of our response metrics, p-values for the squared and interaction term were far from significant, indicating that the significance of the aggregate term was likely driven by the main effect of non-crop habitat (Table 1; Table D1). Likelihood ratio tests from the linear model bore this out -- p-values for the main effect of landscape were significant for most response metrics (Table 1; Table D1). There was no support for an interaction between landscape-scale habitat and the floral index in either year, nor was there any evidence of a curvilinear (squared landscape term) response as a function of landscape habitat availability (Table 1; Table D1).

Effects of landscape-scale habitat and field corner flowers on bees in field corners

The following results are from the linear model, unless otherwise stated (generally results from the two models were in agreement, with the linear model showing slightly more significant effects). In

2018, landscape-scale habitat was significantly, positively associated with all our response metrics except nesting: bee abundance and richness in field corners (p=0.027, p=0.016), bee abundance and richness in crop fields (p=0.019, p=0.002), and crop yields (p=0.016) (Table 1; Table D1). However, landscape-scale habitat had no significant effect on any of these responses in 2019 (Table 1; Table D1). In 2018 the field corner flower index had a significant, positive effect on pollinator richness in field corners (p=0.015), and on bee abundance and richness in crop fields (p=0.024, p=0.020) (Table 1; Table D1). There was also a significant positive effect of field corner flowers on crop yields in the polynomial model only (p=0.037) (Table 1; Table D1). In 2019 the flower index had a marginally significant ($\alpha < 0.01$) positive effect on pollinator richness in field corners (p=0.070) (Table 1; Table D1).

Effect of landscape scale habitat and field corner flowers on nesting

There was no significant effect of landscape scale habitat or field corner flowers on nesting in 2018 (Table 1; Table D1). However, in 2019 landscape scale habitat had marginally significant effect on nesting in the polynomial model (p=0.10), and field corner flowers had a significant effect on nesting in the polynomial model (p=0.031) (Table 1; Table D1).

Nesting success

Nest tubes were used as an indicator of local stem-nesting bee success across sites. The percentage of occupied nest box straws was relatively consistent across years ranging from 0 - 12% in 2018 (average 6%), and from 1-12% across sites in 2019 (average 7%). Across all sites, emergence rates from occupied straws were slightly higher in 2018 (14%) than in 2019 (10%). Three species of bees emerged: *Megachile pugnata*, *Megachile relativa*, and *Heriades carinata*. *M. pugnata* made up more than half of the bee community in both years (Appendix C). A non-parasitic vespid wasp, *Ancistrocerus* *antilope* also emerged at a few sites. In 2018 *A. antilope* made up 8% of the hymenoptera that emerged, while in 2019 it made up 67% due to a large number of individuals that emerged at a few sites.

In 2018 there was no significant effect of either natural area or field corner flowers on nesting success. However, in 2019 non-crop habitat had a marginally significant effect in the polynomial model ($\alpha<0.1$), and field corner flowers had a significant effect in the polynomial model (Table 1; Table D6).

Discussion

We set out to investigate how non-crop habitat in the landscape impacts field edge pollinator plantings and to what degree these restorations support wild bee conservation and crop pollination. Theory predicts that wild bee responses to field corner flower plantings should be most pronounced in landscapes that have an intermediate amount of existing non-crop habitat (Tscharntke et al., 2005). However, we found no evidence to support this theory. Instead, local flower availability and landscape-scale habitat both had independent and positive effects on bee responses, at least in one of the two study years.

The cross-year difference in in bee responses to flower plantings may be due to differences the overall cover and quality of field corner flowers across years. We believe that limited flowers may have had more of an impact than flower plantings on pollinator abundance and richness within field corners and in crop fields. However, successful flower plantings may be more impactful for increasing bee populations over time, thereby supporting pollinator conservation and crop pollination in the long term.

Impact of landscape-scale habitat on field edge flower plantings

To determine if the amount of habitat in agricultural landscapes influences the effectiveness of flower plantings, we had to define the spatial scale at which habitat in the landscape could impact our response variables. Many studies assume that ~1500-2000m is the relevant landscape for bee communities. In this study, the relevant spatial scale for field corner bee abundance was close to this value, but this varied substantially for other response metrics (Figure 4; Table D6). This emphasizes the importance of evaluating the appropriate spatial scale for each response variable, rather than making *a priori* assumptions about the spatial scale (Lowe et al. 2022).

Landscape-scale habitat had an independent positive effect on most of our response variables in one of the two years of this study. However, contrary to the ICH (Tscharntke et al. 2005) we found no evidence that landscape-scale habitat influenced the impact that flower plantings had on pollinators along field edges or within adjacent crop fields (Table 2). This is consistent with a large, cross-study analysis conducted by Albrecht et al. (2020) which found that landscape did not significantly alter the influence of restorations on crop pollination, although it is inconsistent with Scheper et al. (2013) who found the opposite effect for bee abundance and richness along field edges.

Among studies that have found results consistent with the ICH, many disagree on the proportion of non-crop habitat in the landscape that produces the best outcomes for pollinators (Carvell et al., 2015; Grab et al., 2018; Scheper et al., 2013). However a recent review of a limited number of empirical studies indicates that this range may be as broad or broader than 10%–50% non-crop habitat (Lowe et al., 2021). In this study, the amount of non-crop habitat within 1500m varied from 13-79% in 2018 and 4-70% in 2019 (Table A1). It is therefore possible that there could be an interaction effect whereby restoration effectiveness would decrease in landscapes with very low or very high non-crop habitat. However, our results support the idea that restorations and/or field edge management may be important across a wide range of landscape contexts.

Inter-annual differences: landscape-scale habitat

The independent positive effect of landscape-scale habitat on bee responses in 2018 is consistent with past research (Holzschuh et al., 2012; Kremen et al., 2004). However, this effect was only evident in one of the two years of this study. It is possible that these inter-annual differences may be due to variation in the bee groups present across years. 2018 featured an abnormally late spring followed by some extremely warm periods early in the summer. This may have impacted bee community composition. For example, there was a much higher proportion of non-*Bombus* bees in field corners in 2018 relative to 2019 (Figure 3; Appendix C). Additional analyses comparing the response of *Bombus* and non-*Bombus* bees in field corners in each year found that non-Bombus bees responded positively to the landscape in 2018 (while Bombus did not), lending support this hypothesis (Appendix C). Future studies could focus on the response of specific groups or species of bees that differ in important functional traits, such as body size, rather than on entire bee communities.

Inter-annual differences: field corner flowers

Overall, there was a weaker effect of plantings on bee responses in 2019 relative to 2018 (Table 1). This was surprising because we had better restoration establishment and overall higher floral index scores in 2019 (Figure 2). One possible explanation for this is that many field corners already had enough floral resources without the addition of flower plantings that there was less of a measurable difference in floral index between control sites and sites with restorations. If this is true, the significant effect of field corner flowers on bee richness in 2018 may be less attributable to the restorations and more to poor restoration establishment which decreased, rather than increased field corner flower quality relative to the natural baseline. This is consistent with the patterns we saw in the order of planted sites ranked by floral index: in 2018, far more planted sites ranked near the bottom in terms of floral index scores than in 2019 in which the opposite was true (Figure 2).

While in this study most of the intentionally planted species ranked highly based on floral index scores, many of the naturally-occurring flower species ranked well too. Furthermore, within the top 20 species ranked by floral index score, 5 of the naturally-occurring species are considered weedy or invasive in Wisconsin (Appendix A, Table 2). Managing certain weedy or invasive species can be important in some agricultural and ecological contexts. However, our results indicate as others have, that leaving some weedy species could be beneficial to bees (Balfour & Ratnieks, 2022; Bretagnolle & Gaba, 2015; Nicholls & Altieri, 2013) and that a multiplicity of ecosystem services should be considered when making field-edge management decisions.

Nesting success

We used nesting success (the percentage of occupied nest straws from which bees emerged in the next spring) to evaluate the ability of flower plantings to increase pollinator populations. While research on the effects of flower plantings on nesting or reproductive success has been limited, studies have found positive results both for *Bombus* (Bommarco et al., 2021; Geppert et al., 2020; Holland et al., 2015; Klatt et al., 2020; Wood et al., 2015) and wild bees (Ganser et al., 2021). Interestingly, our nesting data showed the opposite pattern of our other response variables—in 2018 there was no significant effect of field corner flowers on nesting success, but in 2019 this effect was significant in the polynomial model (Table 1). There was also a marginally significant effect of landscape-scale habitat in 2019, however, two-thirds of the landscape effect occurred within a very small area (35m radius or an area of 3,846m^2), small enough to fall inside over half the field corners (Table D6). Thus, it is likely that the effect of “landscape-scale habitat” may primarily reflect the effect of the field corners rather than habitat in the surrounding landscape.

Because our data was limited in 2019, conclusions should be taken with caution. However, our results may indicate that while it is lack of flower quality and quantity that most strongly dictates foraging patterns, nesting success may be more influenced by the abundance of local, high-quality floral resources. In other words, foraging may be more strongly influenced by the low end of floral index values and reach a threshold at the higher end, while nesting may be more strongly influenced by high floral index values (Figure 2). This indicates that the benefits of field edge flower plantings may manifest more strongly in the longer-term through their effects on pollinator population growth, rather than on short-term changes in abundance or richness.

Crop pollination

In 2018 both landscape-scale habitat and field corner flowers had a significant positive effect on all of our crop pollination metrics in at least one of the two models, while in 2019 we found no significant effects of either field corner flowers or landscape-scale habitat on crop pollination (Table 1; Table D6). It is important to note that although we did not find a positive effect of our habitat metrics on crop pollination in 2019, their impact was neutral, not negative. Many farmers are concerned that non-crop habitat, and particularly flower plantings, will draw bees away from crop fields. However, these results support past research that has found that this is not the case (Lowe et al. 2021).

There are two mechanisms by which flower plantings are expected to improve crop pollination: either the restoration will attract bees who will also forage on the crop (“spillover”), or the restoration will support the growth of bee populations so that there will be more bees available for crop pollination. Spillover is a short-term foraging effect while the second mechanism is dictated by longer-term population increases. In this study, we saw significant increases in bee richness in field corners in 2018 but only marginally significant effects in 2019. This mirrors the pattern we saw in terms of significant effects on our crop pollination metrics in 2018 but not in 2019, indicating that field corner flowers may impact crop pollination via spillover. We proposed that the effect of field corner flowers on bees in field corners in 2018 was due to a decrease in flower availability created by poor restoration establishment. Thus, the effect of field corner flowers on crop pollination may likewise be impacted by corner management.

We also found positive impacts of field corner flowers on nesting success in 2019, and this was likely due to flower plantings rather than field corner management. This may indicate that the impact of flower plantings on crop pollination may increase along with bee populations over time. This could explain why past studies have found inconsistent results of restorations on crop pollination (Albrecht et al. 2020, Lowe et al. 2021), as many studies are too short in duration to detect benefits due to longer-term trends in pollinator populations. Because of the rotational cropping system in which this study took place, we could not establish flower plantings and survey bees on the crop at the same site for more than one year. This limited our ability to observe the impact of bee population increases. Future research should evaluate both nesting success and bee populations within crop fields for several years after restorations mature to evaluate this hypothesis. In addition, the bees emerging from our nest boxes were primarily *Megachile* which were not seen foraging on the crop, though they may forage on crops other than cucumber. Depending on the crop of interest, it may therefore also be helpful to focus on evaluating the nesting success of ground-nesting bees in addition to stem-nesters.

Conclusions

A key finding of this study is that the amount of habitat in the surrounding landscape does not appear to impact the effect that flower plantings have on bee conservation or crop pollination. We also found that managing field edges in a way that maintains naturally-occurring flowers may matter as much or more than establishing flower plantings for localized increases in bee abundance and richness. However, flower plantings may improve bee nesting success, the outcome that is more important for both bee conservation and sustained crop pollination. To explore this hypothesis, future studies could both report more data on floral resources pre- and post-restoration establishment (e.g., implementing a BACI design, see Scheper et al., 2015) and measure nesting success and crop pollination over several years after restorations have matured.

The focus of this research was on non-crop habitat – field edge restorations and how they interact with non-crop habitat in agricultural landscapes. Field edge restorations are intended to help address loss of habitat at farm and field margins due primarily to the expansion of large-scale crop monocultures. However, the real issue lies in the policy and economic incentives that are driving the expansion of monocultural crops (Angelo, 2010; Bruckner et al. 2016; Socolar et al., 2021; USDA ERS 2021; Wang & Ortiz-Bobea, 2019). The majority of research funding and policy incentives go toward supporting this form of agriculture while a smaller share is dedicated to supporting conservation practices, like flower plantings (DeLonge et al., 2016). While somewhat helpful, these types of restorations do little to address the underlying issues with monocultures or with the structure of agricultural landscapes themselves. Recent research has also highlighted the pollinator conservation value (as well as other benefits) of diversified crops at both a field and landscape scale (Beillouin et al., 2021; Guzman et al., 2019; Hemberger et al., 2021; Isbell et al., 2017; Tamburini et al., 2020). Thus, in the future, far more research effort and policy support should be dedicated to developing cross-scalar agroecological management strategies that enable positive changes to both agricultural management and to the structure of agricultural landscapes (Gemmill-Herren et al., 2021; Hill et al., 2019).

Tables and Figures

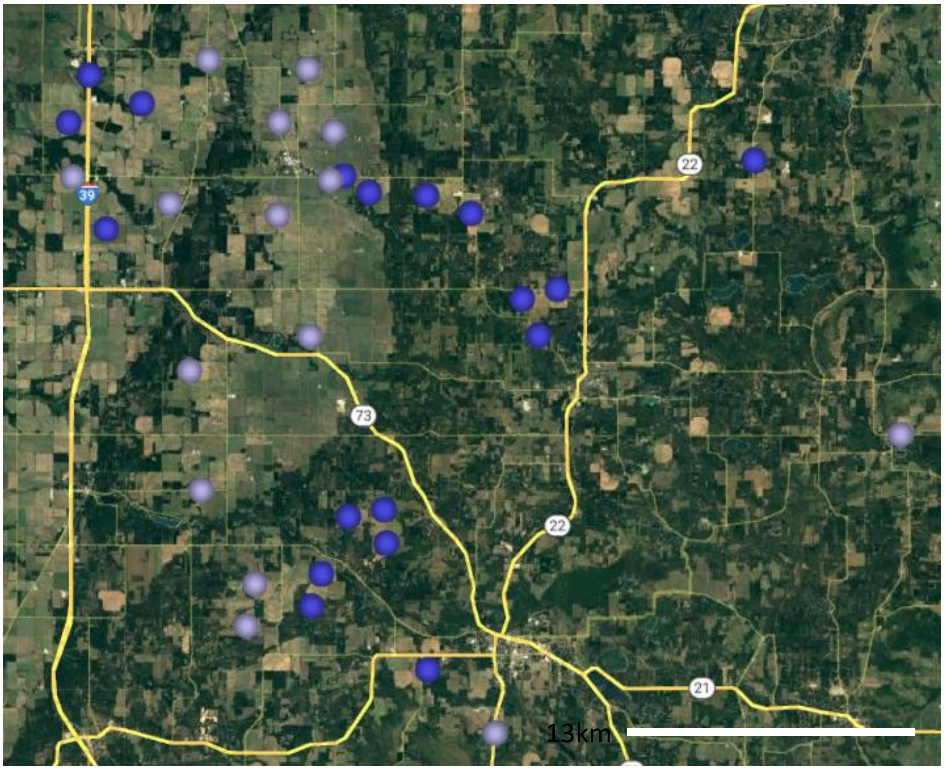

Figure 1. Field site locations in Central Wisconsin, USA. 2018 fields are darker blue, 2019 fields are lighter blue. Darker green areas are mixed agriculture and non-crop habitat while lighter areas are agriculturally-dominated.

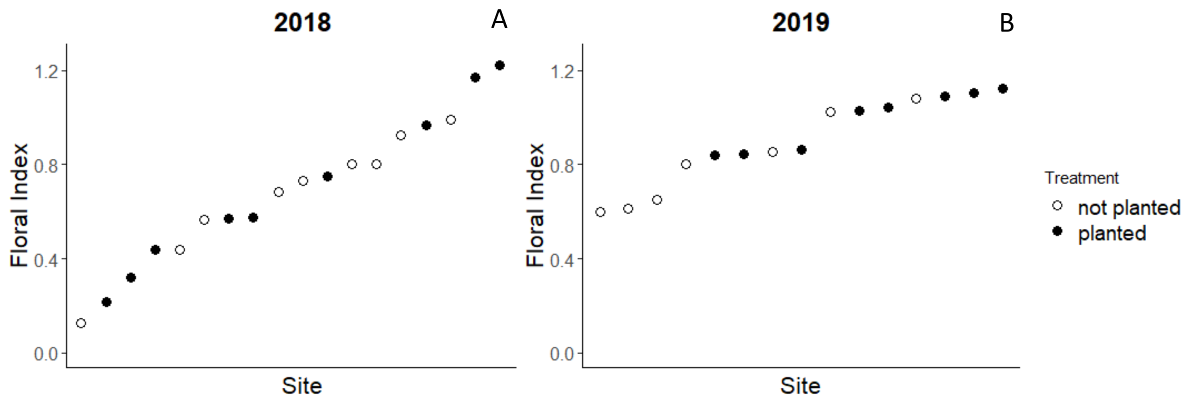

Figure 2. Sites ranked in order of increasing floral index scores in A) 2018 and B) 2019. The floral index is calculated based on flower cover and bee preference (from bee foraging data). The way it is calculated also accounts for flower richness (see methods and Appendix B for details).

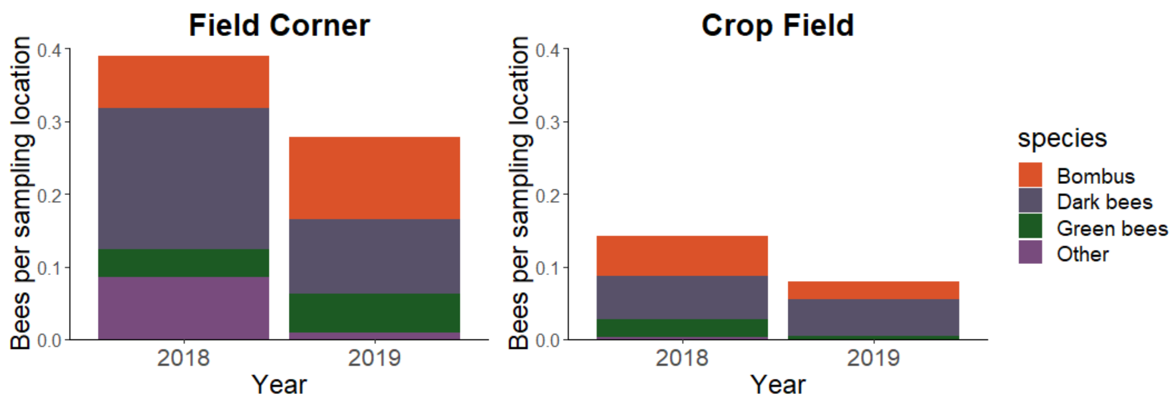

Figure 3. Abundance (bees/per sampling location) of bee groups across all sites in field corners and crop fields in each year. For a detailed breakdown of species groups, see Figure C1 and Table C1.

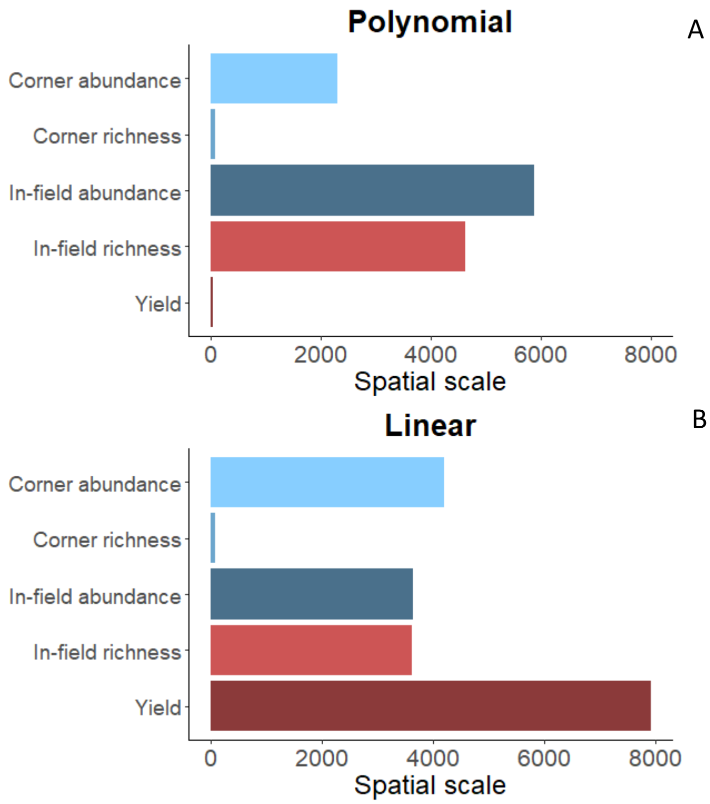

Figure 4. Estimates for the spatial scale at which habitat in the landscape impacted our response variables from A) polynomial and B) linear models in 2018. All variables were significant at $0.1 \geq \alpha$ except for richness in the polynomial model. Nesting and all values from 2019 are excluded as none were significant, leading to poor estimates of the spatial scale.

Table 1. Summary table of model coefficients and p-values given by likelihood ratio tests from A) polynomial and B) linear models. P-value significance levels are denoted by cell shading and symbols ** 0.01 ≥ α > 0.001; * 0.05 ≥ α > 0.01; † 0.1 ≥ α > 0.05; NS = α > 0.10.

	A. Response ~ non-crop habitat^2 + non-crop habitat + floral index + non-crop habitat x floral index + temperature*				**B.** Response ~ non-crop habitat + floral index + temperature*			
	Aggregate p-value for landscape variables	Non-crop habitat^2 p-value	Interaction p-value	Floral index p-value	Non-crop habitat coefficient	Non-crop habitat p-value	Floral index coefficient	Floral index p-value
2018								
Corner abundance	*	NS	NS	NS	1.12	*	0.067	NS
Corner richness	NS	NS	NS	NS	8.07	*	6.17	*
In-field abundance	†	NS	NS	NS	0.13	*	0.04	*
In-field richness	**	NS	NS	NS	22.30	**	4.92	*
yield	**	NS	NS	*	31.37	**	1.35	NS
nesting	NS	NS	NS	NS	-22.15	NS	4.23	NS
2019								
Corner abundance	NS	NS	NS	NS	-0.23	NS	-0.08	NS
Corner richness	NS	NS	NS	NS	-3.58	NS	4.14	†
In-field abundance	NS	NS	NS	NS	-0.01	NS	-0.01	NS
In-field richness	NS	NS	NS	NS	0.94	NS	-0.35	NS
yield	NS	NS	NS	NS	3.43	NS	2.11	NS
nesting	†	NS	NS	*	-34.25	NS	31.04	NS

*Temperature was never significant and is therefore not shown in this summary table (see Appendix D for numeric values for full model including temperature).

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Appendix A: Field Sites

Field site photos

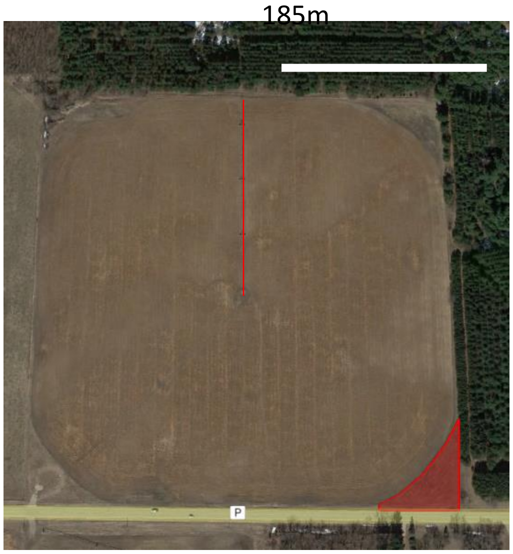

Figure A1. All fields were center-pivot fields. Irrigation lines stretching from the center of the field (red line), and irrigated a circular area leaving fallow field corners (e.g., red triangle, bottom R). Half of the sites received flower plantings in these field corners.

Figure A2. Planted field corners

Figure A3. Working in a cucumber crop field.

Figure A4. Nest boxes and *Megachile pugnata* male emerging from nest straws.

Field site characteristics

Table A1. Field site characteristics across the two study years.

Year	% non-crop habitat within 1500m	Planting?	Planting size (ac)	Crop field size (ac)
2018	79	N		19
	79	N		123
	71	Y	0.31	151
	69	Y	1.25	94
	68	N		34
	66	Y	0.63	33
	66	Y	0.58 (0.76)	81
	62	N		106
	60	N		36
	53	Y	0.73	110
	52	N		17
	51	Y	0.35	50
	49	Y	0.62	26
	42	N		98
	21	N		33
	17	N		135
	16	Y	1.3	52
	13	Y	0.38	35
2019	70	N		20
	68	Y	0.83	85
	65	N		123
	49	N		259
	49	N		29
	43	Y	1	125
	39	N		178
	32	Y	0.32	148
	29	Y	1	130
	27	Y	0.63	155
	22	N		157
	20	Y	0.76	60
	17	Y	0.43	33
	13	Y	0.67	119
	9	N		198
	4	N		223

Appendix B: flower plantings & floral index

Flower plantings

Seed mixes for restorations varied slightly between 2018 and 2019 (Table B1). Because many traditional restorations contain perennial species, in 2018 the seed mix consisted of a mix of annuals and perennials. The perennial species chosen were all documented to bloom robustly within their first year after planting. In 2019 the mix was modified in favor of annuals as not all species bloomed in 2018. Most species were chosen based on recommendations in (Adamson et al. 2017; Tuell et al., 2008; Williams et al., 2015,).

Before seeding we sprayed planted areas with Roundup to remove existing vegetation. We then hand-broadcasted seed with the exception of two restorations in 2018 which were drill-seeded with a no-till seed drill. Seed-to-soil contact was ensured by rolling over restorations 1 day after planting with cultipacker-type rollers.

Table B1. Flower species used in field-edge flower plantings in each year.

Species	Common Name	Annual/Perennial	Year(s) planted
Aster novae-angliae	New England Aster	P	2018
Agastache foeniculum	Anise Hyssop	P	2018
Achillea millefolium	Yarrow	P	2018
Lupinus perennis	Wild Lupine	P	2018
Monarda fistulosa	Wild Bergamont	P	2018
Solidago graminifolia	Grass-leaved Goldenrod	P	2018
Zizia aurea	Golden Alexander	P	2018
Grass species: Bouteloua curtipendula and Koeleria cristata (macrantha)	Sideoats Grama and Prairie Junegrass	P	2018
Chamaecrista fasciculata	Partridge Pea	A	2018, 2019
Coreopsis lanceolata	Lanceleaf Coreopsis	P	2018, 2019
Phacelia tanacetifolia	Lacy Phacelia	A	2018, 2019
Rudbeckia hirta	Black-eyed Susan	P	2018, 2019
Gaillardia pulchella	Firewheel	A	2019
Trifolium incarnatum	Crimson Clover	A	2019

Floral index

The index was calculated as the sum of floral cover (C) and a preference score (P_i) for each flower species based on observed bee foraging data (FQI = P_i + C). Floral cover was measured as the proportion of quadrats across all visits to each field site that contained flowers. The floral preference score was calculated based on the Chesson Foraging Index (Chesson, 1983; Sam et al., 2017) and was calculated separately for each flower species using data from all field sites as:

$$P_i = \frac{r_i/n_i}{\sum_{j=1}^{m} r_j/n_j}, \ i=1, \ldots , m$$

where r_i is the number of bee visits to flower species i, n_i is the number of times species i appeared in flower sampling stations, and $\sum_{j=1}^{m} r_j / n_j$ is the sum of the numerator calculations for all species. The data used to calculate bee preferences included the total number of bee visits across both transect and meander observations at all field sites, meaning that bee data and floral data were semi-independent measures. Preference scores were summed for all the flower species at each field site, thereby accounting for differences in floral richness as well.

Table B2. Flower species ranked by preference score[1] (based on bee foraging data). Species considered weedy or invasive in Wisconsin are indicated by an asterisk.

Species	Family	Common name	Year planted	Preference score
Heliopsis helianthoides	Asteraceae	False sunflower		0.2923
Monarda fistulosa	Lamiaceae	Wild bergamot	2018	0.1207
Phacelia tanacetifolia	Boraginaceae	Lacy phacelia	2018, 2019	0.1032
Asclepias syriaca	Apocynaceae	Common milkweed		0.0953
Tradescantia ohiensis	Commelinaceae	Spiderwort		0.0762
Hypericum perforatum*	Hypericaceae	Common St. John's wort		0.0477
Solidago spp.	Asteraceae	Goldenrod	2018	0.0301
Chamaecrista fasciculata	Fabaceae	Partridge pea	2018, 2019	0.0282
Linaria vulgaris*	Plantaginaceae	Butter and eggs		0.0154
Coreopsis lanceolata	Asteraceae	Sand coreopsis	2018, 2019	0.0153
Melilotus spp.*	Fabaceae	White and yellow melilot		0.0149
Centaurea stoebe*	Asteraceae	Spotted knapweed		0.0143
Vicia villosa	Fabaceae	Hairy vetch		0.0138
Gaillardia pulchella	Asteraceae	Firewheel	2019	0.0135
Trifolium pratense	Fabaceae	Mammoth red clover		0.0135
Rudbeckia hirta	Rudbeckia hirta	Black-eyed susan	2019	0.0129
Raphanus raphanistrum	Brassicaceae	Jointed charlock		0.0127
Oenothera biennis	Onagraceae	Common evening primrose		0.0109
Berteroa incana	Brassicaceae	Horay alyssum		0.0095
Hieracium umbellatum	Asteraceae	Canada hawkweed		0.0079
Medicago sativa	Fabaceae	Alfalfa		0.0069
Potentilla norvegica	Rosaceae	Rough cinquefoil		0.0064
Potentilla recta	Rosaceae	Sulfur cinquefoil		0.0059
Trifolium incarnatum	Fabaceae	Crimson clover	2019	0.0052
Erigeron strigosus	Asteraceae	Daisy fleabane		0.0047
Asclepias verticillata	Apocynaceae	Whirled milkweed		0.0032
Trifolium repens*	Fabaceae	Clover		0.0028
Saponaria officinalis*	Caryophyllaceae	Soapwort		0.0021
Potentilla argentea	Rosaceae	Silver cinquefoil		0.0020

Persicaria maculosa	Polygonaceae	Spotted lady's thumb		0.0019
Silene vulgaris*	Caryophyllaceae	Bladder campion		0.0018
Achillea millefolium*	Asteraceae	Yarrow	2018	0.0017
Heterotheca villosa	Asteraceae	Hairy golden aster		0.0014
Silene latifolia	Caryophyllaceae	White campion		0.0013
Lotus corniculatus*	Fabaceae	Birdsfoot trefoil		0.0012
Fallopia convolvulus*	Polygonaceae	Bindweed		0.0011
Euphorbia corollata	Euphorbiaceae	Flowering spurge		0.0009
Trifolium arvense*	Fabaceae	Rabbitfoot clover		0.0004
Rumex acetosella	Polygonaceae	Sheep’s sorrell		0.0002

We considered including corner area as part of the floral index as our corners varied in size. However, we ultimately excluded it because when it was included, the index was strongly correlated with area thereby over-weighting the value of area relative to metrics of floral cover and quality. Area is encapsulated by analyses of the spatial scale of the landscape effect – when the optimal spatial scale was very small, this reflected habitat that fell within the area encompassed by field corners.

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Appendix C: Data collector training & wild bee sampling protocols

Training data collectors

All data collectors went through rigorous training and testing procedures to ensure accuracy of morpho group IDs and inter-observer reliability. In addition, for every species ID, observers also noted a "confidence score" on a scale of 1-5 representing how confident they were about their ID. Confidence scores <2.5 were excluded from the data (0.9% of corner bee data, 0.4% of in-field bee data). The majority of the data consisted of confidence scores 4-5 (88% of corner bee data, 90% of in-field bee data). Data collectors also rotated through the data collection tasks so that influence of inter-observer effects were mitigated for any particular type of data.

Details on the bee community across sampling locations and years

Figure C1 is a more detailed version of Figure 3 in the main text. Note that neither Figure 3 nor Figure C1 includes data from the meandering survey because meander surveys were used to calculate richness only.

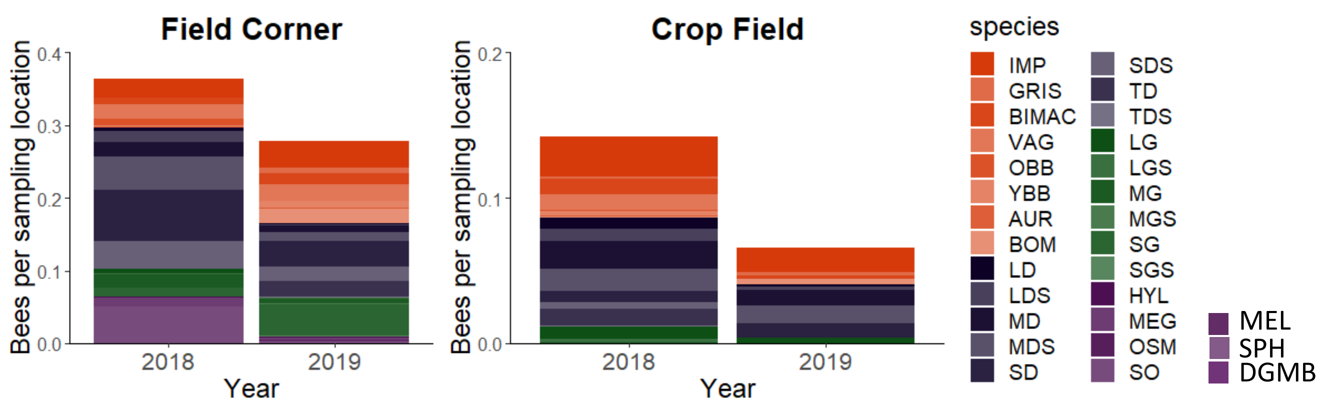

Figure C1. Relative abundance (bees/per sampling location) for bee groups across all sites in field corners and crop fields in each year. Note the different scales on Y axes between the two locations. Each color represents a different group of bees: red is *Bombus,* blue is dark bees, green is green bees, and purple is other bees. Within these categories, bees were identified to subcategories (color shades on Figure C1) based on ease of identification in the field (see Methods). *Bombus* were identified to species so the subcategories (shades of red) represent individual species. Dark and green bees were identified to size categories, so subcategories represent sizes (tiny = ≤7 mm; small = <9mm in 2018, 8-9mm in 2019; medium = 10-13mm; large = ≥14mm). Other bees were identified to genus, so subcategories represent genera. For more details on subcategory codes, see Table C2 below.

Table C1. Percentage of bee population represented by the bee groups and subcategories on Figure C1. Note that 'tiny dark' and 'tiny dark stripey' were only categories in 2019.

Group	Code on figure key	Subcategory	Field Corner		Crop field	
			2018	2019	2018	2019
	% of bees in field corners vs crop fields		74	78	26	22
Bombus	IMP	B. impatiens	36	33	50	70
	GRIS	B. griseocolis	5	6	3	10
	BIMAC	B. bimaculatus	14	14	21	10
	VAG	B. vagans	28	19	19	0
	OBB	B. ternarius / B. rufocinctus	11	1	1	0
	YBB	B. fervidus / B. borealis	3	7	5	0
	AUR	B. auricomus / B. pensylvanicus	3	2	1	0
	BOM	Unidentified *Bombus*	0	17	0	10
	% of total bee community		18	41	39	31
Dark bees	LD	Large dark	1.3	0.8	0.9	6.7
	LDS	Large dark stripey	5	1.6	8.6	2.2
	MD	Medium dark	6.3	4.9	9.5	4.4
	MDS	Medium dark stripey	14.4	7.3	21.6	20
	SD	Small dark	21.9	22	18.1	22.2
	SDS	Small dark stripey	11.9	11.3	8.6	17.8
	TD	Tiny dark	0	13	0	17.8
	TDS	Tiny dark stripey	0	0.8	0	0
	% of non-*Bombus* bee community		61	62	68	91
Green bees	LG	Large green	1.9	0.8	5.2	0
	LGS	Large green stripey	0.6	0.8	0	0
	MG	Medium green	5.6	3.3	12.9	0
	MGS	Medium green stripey	0	0.8	0.9	0
	SG	Small green	3.8	26	9.5	6.7
	SGS	Small green stripey	0	0.8	0	2.2
	% of non-*Bombus* bee community		12	32	28	9
Other bees	HYL	Hylaeus spp.	0.6	0.8	0	0
	MEG	Megachile spp.	3.8	2.4	0	0
	OSM	Osmia spp.	0	0.8	0	0
	SO	Lasioglossum (Dialictus) vierecki	15.6	1.6	0.9	0
	SPH	Sphecodes spp.	3.8	0	0	0
	MEL	Mellisodes spp.	1.9	0	2.6	0
	DGMB	Dark green metallic bee	1.3	0	0	0
	% of non-*Bombus* bee community		27	6	3	0

Relative abundance of bee groups in field corners

In field corners, *Bombus* made up a higher proportion of the total bee community in 2019 than in 2018. Dark bees made up the majority of the non-*Bombus* bee community in both years (Table C1). Green bees made up a relatively higher proportion of the non-*Bombus* bee community in 2018 than in 2019 (Table C1), while other types of bees made up a higher proportion in 2018 (Table C1). Amongst the green and dark bees which were identified to size categories, large bees (≥14mm) made up the lowest proportion of the bee community: 15% of the population in 2018 and 9% in 2019. Medium bees (10-13mm) made up 46% of the bee community in 2018 and 24% in 2019; and small bees (<9mm) made up 38% of the bee community in 2018 and 67% in 2019.

Relative abundance of bee groups in crop fields

Likewise, the relative proportion of *Bombus* to other bee species was relatively consistent (Table C1). As in field corners, dark bees dominated the non-*Bombus* bee community in both years, however it was more strongly skewed toward dark bees in 2019 than in 2018 (Table C1). Green bees were the second most prevalent group of non-*Bombus* bees in crop fields; no other bee groups were seen in crop fields in 2019, while *Mellisodes* and *Lasioglossum (Dialictus) vierecki* made up just 3% of the in-field bee community in 2018 (Table C1). Large bees made up a relatively small proportion of dark and green bees in crop fields in both years (~15% in both years). In 2018 there were more medium bees in crop fields than any other size category (~46% vs ~38% small bees), while in 2019 the majority of bees in crop fields were small bees (~67% vs ~24% medium bees).

Bombus vs. non-Bombus analyses

In 2018, landscape-scale habitat had a significant influence on nearly all our response metrics while in 2019 it did not. We were interested in discerning if these conflicting results could be due to differences in bee community composition; for example, if certain bee groups that were more sensitive to landscape were also abundant in 2018 relative to 2019, they may have driven the overall community's response. One of the ways in which the bee community differed in field corners across years was in the proportion of *Bombus* versus non-*Bombus* bees: in 2018, non-*Bombus* bees made up 82% of the bee community in field corners, while in 2019 they made up only 52% of the bee community in field corners. Because non-*Bombus* are smaller-bodied and less able to disperse over long distances, they may be more sensitive to the amount of habitat in a landscape than *Bombus,* driving the significant response to landscape in 2018.

Our analysis provides evidence that this may have been the case. In 2018, the abundance of non-*Bombus* bees was significantly and positively impacted by landscape-scale habitat (while *Bombus* abundance was not), reflecting the overall positive response of the entire bee community to the landscape. Conversely, in 2019 *Bombus* abundance responded positively to landscape-scale habitat (while non-*Bombus* abundance did not). However, even though they made up a larger proportion of the bee community in 2019, *Bombus* may not have been a large enough part of the community to drive the patterns expressed by community overall. It is unclear why *Bombus* and non-*Bombus* bees would both show opposite responses to landscape-scale habitat across years, but perhaps this is due to the fact that just as the full bee community is not a monolith, neither are *Bombus* and non-*Bombus* bees. The composition of species within those two groups differed across years (Figure 3; Appendix A, Table A5) and this may have affected their response to the landscape.

Likewise, the differences in the effect of landscape-scale habitat on crop pollination across years may be explained by the same patterns driving cross-year differences in bees in field corners. While the proportion of *Bombus* to non-*Bombus* bees was similar in crop fields across years, there may be differences within these categories that were more influential. For example, *B. maculatus* was twice as abundant in crop fields in 2018 as in 2019 and may have responded more strongly to the landscape overall or to a feature of it.

Nesting data

Three species of bees emerged from nest boxes each year: *Megachile pugnata*, *Megachile relativa*, and *Heriades carinata.* The largest species, *Megachile pugnata*, accounted for the majority of bees that emerged in both years (77% in 2018, 62% in 2019). *Megachile relativa* was second-most prevalent but was more common in 2019 than in 2018 (17% in 2018, 27% in 2019). *Heriades carinata* was least common in both years, but was also more prevalent in 2019, accounting for 6% of the bees that emerged in 2018 and 12% in 2019. We could not readily distinguish males and females of *Heriades carinata* but we were able to calculate male to female ratios for the the two *Megachile* species. In 2018 the male to female ratio for *Megachile pugnata* was 5:1 and for *Megachile relativa* it was 3:4. In 2019 the ratio skewed more strongly female for *Megachile pugnata* (3:1) than it did in 2018, while the 1:1 ratio for the *Megachile relativa* skewed slightly more male.

The vast majority of wasps that emerged from our nest boxes were *Ancistrocerus antilope*, however there was one individual from the family, *Chrysididae* that emerged in each year. *Ancistrocerus* were far more abundant in 2019 than in 2018. Of the bees and wasps that emerged in 2018, 92% were bees, whereas only 33% were bees in 2019. In 2018 *Ancistrocerus* emerged at only two sites. In 2019 it emerged at half our sites, however, the vast majority were concentrated at just three sites (at all others, only one individual emerged).

Nest boxes were composed of 120 cardboard tubes with an equal number of tubes of four widths, 3.5, 5.5, 7.5, 10mm (all 150mm in length). In both years the majority of the tubes contained cells capped primarily with mud as opposed to grass, although the proportion mud was far greater in 2019 (98%) than in 2018 (74%). The grass cells were only found in the three largest straw sizes with the vast majority in both years in 7.5 or 10mm straws. The mud cells were found primarily in 5.5 and 7.5mm straws. Future studies could should either open all unoccupied straws to determine if they're occupied by wasps or bees so that it is possible to get true emergence rates.

Appendix D: models & analysis

Producing p-values from 'scalescape'

'Scalescape' produces accurate p-values via bootstrap likelihood ratio tests under the null hypothesis that landscape predictor(s) have no effect on the response. A null model with one or more landscape predictors removed from the full model is used to simulate data under the null hypothesis that the removed predictors have no effect on the response. The full and null models are then refit to each of the simulated datasets, and the log-likelihood ratio between them calculated, giving a distribution of the log-likelihood ratio values under the null hypothesis. Comparing the likelihood ratio from the original data to the distribution of values from data simulated under the null hypothesis generates a p-value representing the significance of the landscape predictors that were removed from the full model. For more information see Lowe et al. 2022.

For this data we ran the following series of likelihood ratio tests for each response variable. Temperature (averaged across sampling dates) was included only for models assessing in-field or corner bee abundance and richness as nesting and crop yields were influenced by temperature across the whole season.

To produce a p-value for **non-crop habitat^2**

Full model: Response ~ non-crop habitat^2 + non-crop habitat + floral index + non-crop habitat x floral index (+ temperature)
Null model: Response ~ non-crop habitat + floral index + non-crop habitat x floral index (+ temperature)

To produce a p-value for the interaction term (non-crop habitat x floral index)

Full model: Response ~ non-crop habitat^2 + non-crop habitat + floral index + non-crop habitat x floral index (+ temperature)
Null model: Response ~ non-crop habitat^2 + non-crop habitat + floral index (+ temperature)

Because it is necessary to have main effects in a model in which higher order effects are included, we could not construct a likelihood ratio tests by removing non-crop habitat from the full polynomial model with the squared and interaction terms, above. Thus, the p-value for **non-crop habitat** came from the following linear model:

Full model: Response ~ non-crop habitat + floral index (+ temperature)
Null model: Response ~ floral index (+ temperature)

We also plotted data to look at the effects of wind speed, in-field floral density, and crop field size on our response metrics, but none of them appeared to have strong effects. Therefore, none of these variables were included in models.

Table D1. Model coefficients and p-values given by likelihood ratio tests from polynomial (L) and linear (R) models. Significance for different levels of α is indicated by green shading.

Response ~ non-crop habitat^2 + non-crop habitat + floral index + non-crop habitat x floral index (+ temperature)						Response ~ non-crop habitat + floral index (+ temperature)				
	Optimal spatial scale (m)	Aggregate p-value for landscape variables	Non-crop habitat^2 p-value	Interaction p-value	Floral index p-value	Optimal spatial scale (m)	Non-crop habitat coefficient	Non-crop habitat p-value	Floral index coefficient	Floral index p-value
2018										
Corner abundance	2293	0.0299	0.7821	1	0.7833	1901	1.1162	0.0270	0.0672	0.7403
Corner richness	80	0.1279	1	1	0.8690	80	8.0673	0.0160	6.1665	0.0152
In-field abundance	5864	0.0679	1	0.9801	0.1814	3631	0.1305	0.0190	0.0418	0.0243
In-field richness	4619	0.0140	1	1	0.2930	3619	22.2952	0.0020	4.9173	0.0195
yield	41	0.0110	1	1	0.0367	7929	31.3670	0.0159	1.3530	0.7321
nesting	341	0.7921	0.9700	0.9604	0.2070	368	-22.1470	0.7030	4.2250	0.8110
2019										
Corner abundance	2190	0.6832	0.9505	1	0.4410	1480	-0.2316	0.4950	-0.0750	0.6000
Corner richness	80	0.2871	0.9306	1	0.8206	2931	-3.5776	0.4851	4.1391	0.0706
In-field abundance	821	0.8614	0.9406	1	0.8040	7930	-0.0059	0.8515	-0.0108	0.2950
In-field richness	131	0.7624	0.9901	1	0.7830	140	0.9401	0.6320	-0.3511	0.8490
yield	981	0.3366	0.4059	1	0.5783	1218	3.4260	0.7921	2.1060	0.7415
nesting	35	0.1089	1	1	0.0309	43	-34.2500	0.1928	31.0360	0.2278

The impact of floral index on yield in 2018 and the impact of floral index on nesting in 2019 were significant for the polynomial model but not for the linear model. This may be because the polynomial model is overparameterized or conversely because the squared and interaction terms are helping to absorb some of the unexplained model variation. The latter may make floral index more significant because the proportion of the variation it explains is greater relative to the unexplained variation (as there is less unexplained variation overall).

Chapter 2

'Scalescape': an R package for estimating distance-weighted landscape effects on an environmental response

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[1]EL identified the need for this project, conducted the literature review of existing methods, wrote the manuscript, and developed the user guide code template

[2]BI helped with conceptualization of the project, made the figures, edited the manuscript, cleaned the code, conducted simulations, and put the package on GitHub

[3]CG helped with conceptualization of project and provided manuscript edits and funding

[4]TI developed the source code, conducted simulations, and edited the manuscript

Abstract

Context
Landscape studies often focus on determining how the landscape around a discrete set of field sites affects an abiotic or biotic response measured at those sites. To run this type of analysis, a decision must be made about the spatial extent over which the landscape affects the response. Many authors have acknowledged the limitations of common approaches to estimating this spatial extent of a landscape effect and some have proposed alternatives. However, many alternative methods have thus far been difficult to implement.

Objectives
The R package, 'scalescape' which we introduce in this paper, builds on and improves the usability of these alternative methods for estimating the spatial scale of a landscape effect on an abiotic or biotic response.

Methods and results
The package uses established approaches that weight landscape variables based on their distance from where a response is measured. It integrates well-used functions for performing regression in R, such as lm(), glm(), lmer(), glmer(), and gls(), with landscape weightings of spatial predictor variables. Here, we provide an introduction to 'scalescape' including a user guide detailing its functionality and step-by-step instructions. We also conduct simulations to illustrate and validate the 'scalescape' approach.

Conclusions
We conclude that 'scalescape' builds on previously proposed methods for landscape analyses by making it easier to implement distance-weighted approaches and by improving the statistical validity of these analyses through the use of GLS models and bootstrapping.

keywords: landscape analysis, spatial scale, buffer, distance weighting, kernel, spatial smoothing

1. Introduction

Landscape studies often focus on determining how the landscape around a discrete set of field sites affects an abiotic or biotic response (e.g., water quality or bee abundance) measured at each of those sites. These sites are usually chosen to vary in surrounding landscape characteristics (e.g., following a gradient of agricultural management intensity). A key challenge in these types of studies is determining the relevant spatial extent over which landscape predictor variables influence the response variable (Smith et al. 2011, Jackson and Fahrig 2015, Miguet et al. 2016, Martin 2018). This involves both determining the spatial scale that should be analyzed to infer the effect of the landscape on the response and determining the relative influence of elements of the landscape (i.e., their "weight") over that distance.

In this paper, we introduce a new R package called 'scalescape' that provides a user-friendly regression tool to estimate the spatial extent and weight of landscape variables while overcoming many of the problems associated with other commonly used approaches. We start by providing an overview of the existing methods for defining the spatial extent of a landscape effect and outline some of the issues with these methods. We then introduce 'scalescape' and describe how to implement it with a step-by-step user guide. Finally, we validate 'scalescape' using two types of simulations. Throughout this paper we use biotic response variables as examples, although the methods we discuss are applicable to analyses of abiotic responses as well.

1.1 Existing methods and issues

Landscape analyses typically use regression models to examine the relationship between one or more landscape predictor variables and a response variable measured at discrete field-site locations embedded within that landscape. In addition to landscape predictor variables, the model might also contain local variables measured at each field site, such as flower abundance. To run such a regression model, a decision must be made about the spatial extent over which the landscape predictor(s) affect the response. Traditionally, researchers have chosen this spatial extent in one of two ways. One way is to simply choose the spatial extent of the landscape *a priori* based on what is known about the biology of the study organism. For example, if it is known that an organism can disperse 1 km, a circle (i.e., "buffer") with a 1 km radius might be defined as the relevant landscape extent around each study site over which a landscape-associated variable could influence the response (Figure 1a). The values of all of the relevant landscape variables that fall within this buffer are assumed to have an equal impact on the response, while any landscape elements outside it are assumed to have no impact. If less is known about the spatial scale that might influence a response, researchers often compare the effects of a landscape variable measured across several concentric circles of different radii and choose the scale that best fits the data (Holland et al. 2004, Jackson and Fahrig 2015, Huais 2018) (Figure 1b). Fit is most commonly based on an information criterion (e.g., AIC) or significance tests (Stuber and Gruber 2020). Hereafter, we will refer to this method as "the multiple-buffer method." Like the *a priori* method, the multiple-buffer method assumes the effect of the landscape is equal within each buffer and that the landscape has no effect outside of the largest buffer radius. Because of this assumption, both fixed and multiple-buffer methods are sometimes referred to as "threshold methods" (Miguet et al. 2017).

While these two methods are commonly used, researchers increasingly recognize their methodological and conceptual limitations (Table 1) and acknowledge the need for a new way of estimating the spatial scale of landscape effects (Aue et al. 2012, Chandler and Hepinstall-Cymerman 2016, Miguet et al. 2017, Stuber and Gruber 2020). The greatest limitation to choosing a single spatial scale *a priori* is that often not enough is known about the study organism to make an accurate estimate of the relevant landscape extent (Jackson and Fahrig 2015, Miguet et al. 2016). For example, the scale at which landscape variables impact organisms depends on species traits and life-history characteristics (Thornton and Fletcher 2014, Jackson and Fahrig 2012), population dynamics (Ricci et al. 2013), the response being measured (Moraga et al. 2019, Martin 2018), and the landscape variable being evaluated (Miguet et al. 2016). Studies that focus on a community of organisms face the added challenge of estimating an appropriate scale for a set of organisms that may differ substantially in a variety of features (Stuber and Gruber 2020).

Because the multiple-buffer method compares a variety of spatial scales rather than relying on a single *a priori* decision, it may seem more appropriate. However, this method has a number of limitations as well (Table 1). First, it still requires that researchers make *a priori* decisions about maximum and minimum buffer sizes and the number of buffers to evaluate – decisions that are often based on unknowns. Underscoring this point, Jackson and Fahrig (2015) reevaluated data from 71 multiple-buffer studies and found evidence that spatial scales chosen for the same species varied widely across studies, indicating that researchers' choice of spatial scale may have been somewhat arbitrary. Furthermore, the range and/or number of spatial scales evaluated may have been too limited in many cases to accurately predict the scale of effect; for most papers in the review, the "best" spatial scale was either the smallest or largest scale evaluated.

Second, because most researchers evaluate landscape elements within concentric circles, the elements in the larger circles include the elements in the smaller circles, leading to a high degree of spatial autocorrelation between buffers. Such correlation will lead to similar effect sizes across scales, making it difficult to estimate the true scale of the effect (Miguet et al. 2016). Some authors have used concentric rings instead of circles to minimize this problem (Carrière et al. 2004). However, landscapes are often patchy such that nearby landscape elements are more alike than elements that are farther away, resulting in a similar problem with spatial autocorrelation. One solution to this problem is to strategically select study sites for which the landscape variable of interest at smaller spatial scales is uncorrelated with the same variable measured at a larger spatial scale (Benjamin et al. 2014). This allows a comparison of two buffer radii while minimizing the issue of spatial autocorrelation. This method, however, may not be possible in all landscapes.

Third, a statistical issue with the multiple-buffer method is post-selection bias (Miguet et al. 2016). When a model selection method is employed to choose the “best fitting” model, the selected model has a higher likelihood than other models. Because the statistical significance of the model coefficients depend on the likelihood, p-values reported from the multiple buffer method may be artificially low, leading to inflated type I error rates (excessive numbers of false positives) (Taylor and Tibshirani 2015).

A final problem with all the threshold methods is their assumption that habitat elements within a buffer have equal impact on the response variable no matter how far they are from the location where a response was measured, and that any element outside a buffer has no effect on the response. Several authors have stressed that this is biologically unrealistic, as landscape elements that are further from where a response is measured are expected to have less impact than those that are closer (Aue et al. 2012, Chandler and Hepinstall-Cymerman 2016, Miguet et al. 2017). Furthermore, the impact of a landscape variable should decline continuously with distance from a focal site, rather than abruptly dropping to zero at the outer edge of the buffer.

To address this challenge, a number of “distance-weighted” methods have been proposed. These approaches continuously weight landscape variables based on their distance from the study sites with areas closer to the response variable having greater weight than those further away (Aue et al. 2012, Williams et al. 2012, Karp et al. 2016, Chandler and Hepinstall-Cymerman 2016, Miguet et al. 2017, Kremen et al. 2018) (Figure 1c, 1d). This requires using a weighting function (usually a Gaussian or exponential decay function) to weight landscape predictors in a model. The weighting function contains a range parameter that defines how rapidly the effects of the landscape predictor variables decline with distance (i.e. the shape of the curve). For a Gaussian function, the value of the range parameter corresponds to the distance at which approximately three quarters (75.8%) of the landscape effect has occurred; for an exponential function, this is 63.2% (Figure 2). Thus, a larger range parameter value produces a flatter curve, giving relatively greater weight to landscape elements farther from each focal site (Chandler and Hepinstall-Cymerman 2016). Like a regression coefficient, the range parameter is associated with each landscape predictor variable in the model, and in conjunction with the regression coefficients it determines the effect of the landscape predictors on the response. More research is needed the types of weighting functions that perform best under different circumstances (Miguet et al. 2017). Miguet et al. (2017) compared Gaussian and Exponential functions and found that the exponential function performed better, although they stress that it is unclear to what degree this finding is generalizable. Because scalescape allows the user to try either Gaussian or exponential weighting functions, the user can choose the one that gives the highest log likelihood.

The challenge with distance-weighted methods is determining the value of the range parameter. Several researchers propose estimating the range parameter using approaches that are similar to traditional, non-distance weighted approaches of estimating the scale of a landscape effect. Williams et al. (2012) and Kremen et al. (2018) select a range parameter *a priori*, based on the value that will make the weighting function essentially zero at the maximum foraging or dispersal range of their target organisms (Figure 1c). While they rely on a single, *a priori* choice about the most appropriate maximum distance, this improves on traditional methods by assigning greater weight to landscape elements that are closer to study sites. Karp et al. (2016) and Miguet et al. (2017) use an approach similar to the multiple-buffer method where multiple values of the range parameter are compared, and the best range value is chosen based on a metric of model fit (Figure 1d). While this ensures that they are not making an *a priori* choice about the maximum value of the range parameter, as in the traditional multiple-buffer method they must make decisions about the extent and range of values to compare.

An alternative approach for estimating the range parameter uses model optimization to define the range parameter during the model fitting process (hereafter the “fitted range” method; Aue et al. 2012, Chandler and Hepinstall-Cymerman 2016, Carpentier and Martin 2021) (Figure 2). Estimating the range parameter via model fitting avoids *a priori* decisions about the scale of the landscape variables. It also avoids issues with spatial correlation between the buffers around a site (Table 1).

While previous adaptations of the fitted range method improve on *a priori* and multiple-buffer approaches to distance weighting, they also have some limitations. Until recently, fitted range approaches required custom computer coding, but in 2021 Carpentier and Martin introduced the R package, ‘siland,’ which makes it much easier for users without complex coding skills to run certain types of models. While ‘siland’ greatly increases the usability of the fitted range approach and can accommodate a variety of models, it is limited in the types of models it can accommodate and it does not allow for GLS or other types of models that account for possible spatial autocorrelation in the residual errors of regression models (Appendix B). Spatial autocorrelation can occur when the sites at which a response is measured share similar underlying factors (e.g., soil type) based on spatial proximity. In many studies, the sites at which response variables are measured are close enough that they should not be assumed to be independent. This is especially relevant when additional sites occur within the range of a buffer around a particular site. Autocorrelation in the residual errors of regression models has the well-known effect of increasing type I errors, generating too many false positives for a given alpha significance level when the null hypothesis is correct. Another limitation of existing fitted range approaches is that simultaneously estimating the regression coefficient for the landscape variable and the range parameter creates a statistical challenge which may increase type 1 error rates. When the regression coefficient and the range are estimated together, two questions are being asked: 1) is there a landscape effect (the magnitude of which is represented by the regression coefficient), and 2) at what spatial scale does the effect happen (the range of the effect). These questions depend on one another—

if one is 0, the other is too, although each explains a different component of the landscape effect. This dependency creates uncertainty around the distribution of the range parameter which cannot be incorporated into standard test statistics (such as a Wald or likelihood ratio test), which may give p-values that are too low, inflating type 1 error rates.

1.2 Introducing 'scalescape'

The R package 'scalescape' provides a user-friendly way to perform distance-weighted analyses by leveraging well-known functions in R. Like previous fitted range approaches, 'scalescape' estimates two quantities during the model fitting process: 1) the regression coefficient for the landscape variable which represents the direction and magnitude of the landscape effect, and 2) the range parameter which weights landscape predictor variables based on their distance from each site and ultimately determines the spatial scale of the landscape effects. To calculate the range parameter, a value is calculated for each raster cell within the max radius. These values are then summed so that the effect of each landscape predictor at location i is assigned a value:

$bSx_j \, w(d_{ij})$

where x_j is the value of the landscape variable at location x_j (0 or 1 for a binary raster, the value of the landscape variable for a continuous raster), d_{ij} is the distance between locations i and j (where i is the site location), and w() is a distance weighting function (Gaussian or exponential). x_j, d_{ij} and w() are calculated for each raster cell within the max.radius and summed. Predictor variables in 'scalescape' can include those measured at each site location (local variables) as well as landscape variables, and the model can be a simple least-squares regression model, a generalized linear model, a generalized linear mixed model, or a model with autocorrelated residual errors.

'Scalescape' builds on the fitted range approach used by Aue et al. (2012) and Chandler and Hepinstall-Cymerman et al. (2016), as well as the R package, 'siland' (Carpentier and Martin 2021), in several ways (Table 1). First, 'scalescape' can be used with multiple types of models (lm, lmm, glm, glmm, lme, gls) without complex coding, greatly increasing the usability of the fitted range approach. The ability to easily run GLS models is particularly useful because GLS models can account for a spatial correlation in the residual errors between sites (Ives and Zhu 2006; Pinheiro and Bates). In addition, 'scalescape' adds bootstrapping for hypothesis testing, giving more accurate p-values for the effects of landscape predictor variables than previous approaches. Bootstrapping addresses the uncertainty in the distribution of the range parameter that comes from simultaneously estimating the regression coefficient by generating a parametric bootstrap likelihood ratio test for the joint distribution of the regression coefficient and range parameter. For more information on differences between 'scalescape' and 'siland' and on the importance of bootstrapping, see Appendix B.

2. Using 'scalescape'

2.1 Functionality

'Scalescape' can be run with many types of regression models in R: lm() and glm() in base R, lmer() and glmer() in 'lme4', and lme() and gls() in 'nlme.' It adopts the model syntax of the specified regression model making it easy to use models of any type. This also allows 'scalescape' to accommodate analyses for many types of landscape predictor variables including binary (e.g., cropland/non-cropland) or continuous (e.g., elevation) variables. Models can also include polynomial landscape terms, multiple landscape predictors (e.g., cropland and elevation), non-spatial or "local" variables (e.g., local plant characteristics), and interactions between local and landscape predictors or between multiple landscape predictors.

2.2 Data and data formatting

To run a model in 'scalescape' you will need:

1. Raster map(s) with the desired landscape variable(s). All rasters must have square cells.

2. A data.frame with response variable(s) and any local predictors, where each row is a site.
3. A spatial data.frame with site locations (sp or sf format). Basic data frames with site coordinates (where the first column is x, longitude, or UTM easting, and the second is y, latitude, or UTM northing) can be converted to spatial data.frame formats. Site location data need to be in or converted to the same projection coordinate reference system (CRS) as your raster.

To run analyses for binary landscape predictors, you will need a single raster classified accordingly. If you are interested in polynomial landscape terms or multiple landscape predictor variables, you will need a separate raster for each of these variables (see example in Appendix A). To increase computing speed, it is helpful to crop your raster(s) around your sites rather than using the full raster. When cropping, ensure that you leave enough space around outer sites to accommodate the maximum extent of the analysis you wish to run.

2.3 Running 'scalescape'

The primary functions in 'scalescape' are dist_weight() and dist_weight_boot(). dist_weight() fits the model using the function optim() (with L-BFGS-B as the default method) to find the values of the model parameters that maximize the log-likelihood of the model fit to the data. Although dist_weight() produces p-values for the regression coefficients (given by the underlying lm(), glm(), lmer(), glmer(), lme(), or gls() functions), these p-values are conditional on the estimate of the range parameter, and consequently they will likely have inflated type 1 error rates. The dist_weight_boot() function uses a likelihood ratio test from the parametric bootstrap to generate a single p-value for the landscape predictor variable(s) in the model. By bootstrapping, it accounts for the co-dependence of regression coefficient and range parameter. Therefore, *p-values reported for landscape predictor(s) should come from dist_weight_boot() rather than dist_weight()* (Appendix B, Figure B4).

The dist_weight_boot() function performs a parametric bootstrap likelihood ratio test under the null hypothesis that the landscape predictor(s) have no effect on the response. Specifically, a null model with one or more landscape predictor variables removed from the full model is used to simulate data under the null hypothesis that the predictor variable(s) have no effect on the response variable. The full and null models are then refit to each of the simulated datasets, and the log-likelihood ratio between them calculated. The distribution for log-likelihood ratios from a large number of simulations (e.g., 2000) gives the bootstrap approximation of the distribution of the log-likelihood ratio under the null hypothesis. This creates a parametric bootstrap distribution of likelihood ratio values which can then be compared to the likelihood ratio value from the original data. Comparing the likelihood ratio from the original data to the distribution of values from the simulated data generates a p-value representing the significance of the landscape predictor variable(s) in the model. Because this bootstrap procedure is based around the removal of predictor variables, it gives the joint significance of the regression coefficient and range parameter for each tested landscape variable.

The following example details how to run a simple model in 'scalescape.' This is the method you would use if you had a model with either a single binary landscape predictor or a single continuous landscape predictor, with or without local predictor variables (for more complex model structures, see Appendix A). To create an artificial dataset, data for this example were simulated using empirical data from a landscape-scale experiment examining the effects of local and landscape drivers of wild bee communities in an agricultural region of Wisconsin, USA. In this experiment, 18 commercial cucumber fields were selected along a gradient from crop-dominated to forest- and grassland-dominated landscapes. Data collected at each cucumber field included air temperature, field margin flower cover and richness (collated into a "floral index"), and wild bee abundance. To simulate data, we fit a linear model in 'scalescape.' This model estimated bee abundance (square-root transformed counts) as a function of temperature and floral index (local-level variables) and surrounding natural habitat, a landscape-level variable derived from a binary raster classified as "natural habitat" (e.g., forest, grassland) and "non-natural habitat" (e.g., cropland and urban). We then used this model to simulate a single, new set of bee abundance values. These values were generated by taking the original model, pre-defining the value of the range parameter (1000m) and regression coefficient of the landscape predictor (β=0.8), and then adding randomly drawn error terms generated from a normal distribution with the same standard deviation estimates as the original model. The simulated data and the following code are available in the supplementary materials.

2.3.1 Sample code

The R code and data corresponding to this example can be found in the supplemental data. It is also included in the package as a vignette. In this example, 'raster.nat' is a raster classified as binary with "natural" and "non-natural" habitat. The landscape predictor variable (derived from the raster) is called 'natural.area'. Local predictor variables include floral characteristics measured at each field site ('floral.index') and temperature ('temp'). The response variable is the square root of bee abundance ('sqrt.abundance'), and site data are held in sites.spdf.

Before running dist_weight() and dist_weight_boot(), you must create a landscape matrix from your raster using the landscape_matrix() function. This matrix will be used by dist_weight() and dist_weight_boot() to do the weighting and fit the model. landscape_matrix() creates a matrix in which each row corresponds to a raster pixel at a given location around a site, and each column corresponds to a site. The column 'dist' gives the distance of each pixel to the focal site. For binary classifications, cell values in the matrix represent whether that pixel is filled by a land cover type of interest (1 if yes, 0 if no), and for continuous classifications they correspond to the value of the landscape variable of interest.

When applying landscape_matrix() to a raster, you will need to specify:

1. The raster associated with the landscape variable you are interested in.

2. A list of sites formatted as an sf object or sp object.
3. The maximum radius you wish to evaluate. This radius should be larger than what you believe to be the maximum relevant spatial scale for your response variable (although the larger it is, the longer the computation time). All raster cells up to this distance will be included in the parameter optimization process used to define the range parameter. The variable max.radius must fall within the bounds of the raster. If max.radius around at least one site falls outside the bounds of your raster, you will receive an error message indicating this problem and should select a raster with a greater extent or choose a smaller max.radius.

```
#create the landscape matrix
landscape.matrix <- landscape_matrix(raster=raster.nat, sites=sites.spdf, max.radius=8000)
```

Next you will specify a null or “local” model without the landscape predictors. For a simple regression model using the bee abundance data described above, this would be:

```
mod0 <- lm(sqrt.abundance ~ floral.index + temp, data=data)
```

Next, run dist_weight(). Within dist_weight(), there are a number of arguments you will need to specify:

1. mod0 = the name of your "local" model without landscape variables, specified above
2. landscape.vars = a list of names for the landscape matrix or matrices that you specified with landscape_matrix()
3. landscape.formula = a formula containing all the landscape predictors (using the same names as given to the landscape matrix/matrices in landscape.vars). The ‘~ . + …’ (see example below) is a necessary part of the formula which calls the non-spatial elements of the model
4. data = a data.frame with your local predictors and response variables, with each row as a site sorted in the same order as your original site data.frame
5. You may also specify several optional arguments within dist_weight():

a. weight.fn = the type of weighting function (Gaussian or exponential). Rather than choosing which function to use, you could also run both and choose the function with the highest likelihood.

b. plot.fits = switch to turn on plots. If plot.fits = TRUE (recommended), dist_weight() produces 2 plots. The first shows log-likelihood values for the range parameter up to the distance (in meters) that you specified as max.radius when you created the landscape matrix in step 1. *It is important to assess the plot of log likelihood vs. distance to make sure optim() has chosen the proper maximum value for the log likelihood*; if there are multiple local maxima, optim() chooses the first it encounters rather than global maximum (highest log likelihood value). If optim() has chosen the wrong value, you can use several of the optional arguments to correct it (see below). The second plot shows how the weight of the landscape predictor decreases with distance (in meters) given the maximum likelihood range value.

c. If you notice that there are two or more maxima on the plot of the log-likelihood vs distance and optim() has selected the wrong one, you can manually correct it by specifying lower = xxx and upper = xxx, init.range, or n.partition. Lower = xxx and upper = xxx specifies bounds inside which optim() should search for the maximum value. Init.range = specifies a starting value for the optim() function. Optim() generally runs "uphill" (from low to high values of the log-likelihood) from its starting value, so if you're using init.range you will want to choose a value "downhill" from the true maximum. n.partition = allows you to specify any number of evenly spaced between 0 and max.range. Optim() will then calculate the log likelihood between each partition and choose the highest log-likelihood value from all the partitioned sections.

d. opt.range = a specified value of range. If you specify a value for opt.range (in meters), dist_weight() will fit the model using that value as the value of the range parameter (rather than using optim() to identify the value that maximizes the log likelihood). This is analogous to using the method of distance weighting depicted in figure 1c.

e. optim.method = the optimization method. Scalescape is set to run optim() with L-BFGS-B as the default.

```
#run dist_weight
mod <- dist_weight(mod0 = mod0, landscape.vars = list(natural.area = landscape.matrix),
landscape.formula = landscape.formula = '~ . + natural.area', data = data, weight.fn =
"Gaussian", plot.fits = TRUE)
```

The p-values for local variables in this table as well as the coefficient estimates, and AIC and log likelihood values are accurate. However, the p-values for the landscape variables are conditional on the estimates of the ranges and should not be trusted.

The function dist_weight_boot() conducts a parametric bootstrap test of the null hypothesis that one or more of the landscape predictors have no effect on the response variable (Ives 2018). The bootstrap simulates datasets under the null hypothesis using the attributes and parameter values from the model specified with dist_weight() and then re-fits the full and reduced models to all the datasets using optim() to maximize the range parameter with each iteration. When you run dist_weight_boot(), a progress bar giving the percentage of bootstrap iterations that have run will appear in the R console, as the bootstrapping process can be relatively time intensive. To run dist_weight_boot(), you will need to specify the following two arguments:

1. mod.full = the name of your full model. To test the significance of landscape variables, these would be included in the full model.
2. mod.reduced = the name of your reduced model. To test the significance of one or more landscape variables, these would be excluded in the reduced model.

3. There are also a number of optional arguments including the following (for a full list, see 'scalescape' documentation):
    a. nboot = the number of bootstraps. To determine whether a variable is significant at the $p < 0.05$ level, nboot = 2000 should be used, since 2000 bootstrap simulations are sufficient to give the distribution of log likelihoods under the null model for accurate p-values at the 0.05 significance level.
    b. plot.fits = if TRUE (default), the output will produce 2 plots: a plot of the frequency with which each value of the range parameter was identified as optimal and a plot of the distribution of deviance values generated by the bootstrap test from which the p-value is derived (Figure 4).

```
mod.boot <- dist_weight_boot(mod.full = mod, mod.reduced = mod0, plot.fits = TRUE, nboot =
2000, verbose = FALSE)
```

The p-value for full.mod.boot will often be larger than the p-value from dist_weight(). This underscores the idea that dist_weight() produces p-values that are artificially low and therefore should not be trusted. A number of values and plots (including AIC and BIC values) are stored with the model objects produced by dist_weight() and dist_weight_boot() (in this example, "mod" and "mod.boot"). These can be called by using mod$... or mod.boot$...). mod$data.with.landscape produces a data table with a column for "natural.area": the percent natural area within the distance represented by the optimal value of the range parameter. plot() will reproduce the plots from dist_weight() and dist_weight_boot.

To determine the weighted landscape effect at a given distance (in meters), use the functions dnorm() (or dexp()) as follows:

```
#for Gaussian weighting :
distance <- 500
```

```
1-dnorm(distance/mod$opt.range)
```

3. Simulations

To demonstrate the functionality and statistical validity of ‘scalescape’, we conducted two sets of simulations. The first set of simulations investigated the scenarios in which ‘scalescape’ performs the best; specifically, those scenarios for which it successfully identified the magnitude and direction of a landscape effect (the value and sign of the regression coefficient) and accurately predicted the spatial scale of the effect (the value of the range parameter). The second set of simulations deployed ‘scalescape’ with different types of regression models under scenarios with varying amounts of spatial autocorrelation in the response variable. This set of simulations demonstrates the importance of using models that account for spatial autocorrelation when this autocorrelation is present, as well as the utility of ‘scalescape’ in allowing for gls() models that can appropriately handle this autocorrelation. Both sets of simulations use data derived from the same landscape-scale experiment used to simulate data for the ‘Using Scalescape’ section above. As for the data in the user guide, we used a linear model with surrounding natural habitat (landscape-level variable), and temperature and floral index (local-level variables) to simulate new values for the response variable, bee abundance. Each of these new sets of values constituted a different data-set.

The first set of simulations were constructed to evaluate the performance of ‘scalescape’. We simulated 1000 new data sets for 44 combinations of values of the regression coefficient and range parameter (β = 0 to β = 1.0 in increments of 0.1, and range parameter = 250m, 500m, 1000m, and 2000m) with a Gaussian weighting function and a maximum landscape extent of 7000m. We then fit each of these datasets using ‘scalescape’ to determine how often the regression coefficient (β) and range parameter values produced by ‘scalescape’ matched the true values used to generate that dataset (Figure 5; Appendix B, Figure B2).

The results of the simulation study indicate that 'scalescape' is better able to estimate both range parameter and regression coefficient when the spatial scale of the effect (range parameter) is small, and the effect size is large. At small effect sizes (e.g., β = 0.2), 'scalescape' infrequently detected a significant landscape effect, and when it did, the estimate of the range was highly variable (Figure 5, top panels). At larger effect sizes (e.g., β = 1.0), the estimated value of the range was close to the simulated range value, especially when the simulated value of the range parameter was small (Figure 5, bottom panels). Furthermore, the power to detect a landscape effect was greatest at the smallest range parameter tested (250 m) and decreased as the range parameter increased (Figure 6), and at small effect sizes and large ranges, 'scalescape' occasionally failed to identify a maximum for the likelihood of the range parameter and produced an estimate that corresponded to the maximum landscape extent (here 7000 m). We suspect that this is an inherent problem with estimating range parameters, rather than a failing of ‘scalescape.’ Since the weight of the landscape is relatively less at greater distances, the impact of increasing the value of an already large range parameter does not substantially change the value of the weighted landscape variable that is produced. This may account for both the lower power to detect a landscape effect and lead to an abundance of high range parameter estimates.

In the second set of simulations, we varied the amount of spatial autocorrelation between the values of the response variable observed across sites. This type of spatial autocorrelation (between the errors of the regressions for each site) could be caused by unmeasured variables that affect the response that are more likely to be shared by nearby sites (e.g. for bumble bee abundance, a factor like suitable soils for bumble bee nests). We assumed that the correlation between random errors between two sites was given by a Gaussian distance function with range parameter *r*. Larger simulated autocorrelation values indicated that spatial autocorrelation occurred across a greater distance. For these simulations we maintained a range parameter value of 50m and simulated datasets at for β = 0, 0.2, 0.4, 0.6, 0.8, and 1 for autocorrelation values of = 0, 0.2, and 0.4. We then fit these simulated datasets in ‘scalescape’ using lm() which does not account for spatially autocorrelated errors, and using gls() with a Gaussian spatial autocorrelation function. Figure 7 plots the proportion of 1000 datasets for which the null hypothesis $\beta = 0$ was rejected at an alpha significance level of 0.05.

Ideally, the proportion rejected would equal α=0.05 when the null hypothesis ($\beta = 0$) is true. However, the results from the simulation study show that, as expected, the presence of spatial autocorrelation in the residuals among sites can inflate the type I error rate (false positives) when it is not accounted for (purple and orange dashed lines at $\beta = 0$, Figure 7). Likewise, when there was stronger spatial autocorrelation (purple lines), a greater proportion of the simulations were correctly rejected for the GLS model than for the LM model when the null hypothesis was false (the GLS model had greater power). The power to correctly reject the null hypothesis was greatest for both models when there was strong spatial autocorrelation (0.4), although we do not know whether this would be expected for other landscapes. These simulations highlight the importance of accounting for spatial autocorrelation in regression models, especially to avoid inflated type 1 error rates.

4. Discussion

‘Scalescape’ is one of two user-friendly R packages that allows for a distance weighting approach to landscape analysis, enabling the user to weight landscape predictors based on their distance from focal sites where a response was measured. The method used in 'scalescape' follows the conceptual “fitted range” approach developed by Aue et al. (2012) and Chandler and Hepinstall-Cymerman (2016) and implemented by Carpentier and Martin (2021), that solves many of the issues with both traditional threshold methods and other distance weighting approaches (Table 1). 'Scalescape' builds on previous fitted range methods by increasing usability (providing a user-friendly interface with commonly used regression packages in R that allows users to run many types of models) and by improving statistical validity by making it easier to use gls() models and adding bootstrapping to obtain correct p-values for the model coefficients.

In addition to solving many of the statistical issues with threshold methods, distance weighting approaches such as 'scalescape' can aid in making more informed habitat management decisions (Miguet et al. 2017). Distance weighting approaches generate a curve that dictates the weight of a landscape effect at a continuous range of distances, thereby enabling users to estimate the proportion of the landscape effect that has occurred at a given distance from the response. Miguet et al. (2017) outline ways in which this information could be informative in a management context, for example preserving a greater proportion of the little remaining habitat for an endangered species versus conserving a smaller amount of habitat across a greater area for a more widespread organism.
The structure of scalescape in which fitted model objects from other packages (`stats`, `lme4`, and `nlme`) are taken as inputs makes it possible to add other types of model objects. In the future, it would be possible to expand scalescape's capabilities to include zero-inflated models such as those available in the package `glmmTMB`. It is also possible to extend the approach to Bayesian models. One downside to Scalescape is that depending on the complexity of the model and the amount of data, the bootstrapping process can take some time. Parallelizing the bootstrap could allow users who have a computer with multiple cores to run several sets of bootstraps simultaneously. Translating part of the code into C++ would also make it run faster. Overall, we believe that 'scalescape' is a useful step forward in terms of landscape analysis, increasing the usability, flexibility, and utility of statistical approaches for answering these types of questions. Future research could explore how the suitability of different weighting functions (e.g. Gaussian or exponential) changes for particular species, response metrics, and with the spatial structure of landscape variables (Miguet et al. 2017).

Tables and Figures

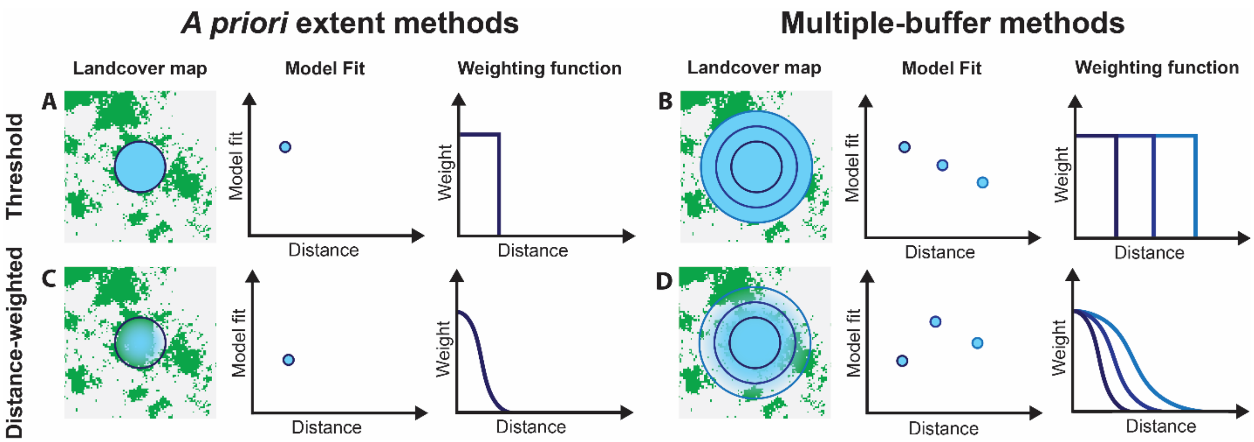

Figure 1. Illustration of different methods for estimating landscape effects on a response variable measured at focal site (x). Panels on the top (A, B) represent "threshold methods" whereby the effect of the landscape is considered equal up to a certain threshold at which point it drops to zero. Panels on the bottom (C, D) represent "distance-weighted" methods, whereby landscape elements have a decreasing effect with increasing distance from a field site. The panels on the left (A, C) represent methods that involve choosing a maximum distance *a priori*, and the panels on the right (B, D) represent methods that involve comparing the landscape effect at multiple distances using model selection methods.

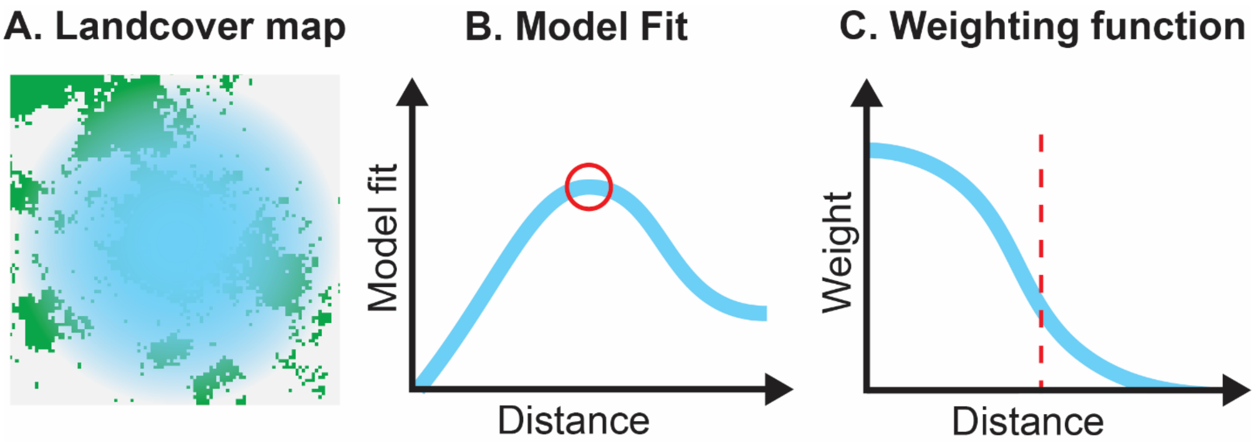

Figure 2. Illustration of the 'scalescape' methods for estimating landscape effects on a response variable measured at focal site. (A) A maximum radius is chosen so that it is significantly larger than the expected extent of the landscape effect. Within this radius all landscape elements will be weighted (light blue area) based on their distance from a focal site, (B) Parameter optimization during the model fitting process determines the optimal value of the range parameter (circled in red), which (C) dictates the shape of the weighting function (i.e., the spatial scale of landscape effect). The red dotted line indicates the value of the range parameter, which for a Gaussian function corresponds to the distance at which approximately three quarters (75.8%) of the landscape effect has occurred; for an exponential function, this is 63.2%.

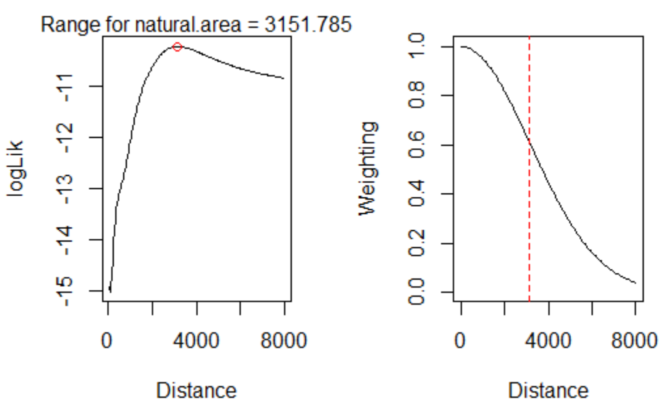

Figure 3. 'Scalescape' plots produced by dist_weight(). The "Range for natural area" value shown on the lefthand panel is the value of the range parameter estimated by ML. This value dictates the shape of the curve, or the relative weight of the landscape at a given distance as shown on the righthand panel. When using Gaussian weighting, this value corresponds to the distance at which 75.8% of the landscape effect has occurred (vertical dotted line); this value would be ~⅔ of the landscape effect for an exponential function.

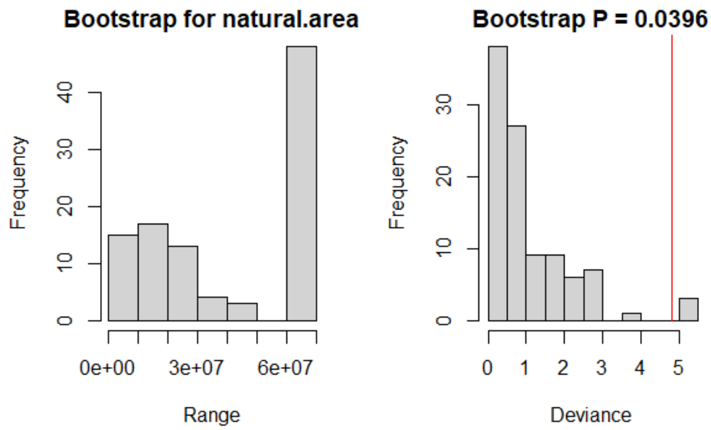

Figure 4. 'Scalescape' plots produced by dist_weight_boot().

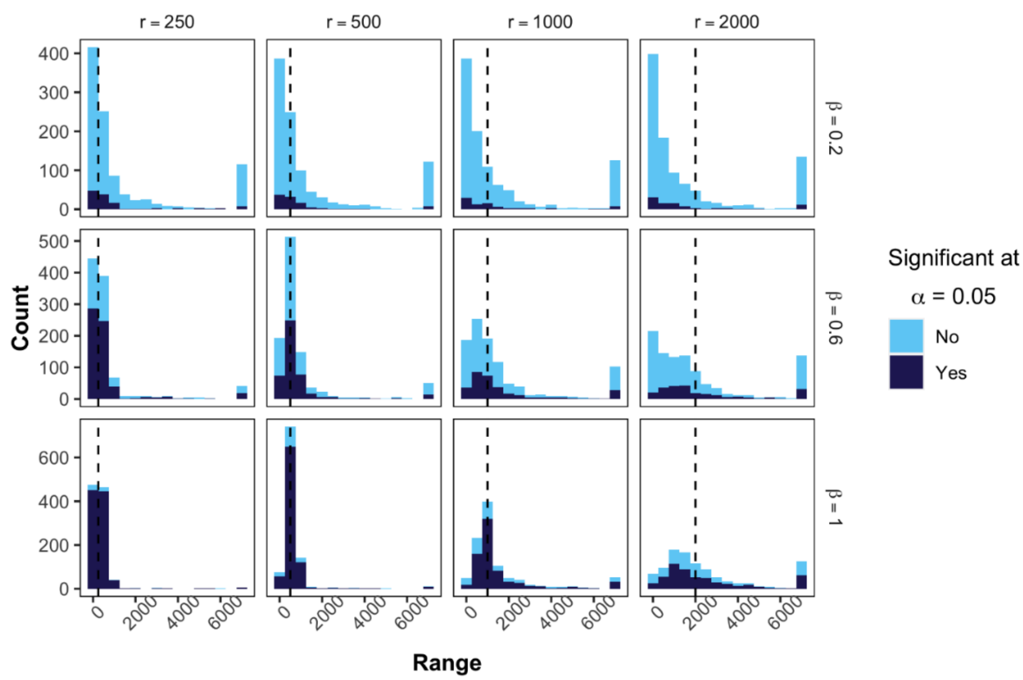

Figure 5. The estimated range values from 'scalescape' fit to 1000 simulated datasets across values of the range parameter (250m, 500m, 1000m, and 2000m) and regression coefficient (β = 0.2, 0.6, and 1.0). Vertical dashed lines represent the actual value of the range parameter used to simulate data.

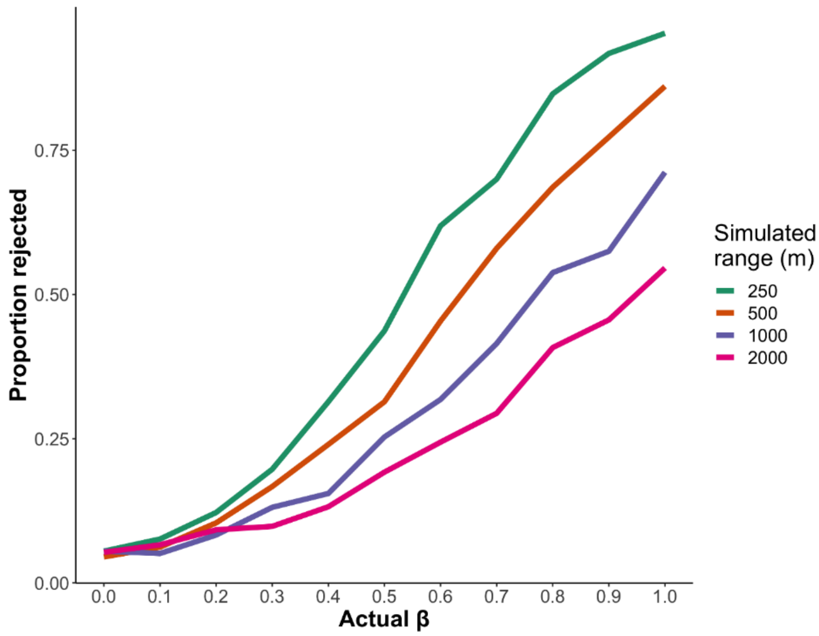

Figure 6. Proportion of 1000 simulated datasets in which the null hypothesis that $\beta = 0$ was rejected at an alpha significance level of 0.05 for values of the regression coefficient (β) between 0 and 1. Values of the range parameter were 250m, 500m, 1000m and 2000m.

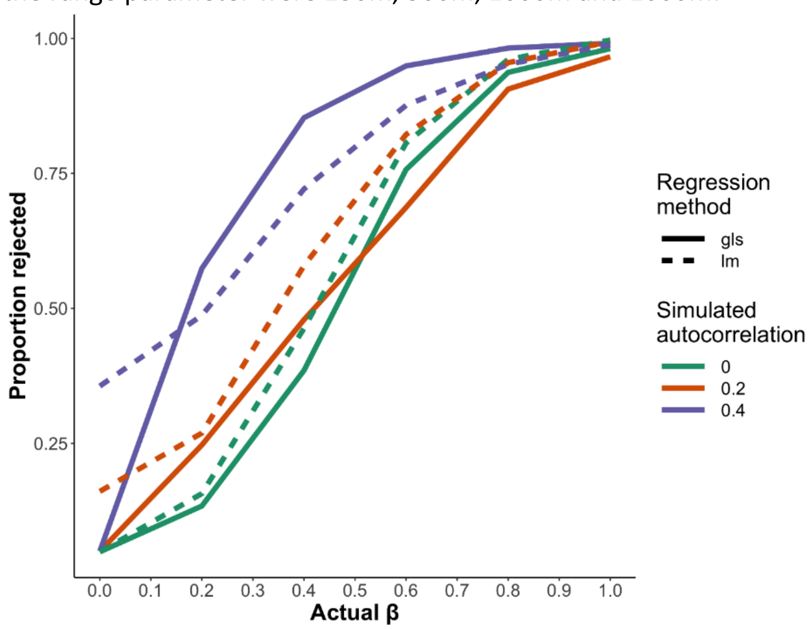

Figure 7. Proportion of 1000 simulated datasets in which the null hypothesis that $\beta = 0$ was rejected at an alpha significance level of 0.05 for values of the regression coefficient (β) between 0 and 1. Spatial autocorrelation in the random errors was 0, 0.2, and 0.4 (line colors), and the datasets were fit using lm() (LM, dashed lines) and gls() with a Gaussian autocorrelation function (GLS, solid lines). The value of the range parameter was 50m. Higher power is indicated by higher proportion rejected when the null hypothesis is false ($\beta \neq 0$).

Table 1. Issues with existing methods for estimating landscape effects on a response variable. Rows represent methods for estimating landscape effects, columns represent issues. Methods that result in a given issue are denoted by an X; N/A indicates that the issue does not apply to the method based on the way the method is implemented; blank cells mean the given issue is not a problem for that method. Several of the issues including both types of landscape correlation, and post-selection bias lead to inflated type I error rates.

Issues						
	A priori decision -making	Landscape correlation between buffers	Post-selectio n bias	Consistent landscape effect to a "threshold," no effect beyond it	Landscape correlation between sites	Inflated error rates from jointly estimating range and beta parameters
Threshold methods						
A priori (Figure 1a)	X	N/A	N/A	X	X	N/A
Multiple-buffer (Figure 1b)	X	X	X	X	X	N/A
Distance-weighted methods						
A priori (Figure 1c)	X	N/A	N/A		X	N/A
Multiple-buffer (Figure 1d)	X	X	X		X	N/A
Fitted range (previous methods) (Figure 2)					X	X
Fitted range ('scalescape') (Figure 2)						

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Chapter 3

Food systems transformation: Political ecology and managed grazing in the Midwestern United States

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Abstract

There is a need to transform the dominant food system into a system that better supports farmers, communities, and the environment. We explored what could facilitate such a transformation through the lens of managed livestock grazing in the Midwestern United States. To do this, we use principles of political agroecology to assess the transformative potential of a subset of change strategies proposed through 127 interviews and 3 participatory workshops with Midwestern community members. According to political agroecology, actions that support transformative change address underlying social and governance structures that maintain the power of the current agricultural system. In our context, these include those that address consolidation of markets and inequities in the distribution of land and capital; provide support for farm owners and workers; and challenge the social norms that support our current agricultural system. The actions with the greatest transformative potential do this in a way that shifts power to support community agency and promote more equitable resource allocation at a systemic level. This includes supporting cooperative models of farming, marketing, and resource-sharing; providing healthcare and living wages to farmers; supporting farmer-to-farmer networks; enacting legislation on crop insurance and anti-trust; curbing financial speculation in farmland; expanding agroecological education; and enacting policies that dismantle and repair colonial and racial violence. A disproportionate share of attention within the Midwest sustainable agriculture movement is currently focused on strategies that support sustainable farming practices but do little to address structures that maintain the power of the current agricultural system. While current efforts are important, some of this attention should shift if the goal is to facilitate transformative change.

1. Introduction

There is growing recognition that the dominant agricultural system is not working for many people, and that there is an urgent need for transformation (HLPE 2019; IPES 2021). Around the world, the expansion of intensive monocultures has led to degradation of soil health, water quality, and biodiversity (Altieri, 2009; Rasmussen et al., 2018). Because fewer people are needed to farm in this way, this has resulted in rural depopulation and community decline, an issue exacerbated by shrinking profit margins, which make farming an increasingly difficult profession. Moreover, many people globally are going hungry, not because of a lack of food, but because they cannot afford it (Basserman 2020; IAAKSTD 2009; Stone, 2019; Lappe 1998; Cleaver, 1972). Many of the current problems with the food system are interrelated – they are created and maintained by the same social and economic structures. While this presents a complicated web of challenges, it also means that the dominant food system is not inevitable and that it is possible to change. Alternative food systems exist, many in Indigenous communities, in which those who grow food are able to feed people in a way that creates positive outcomes for both the community and the environment (e.g., Altieri & Toledo, 2011; Marrero & Mattei, 2022; Xolocotzi 1985). In this project, we explored what could facilitate such a transformation through the lens of expanding managed livestock grazing in the Midwestern United States.

Managed grazing is an ecologically and culturally important farming practice in the Midwest. For thousands of years, people have shaped and maintained ecosystems across the region through grazing animals. Before colonization, Native peoples managed sustainable, perennial grazing systems in part through hunting bison migrating across landscape (Mueller et al., 2021; Shamon et al., 2022). During the 1800s, the U.S government slaughtered bison as a means of supporting its colonial campaign to violently displace Native communities from their homelands (Barnard, 2020; Smits, 1994; Taschereau Mamers, 2020). The colonization of Native food systems and the removal of the bison paved the way for dramatic changes. Originally, European settlers in the Midwest also grazed animals, managing diversified farms with both crops and pastured livestock. However, in the 1950s and 1960s, the Green Revolution created global policies and economic incentives that compelled farmers to move increasingly toward monocultures of just a handful of commodity crops (Guendel, 2005; Hemberger et al., 2021). These crops are used primarily to produce inexpensive livestock feed, which has encouraged farmers to shift from grazing livestock to feeding them in confinement (USDA ERS 2021). Re-integrating grazing represents a change that, if structured in the right way, has the potential to transform the agricultural system in the Midwest, revitalizing its cultural and ecological roots and better supporting both people and the environment (Spratt et al., 2021).

We sought to understand community perspectives on how to achieve this transformation through 120 semi-structured interviews and a series of participatory workshops with people who work in agriculture across the Midwest. In this paper, we use principles of political agroecology as a framework to understand the transformative potential of a range of change strategies proposed in the interviews and workshops. Political agroecology acknowledges that any type of systemic change is inherently a problem of power, as power is key to maintaining one system over another (Anderson et al., 2021). Thus, while many actions may support the practice of managed grazing, not all of these will promote transformative change. Transformative changes are those that shift power at a systemic level so that people who work in food systems can regain control over agricultural land, markets, and institutions; that address inequities in the distribution of power and resources; and that support healthy environments, communities, and livelihoods. To understand what is needed to promote this kind of transformation, it is necessary to address the social, economic, and political governance structures that maintain the food system itself. Therefore, in this paper we discuss actions that could support managed grazing in the Midwest, but the scale of many of these actions is broader than the region or any specific farming practice.

1.1 Theories of change

We have defined transformative change as changes that shift the power structures that maintain our current agricultural system in ways that empower farmers, communities, and the environment. However, many common approaches to sustainability transitions do not center power. For example, socio-technical transition theories (such as transition management and innovation systems) are commonly applied to sustainability-focused transitions, particularly in sectors like green energy. These approaches have been critiqued for emphasizing the technical elements of transitions (e.g., developing niche markets or providing technical support for alternative practices) without attending the power dynamics that inhibit change at a structural level, or influence who has a say in the change process (Kenis et al., 2016; Lawhon & Murphy, 2012; Markard et al., 2012; Ollivier et al., 2018; Voß et al., 2009). Much of the sustainable agriculture movement in the United States has adopted a similar focus, emphasizing more technical changes and relying on those considered experts or industry leaders to define how this process plays out (Anderson et al. 2020).

Political agroecology addresses these critiques by centering the knowledge of farmers, Indigenous people, and other communities disenfranchised by the agricultural system, and by focusing explicitly on the role of power in promoting or inhibiting change toward agroecological farming systems (Anderson et al. 2020). Agroecological farming systems, as farms that mimic natural ecosystems, have existed for millennia. In more recent history, however, agroecology has been articulated both as a scientific field and as a social movement. Historically English-language scientific literature disregarded many of agroecology's social elements, defining it primarily as the application of ecological principles to agriculture (Wezel et al., 2009). In contrast, social movements, many of which originated in Latin America, have long defined agroecology as a movement aimed at supporting food sovereignty and returning power to rural populations (Wezel et al. 2009). More recently, there has been an effort to merge these visions, defining agroecology as a science, practice, and movement (Rivera-Ferre, 2018). Following this more comprehensive view, Anderson et al. (2020) define agroecology as:

> "…an ongoing *process* of food-system transformation, supported by a set of underlying *values* based on ecological principles and social justice, and honouring the *agency* of food producers and the important role of social movements in transformational change."

Moreover, they define *political agroecology* as the application of political ecology to this vision of agroecology, emphasizing the critical role that "socio-economic power and good governance" play in agroecological transformations.

Political ecology seeks to understand the social and political forces that influence what happens on the land and to the people on it. It acknowledges that global markets, land policy, and conservation policy among other structural forces dictate how land is used, and like the environmental justice movement, it recognizes that the costs and benefits of this land use are often unevenly distributed (Robbins 2012). Likewise, it understands environmental (including agricultural) decision-making as a power-laden process because it involves determining who has or should have access to land or resources (Lawton and Murphy 2011). If these power dynamics are ignored, decisions tend to uphold the advantages of whichever groups are already the most socially powerful, thereby perpetuating inequities (Anderson et al. 2020).

By defining issues based on their broader social and political context, political ecology seeks to illuminate the linked causes of social and environmental inequities and the role that power plays in maintaining them (Robbins 2012). Farmers, for example, are often forced to make decisions on the basis of limited land or capital, or market forces outside of their control. Without understanding this context, we might define an issue with erosion on a farm as a problem of over-grazing. However, the underlying social cause of this problem may be insufficient land access and inability to make a living off a small number of animals (Lawton and Murphy 2011). Defining the problem based on this broader context may lead to different solutions, like changes in land or economic policy. While harder to achieve, such solutions often lead to more transformative change and equitable outcomes (Lawton and Murphy 2011).

The social, economic, and political structures that influence what happens on individual farms come together to maintain our current food system and inhibit change. These governance structures are upheld by actors with a vested interest in maintaining the current system. Increasingly, power over what happens in the food system has become consolidated in the hands of these few, reinforcing uneven power dynamics between agribusiness and farmers, and people of different races and genders (Anderson et al. 2020). For example, the meat industry is one of the most highly consolidated industries in the U.S., with just four companies controlling the majority of chicken, beef, and pork production (Chemnitz et al. 2021; Deese et al. 2021). This industry is bolstered by large subsidies in the form of crop insurance that support producing corn and soy for animal feed to the detriment of other types of agriculture. Racism and colonialism also play a significant role in structuring power in the U.S. food system, which has a long history of policies aimed at dispossessing farmers of color of land and resources (Graddy-Lovelace, 2017; Horst & Marion, 2019). This has led to an agricultural system in which 97% of farm owners are white (and 97% of wealth in the food system is accumulated by white farmers), while the vast majority of farm labor is done by people of color (U.S. Bureau of Labor Statistics 2022). Political agroecology recognizes that to transform our agricultural system, it is necessary to understand and address these power dynamics. Moreover, doing so can bring about the change needed to promote better outcomes for both people and the environment (Anderson et al. 2020).

While agroecology has in many contexts engaged directly with power and empowerment, some have emphasized that agroecological scholarship has failed to attend to the role of policy and other governance structures in promoting or inhibiting change (Anderson et al., 2021; Giraldo & McCune, 2019; Mier y Terán Giménez Cacho et al., 2018; Ollivier et al., 2018). Moreover, some have directly emphasized the need to identify how to dismantle the governance structures that maintain the current system (in addition to supporting agroecological practices), in order to create change (Geels, 2014; Klerkx & Begemann, 2020; Mier y Terán Giménez Cacho et al., 2018).

Using the principles of political agroecology, Anderson et al. (2020) have heeded this call by developing an analytical framework through which we can view the transformative potential of structural change strategies. This framework consists of six effects (suppress, co-opt, contain, shield, nurture, release) that different governance interventions can have on agroecological transformation (Figure 1). These effects are divided into three categories based on their transformative potential: those that *suppress* or *co-opt* agroecology strengthen the current system; those that *contain* or *shield* it maintain the current system; and those that *nurture* or *release* it, transform the current system to support agroecology. Moreover, the first three effects undermine agroecology and support the current system, while the last three can, under the right circumstances, support agroecological transformations, creating the conditions under which agroecological farming practices and principles can flourish.

1.2 Research system and approach

In this paper, we assess the underlying social causes inhibiting transformative change to the current agricultural system and apply Anderson et al. (2020)'s framework to evaluate the transformative potential of specific actions aimed at promoting transition from commodity monocultures to perennial pasture in the Midwest. Not all grazing is socially or environmentally sound. Like row-crop monocultures, grazing can drive soil erosion and decrease water quality, and when poorly managed grazing is often unprofitable (Bilotta et al., 2007). Likewise, while less labor is needed for grazing, grazing farms can still perpetuate the similar labor abuses as confinement operations. However, a well-structured managed grazing system in which animals are actively moved across pasture represents an agroecological farming practice that can support many positive social and environmental outcomes. By reducing the need for labor, equipment, and purchased inputs, perennial pasture can provide better economic outcomes for farmers. This decreases the need for government support, increases farm viability, and makes it so that farmers do not need to expand to stay in business (Spratt et al., 2021). These economic outcomes in addition to the active management required to sustainably manage a grazing system support and promote a greater number of small farms, creating opportunities to repopulate and revitalize rural communities (Spratt et al. 2021). The perennial plants used in many pasture systems also sequester carbon, improve soil and water quality, and provide better wildlife habitat (Spratt et al. 2021). Finally, many farmers talk about the lifestyle benefits of managed grazing, which creates a less dangerous work environment, enables them to work less overall, and connects them more directly with the environment and the animals they are raising.

Managed grazing is an agroecological farming practice in that it supports positive outcomes for the environment, rural communities, and farmer livelihoods. However, agroecological practices themselves do not represent agroecological transformation – transformative change happens through actions that shift the power dynamics that maintain the current agricultural system. Thus, agroecological practices and principles are supported by the process of agroecological transformation, but it is possible to support these practices (e.g., through providing limited funding and technical support) without truly transforming the system itself. Because the current system privileges conventional monocultures over alternative practices, without changing this system, agroecological practices like managed grazing may become more common, but they will likely remain marginal, occupying nice markets alongside the current agricultural system.

1.2.1 Power in the research process

While the primary focus of this paper is on action strategies that can shift power at the level of agricultural systems, power also plays an important role in dictating who has a say in defining transformation processes. Many critiques of socio-technical transition theories highlight this issue.

Socio-technical transition processes that do not attend to power dynamics amongst actors who are part of a change process are often co-opted by those with a vested interest in maintaining the status-quo, leading to "disappointing" outcomes (Vob et al. 2009).

We applied principles of both agroecology and participatory action research (PAR) to help us avoid some of these pitfalls. PAR is a community-engaged research approach in which researchers and community members participate in an iterative process of collaborative research, reflection, and action (Méndez et al., 2017). One of the goals of PAR is to unsettle traditional power dynamics between researchers and community members, challenging the role of researchers as "experts" and emphasizing a more democratic process of knowledge generation that values lived experience. Agroecology adopts a similar stance, emphasizing in particular, the knowledge of people marginalized within our current agricultural system: sustainable farmers, Indigenous peoples, and people of color. These groups have a long history of developing innovative sustainable agricultural practices as well as strategies that contest the current system (Altieri, 2004; Carney 2010; Kremen et al. 2012; Morales & Perfecto, 2000; Minkoff-Zern 2019; Penniman and Washington 2018; White and Redmond 2018). Thus, they are in many ways the best positioned to identify actions that support transformative change. In accordance with principles of both PAR and agroecology, we were intentional about interviewing and assembling a diverse set of people for our workshops. We specifically sought to learn from Native farmers and farmers of color, aspiring farmers, farmworkers, and organizations serving these groups; people who are often left out of conversations but hold valuable knowledge that can guide the change process.

1.2.2 Vision framing

In accordance with PAR, our research approach was informed by feedback from community members. The design of the workshops, in particular, was heavily influenced by workshop participants, and this feedback was important to both how we structured the workshops themselves and how we chose to frame our discussion of transformative change in this paper. Following Anderson et al. (2020) and others, we were initially thinking about change from the perspective of barriers to and opportunities for shifting away from the current agricultural system. This was reflected in our interview questions, which focused on barriers and opportunities for moving toward managed grazing systems. However, as we gathered feedback on the workshops, a few community members strongly encouraged us to focus less on the barriers created by the current system and more on developing a collective vision for a better future. One community member in particular, felt strongly that this would prompt broad, systems-level thinking, and encourage ideas that were more creative rather than reactive, allowing us to imagine possibilities less bounded by the parameters of the current system.

Following his advice, we used responses from two interview questions that focused on future visions, in conjunction with other instances in which interviewees spontaneously shared a vision for the future of the food system, to develop a picture of what a radically different food system could look like. In the workshops, we found that starting with the vision brought us to the underlying social, economic, and political governance issues we had hoped to highlight through a discussion of barriers to change. However, it achieved this in a way that did indeed prompt more positive and creative thinking. For this reason, we have adopted this framing in this paper. We first present a collective vision for a more just and sustainable future and discuss how this vision highlights the underlying social issues that prevent transformative change. We then turn to Anderson et al. (2020)'s framework to examine the transformative change potential of a range of policy and governance actions that interviewees proposed in the interviews.

2. Methods

2.1 Interviewees and Interview process

We conducted semi-structured interviews with 127 community members across the Midwest as well as 8 people from non-Midwest states to fill in gaps in expertise around anti-trust, land access, and labor organizing in the context of animal agriculture (Table 1). All of these peoples' work intersected with agriculture in some capacity, and most worked specifically with animal agriculture. Thirty-eight interviewees (31%) were people of color, worked in organizations led by people of color, or worked in roles primarily serving people of color. Twenty-seven (22%) interviewees were people of color.

While we interviewed people in many different positions across multiple states in the Midwest, most of the people we talked to were working in alternative agriculture. This was intentional in that we wanted to hear from those who had experience with managed grazing, and because we wanted to capture the perspective of people who were likely to have more transformative ideas about the future.

Most interview questions focused on barriers to and opportunities for expanding managed grazing in the Midwest. These included both questions specific to policy as well as questions on governance more broadly, two questions focusing on the changes that could support farmers of color and others who have been marginalized within the food system, and two questions about interviewees' vision for the future. For examples of our interview guides see Appendix A.

2.2 Data analysis

We used NVIVO (version 1.5) to code the interviews. Two of the researchers completed the coding using both an inductive and deductive coding process. We developed an initial set of codes based on themes we had heard when conducting the interviews. After each researcher had coded ~15 interviews, we discussed, reorganized, and added codes to our coding scheme based on what we had read. We repeated this several times over the course of coding (for our final coding scheme, see Appendix B). Each coder also maintained an individual list of "emerging codes" to track other themes that arose, but that were not common enough to integrate into our primary coding scheme. To increase inter-coder reliability, we coded the same initial set of 5 interviews and compared how we had coded each one. For passages we coded differently, we came to an agreement about how they should be coded. Out of these conversations we developed a set of criteria defining what types of comments should fall under each code as well as a protocol for comments that should be cross-coded to multiple codes.

Our coding scheme had two primary levels. Nearly all comments were coded under our broadest, "level 1" codes. These codes included all statements concerning the benefits/drawbacks of managed grazing, barriers to/opportunities for change, policy/governance, and visions for change. Most statements about policy/governance were cross-coded with barriers to/opportunities for change. Our "level 2" codes consisted of comments that fell under a narrower set of thematic categories e.g., lifestyle, community health, markets, social norms, education, subsidies, and food sovereignty. For a full list of our level 1 and level 2 codes, see Appendix B.

2.2.1 Visions for the future

We asked two questions focused on visions for the future: one asking about interviewees' vision for the future of farming in the Midwest and how managed grazing fit within that vision (if at all), and one about their vision for a just food and farm system. These two questions, as well as any other statements interviewees made expressing future aspirations, were coded as our level 1 code, "vision." To identify themes that emerged from these vision statements, we read through everything coded as "vision" and developed a new subset of codes specific to these statements (Appendix B). We then consolidated the codes into four broad themes: 1) Quality of life, 2) More, diverse farms for food sovereignty and environmental resilience, 3) Opportunities for the next generation of farmers, and 4) Democratizing food systems and redistributing power. In this paper, we use the vision themes to explore the underlying social issues that need to be addressed in order to achieve this vision.

2.2.2 Proposed actions to promote transformative change that supports perennial pasture

We used statements coded under our level 1 barriers to/opportunities for change codes to summarize interviewees' ideas about the policy and governance changes that are needed to transform our agricultural system. Many of these statements were coded under multiple level 2 codes. After reading through all the statements coded as barriers to/opportunities for change, we consolidated interviewees' statements into 8 primary categories of actions. These included: education, alternative markets, processing, essential workers, consolidation, capital, land access, and social norms (Figure 2). The examples we use in our analysis of Anderson et al. (2020)'s framework for transformative change are a subset of the action strategies that fell under these categories. A more complete summary of the actions proposed by interviewees can be found in Appendix C.

2.3 Workshops

The participatory elements of our research primarily came through in the workshops, although early conversations with one of our project partners did to some degree influence what we chose to focus on in the interviews. Half a year prior to the workshops we met with most of the workshop participants to assess their interest in participating in a set of workshops and to understand what could make the workshops useful to them. The workshops took form based on their feedback.

The goals of the workshops were:

1) To share and assess findings from the interviews with a subset of interviewees
2) To develop a vision for what transformative change could look like and create an action plan to carry forward that vision
3) To identify actions based on what we heard in the interviews and build collective power across the many initiatives happening around sustainable agriculture in the Midwest. A big part of this was connecting organizations who were not previously connected and making organizations more aware of each others' current work.

The first workshop focused on exploring interviewees' visions for the future of agriculture. In the second workshop participants identified actions that could help bring about the vision for change identified in the first workshop. We shared a summary of the policy and governance actions that interviewees had shared and facilitated conversations with workshop participants about their current work and additional actions needed to move toward the vision. The third workshop focused on strategies for building the collective power needed to move forward the actions identified in the second workshop. This included conversations on effective organizing strategies, activities to explore the specifics of a few of the actions identified in workshop two, and mini workshops on topics of interest including effective messaging and storytelling, developing cooperatives, and policy strategy.

Convening the workshops primarily with people we had interviewed served two purposes. In the spirt of participatory research, it allowed us to engage some interviewees in the process of analyzing the interview data. It also allowed us to choose people we felt were ready to have serious conversations about racial justice and transformative change. Twenty out of twenty-five workshop participants were non-profit employees and/or worked in Tribal government in Wisconsin and five were farmers. We did not include the people we had interviewed who worked in government positions as many of them had expressed reticence to speak more inspirationally about what they felt fell outside the boundary of their job descriptions. Participants came from Wisconsin, Illinois, Iowa, and Minnesota.

3. Results

3.1 Visions for the future

When asked about their ideal vision for the future, interviewees expressed a diverse set of hopes and dreams. We organized these into four main themes: 1) Quality of life, 2) More, diverse farms for food sovereignty and environmental resilience, 3) Opportunities for the next generation of farmers, and 4) Democratizing food systems and redistributing power. Not everyone mentioned all the elements of every theme, and there was disagreement about certain elements (e.g., the degree to which people wanted to see mostly small farms versus a mix of farm sizes). However, all the elements of the vision as we have defined it were shared by multiple interviewees.

We primarily interviewed people with a vested interest in managed grazing, and unsurprisingly, many saw grazing as both a means of moving toward the future they would like to see and an important element of their future vision. However, grazing was part of a much broader vision for change that encompassed supporting the environment, thriving and resilient communities, and future generations. One non-profit employee shared that he saw grazing as a means of honoring Indigenous practices that have “always been in the Midwest [and] are still alive today [in] the indigenous communities that have persisted in the face of the opposition and the efforts to eradicate their culture and practices.” He went onto talk about how he saw grazing as a means of rebuilding relationships “between animals, cropping systems, wild and natural systems, and human beings,” addressing issues with farm profitability, building resiliency in the face of climate change, and providing healthy food for communities. A farmer shared that grazing made farmers “happier” and provided more jobs for the community. She felt that this was a means of supporting future generations on the farm and addressing the issue of a “rural America that’s dying.” Likewise, a farm manager at a Tribal farm shared that he understood grazing as a means of stewarding the environment for future generations. He said: “…grazing [is] replicating those big herds of buffalo or cattle going across the savannas. Those did not degrade the soil…they built up the environment…We need to be working on those processes and those foods that we can provide for all future generations going forward.” These sentiments about grazing capture many elements of the broader vision that interviewees shared, which we’ve highlighted in the four vision themes below.

3.1.1 Theme 1: Quality of life

Central to this theme is the idea that people who produce and process food should be valued so that they can live a comfortable life and support community and environmental well-being. To some, this meant breaking down the false divide between farm owners and workers (farm workers are farmers in their own right and both are “essential workers”) and ensuring that both have access to social supports like healthcare, housing, a living wage, and a means to retire. These supports would make it easier for farmers to be good environmental stewards—to, as one farmer put it, “make a living…not off the land, with the land.”

3.1.2. Theme 2: More, diverse farms for food sovereignty and environmental resilience

Many people wanted to see more farms creating a “lovely patchwork,” of a variety of farm types and sizes. Managed grazing was a key element of this. People talked about how it could support the goal of having more farms rather than fewer and how it could build more thriving communities. They also stressed the importance building public understanding of the benefits and drawbacks of different ways of farming. Some connected this to building a diverse and regional food system, which they felt would help reconnect eaters with the farmers in their communities.

Interviewees imagined the positive impacts of these changes on community food sovereignty, "having control over what food we eat…where it comes from (and) whether it's destroying our backyard or not," and on building resilience against crises like COVID and climate change. While people talked about how a more diverse, regional food system could improve food sovereignty at a regional scale, they also wanted to see food sovereignty for individuals. They imagined a world in which everyone is able to access affordable, sustainably produced, and culturally appropriate food: one in which "an apple doesn't cost more than a doughnut" and in which "pasture(d) [meat] is the norm [at the] Dollar General."

3.1.3 Theme 3: Opportunities for the next generation of farmers

When interviewees talked about the next generation of farmers, they agreed that anyone who wants to farm should have the opportunity. They wanted to see more equitable access to land and resources, particularly for beginning farmers and farmers of color; pathways to ownership for farm workers; and more people of color in leadership roles. On a community scale, they imagined rural areas that would be far more cooperative and collaborative than many communities have become.

3.1.4 Theme 4: Democratizing food systems and redistributing power

Many envisioned a future in which democratic processes govern the food system and in which power and resources are distributed more equitably. In this vision, land and animals would be stewarded by more people, there would be less concentration in markets and processing, and government support would be shared across farms of all types and sizes. As a part of this, they imagined a food system in which the profits made by large companies would be shared more equitably with farm owners, workers, and consumers. To many Native interviewees, revitalizing cultural practices of cultivating and harvesting food was central to reclaiming power in the food system, as the U.S. government used European ideas of what a farm should look like to justify colonization.

3.2 What's needed to achieve the' vision for the future

The fact that the vision above represents interviewees' ideal *future,* indicates that our current system falls short of what they would like to see. Thus, by focusing on the details of what people shared when they talked about these four themes, we can understand the ways in which they feel the current food and agricultural system is lacking, and importantly, what needs to change to reach their ideal future.

3.2.1 Valuing essential workers

"Essential workers" (farm owners and particularly, farm workers) are disempowered within our current agricultural system. Thus, a critical part of the first vision theme was developing support structures to give them more agency and ensure the work they do is valued. This included guaranteeing both farm owners and workers have access to healthcare, housing, a living wage, and a means to retire. A number of interviewees stressed that this represents a very basic idea: to value the people who provide us with a fundamental service so that they can live life with dignity. One grazier shared that "most cattle producers would say that they're not in it to make millions and millions of dollars, but they want to do what they love, and they want to get a fair price for it." A University employee echoed this sentiment. She said: "we're not talking [about] entitlement to a fancy ass truck. We're talking about basic human needs. Food, nutritious food, health care, and access to a decent place to live. There's no guarantee [of] that, and here these are the people that are harvesting our food, growing our food, transporting our food." As this interviewee mentioned, dignity for farm workers was a critical part of this for a number of people. Another non-profit employee echoed this sentiment, sharing:

> "I think there's a way to [structure the food system] that also creates more equity for the people that have always done this work. [They] are the more marginalized people, whether it's people of color or immigrants. They've always been the ones doing most of the labor to make our food system run and just aren't getting credit for it."

Many farmers also emphasized that basic social supports would give them the agency to become better environmental stewards. As one grazier said, "If I didn't have to worry about profit, God, could I be a good farmer…a sustainable farmer." Another shared: "If…I could wave a magic wand, I would turn every acre that we have into a perennial system. I think it's more resilient…But I want to stay in the business of farming, and I can't do that with perennial systems at this time." Finally, interviewees linked the lack of social supports to the issue of land consolidation. A non-profit employee emphasized how "people hoard resources and land when their other needs aren't being met by the Federal government. I think people wouldn't need to sell land (to the highest bidder) to fund their retirement if we had more support for the dignity and retirement for people who [farm]."

3.2.2 Land, capital, and consolidation

In addition to ensuring that those who grow our food are supported, interviewees also expressed a desire to more equitably distribute the power and wealth that is currently consolidated by industry; large, commodity farms; and wealthy absentee landowners, so that more of the profit goes to farmers, workers, and consumers. One government employee expressed a frustration shared by many others around both with how difficult it is for farmers to get paid enough for their products and how challenging it is for many people to afford healthy, sustainably produced food. He said:

> "A just food system is one where the farmer gets paid and all of the community can access the food that's being grown. But unfortunately, those two sentiments sometimes go at odds with one another because what ends up happening is…grass-fed labels or your organic [products] become [niche foods that] only the wealthy can afford."

Others connected this problem directly to one of its underlying causes – the inequitable distribution of profits that result from industry and market consolidation. One non-profit employee said:

> "When I was in high school, the farmer received on average 45 cents of every dollar the consumer spends. Today the farmer is receiving about 16 to 18 cents of that consumer dollar. Where has that 30 cents gone to? It's basically went to the middleman, whether it's private corporations or private individuals. They're building their wealth very fast, where the farmers not. So really the consumer is paying too much for the products they're receiving versus what the farmer is receiving."

Likewise, a professor shared:

> "I think it's hard to have a just food and farming system if we don't redistribute some of the wealth from the massive corporations that profit off the food system. I think we get stuck in the weeds of talking about farmers versus farmworkers and small business owners…We ignore the fact that…no matter what the economy looks like, money's being made in the food system. I think we need to be targeting our energies towards redistributing that [wealth], breaking up…those monopolies that make it so everyone down the line just gets pitted against each other."

Likewise, redistributing power and wealth by addressing inequities in the distribution of land and resources was central to many of the vision themes. People wanted to see a future that would curb financialization and consolidation of farmland. As part of this, they talked about how addressing the inequitable distribution of crop insurance payments could support land access and environmental health. For example, one grazier shared: "[Because of crop insurance] farmers [are] planting corn knowing that their crop is going to fail just to get the insurance money…they're taking land that we could be using for grazing and…planting [steep] hillsides…this is, it's really harming a lot of things, harming the environment." They also imagined policies that would directly address concentration in land ownership. For example, a non-profit employee shared:

> "We're silent on who owns the land…That's why the largest farm landowner in this country is Bill Gates. There are systems at play that allow the aggregation of land. There are systems at play that allow the theft of land, the marginalization of people, removal of people from land, and we're silent on all of that, right…we're missing the critical piece."

As this interviewee acknowledged, a number of people emphasized that their vision included addressing the structures that have created race-based inequities in land and capital by redistributing resources specifically to people of color. One non-profit said that in her ideal future, "[land] ownership and access [would] prioritize young farmers who are from…historically marginalized communities." While another shared that: “my optimal vision…is that (American) Indian people can own and control and manage what was promised. They have protection of sites off the reservation that are still important to them.”

Community stewardship of land and resources was also an important part of people’s vision. They shared a wide range of possibilities for what this could look like including cooperative or collaborative farming, marketing, processing, and land and resource stewardship. Many felt that this could create stronger rural communities, lower the barriers to entry for beginning farmers, and create more viable opportunities for communities of color. An independent grazier and manager of a Tribal farm shared that if “us old people that are farming [could occupy land close to beginning farmers] we could share equipment, we could share knowledge. That communal farming is something I think that could be utilized to make it so that we actually get more people and get those marginalized communities back out onto the land.” Similarly, a conventional row-crop farmer and grazier shared the following vision for collaborative farming and marketing on her family’s land:

> “[My vision is] to have a collaborative farm that…younger people can feel [is] viable for them. [We can take] away the risk of owning land, housing, and equipment…The (family) farm, 1000 acres, [could] support 510 families on different farms…[we’d] market everything together…or [there could be] someone specific within the collaborative farm that did the marketing…I think for sure 1000 acres could feed a 10,000 population community, no problem. Charles City, which is our nearest town, is 7000 people. If we had the people, we could easily feed that community.”

3.2.3 Social norms

Finally, shifting social norms and values was an important part of all the vision themes and an underlying issue connected to many of the others around land, capital, consolidation, and essential workers. For example, people also spoke of community land stewardship as a means of fundamentally changing our relationship to land and land management. They expressed that the underlying cause of issues with both inequitable land access and detrimental land use is that many people conceptualize land primarily as a commodity and a financial asset. In contrast, as one non-profit employee shared, community land stewardship can provide a means of moving toward a view of land as "something that actually provides for community and that a community has responsibility to steward."

In addition to moving away from the conception of land as a commodity, a number of people talked about changing the way we conceptualize food, farms, and farm landscapes to value the wide range of environmental and community benefits they can produce. One grazier and farm educator shared that she would like to see:

> "Food become less of a commodity and more of a cultural experience where we celebrate around food, where we heal with food, that we recognize that it is a part of the gift of where we're living… our relationship with each other and our relationship with the earth can be healed immensely."

At the farm scale, a non-profit employee emphasized that he would like to see the agricultural system emphasize metrics of farm success based on how much a farm "support(s) the family that's growing that food and how much…that food support(s) the community that it's feeding," rather than on how much yield it produces. A government employee applied this thinking to farm landscapes, stressing that "we need to wonder more about…what does a healthy landscape look like? How does it feed multi-generations sustainably and answer cultural needs?"

Some interviewees also emphasized that the commodification of land, farms, and food is grounded in Euro-centric, colonial ideologies, and thus undoing legacies of colonialism and supporting communities of color is critical to shifting these social norms. For example, a non-profit employee noted that the conception of farms as a business came to the U.S. with European settlers, and that "Black, Indigenous, and people of color farmers and food producers hold significant value and wisdom" to create a food system that values agriculture beyond the profits it produces. Our conversations with Native interviewees underscored these important differences in the way they think about food and farming. For example, many emphasized that they think of "food as medicine" for physical, mental, and cultural healing, rather than as a commodity. Along with this, they underscored the impact that colonization has had on their food systems, culture, and health, and the importance of reclaiming traditional foods and farming practices. One Tribal farm manager shared:

> "When [Indigenous people] were given this highly processed flour and sugar [through colonial government programs] they did their best with what they had, and they made fried bread in grease…it's understood in a lot of people's minds that that's cultural [but] that's one of our foods and it really wasn't [part of our culture before colonization]. It sure as heck isn't healthy for you…we were one of the healthiest peoples. We'd like to get back to that."

3.3 Assessing the transformative potential of governance actions

The interview questions we asked about vision were distinct from those about barriers to and opportunities for managed grazing. However, when asked about barriers and opportunities, interviewees spoke about many of the same categories of issues they mentioned in conjunction with the vision in addition to some more specific, technical issues such as expanding grazing education and markets and increasing processing capacity (Figure 2; Appendix C). As with the vision, there are a number of critical concerns that are woven throughout all these categories, including equity and justice; environmental health and climate change; and human-environment relationships. Similarly, interviewees discussed governmental and non-governmental approaches to achieving many of these actions, and both approaches are woven throughout the 8 categories as well (Figure 2; Appendix C). Here we use the last three effects in Anderson et al. (2020)'s framework: *shield, nurture,* and *anchor/release* (Figure 1), to assess the transformative potential of a few of these actions proposed by interviewees. Shielding strategies can support the change process but on their own they maintain the current system, while strategies that nurture or anchor and release agroecology have the power to support transformational change through shifting power dynamics in support of agroecology.

<u>3.3.1 Shield</u>

Strategies that *shield* agroecology protect or provide support for agroecological practices like managed grazing but fail to unsettle the disproportionate share of resources dedicated toward the current system (Anderson et. al. 2020). Many of the shielding actions proposed by interviewees were centered around education, markets, or processing (Figure 2). These included proposals to increase technical support for managed grazing, beginning, and BIPOC farmers; to revise labeling laws or develop niche markets; and to provide more funding for small processing facilities or exempt them from certain regulations (Appendix C). These actions address technical problems that can support farmers who are farming agroecologically or make agroecological practices like managed grazing more common. However, because they do little to address the underlying issues that support the current agricultural system (consolidation of land, capital and markets, and social norms), they maintain the status quo. This means that with only shielding strategies, managed grazing and other agroecological practices are likely to remain marginal. Because of this, shielding strategies are not transformational on their own. However, they can support the process of agroecological transformation, and can have a powerful impact for individual people marginalized within the current agricultural system.

Government-funded farm conservation programs are an example of shielding strategies. Many interviewees expressed that certain government programs were helpful in enabling them to purchase infrastructure and other resources. However, they were frustrated that most of these programs support conventional farmers rather than supporting those who are already farming agroecologically. As one non-profit employee put it: “NRCS does not incentivize producers who are doing the right thing. They only incentivize people who are addressing a resource concern. Grazers don't have resource concerns because they have already been doing the right thing. So, it's backwards. The incentive structure is backwards.” Similarly, an NRCS employee and member of the Fon du Lac Band of Lake Superior Chippewa in Minnesota shared: “sometimes I think we just develop all these programs and the same people that are already on the land, owning the land, continue to reap the benefit.” This does little to address (and even exacerbates) the disproportionate amount of support dedicated to conventional farms versus those farming agroecologically.

Accordingly, people many wanted to see more programs that would pay farmers based on the degree to which they are farming agroecologically. Structuring programs in this way would have the potential to move these programs into the realm of nurturing, as it would begin to shift the balance of capital and resources dedicated to conventional farms toward agroecological farmers. It could also support beginning farmers who want to start farming agroecologically as opposed to primarily incentivizing existing farmers to change their farming practices. A number of interviewees felt more positively about the Conservation Stewardship Program (CSP) than other conservation programs, because it is set up to pay farmers for current practices. However, others were frustrated because the program does little to support a more agroecological, full-farm approach to farm sustainability. One grazier explained how this continues to benefit conventional farmers: "CSP is set up to give more options to crop farmers to layer on additional payments. [Integrated pest management] is a practice you can get paid for through CSP. I don't need it on my farm, so I don't have access to that incentive payment. You get paid more per acre by having more things stacked up than for having a comprehensive grazing program on your farm."

Another critical part of supporting grazing as part of an agroecological transition is ensuring that grazing farms do not replicate the patterns of labor abuse that characterize our current agricultural system (Spratt et al. 2021). Thus, a final important shielding strategy is farmworker campaigns such as the Milk with Dignity (MWD) campaign, which seek to build sustainable supply chains that improve conditions for farmworkers on dairy farms. MWD intentionally circumvents government policies (that fail to provide farmworkers with even basic labor protections like overtime pay) by having companies pay farmers so that they can afford to improve conditions for their workers. In exchange, farmers are expected to provide their workers with basic protections like quality housing, overtime pay, and paid time off. This approach emphasizes redistributing resources from companies who see a disproportionate share of the profits to farm owners and workers, and it has a critical impact on the lives of workers. This impact should not be understated. A MWD employee shared that:

> "When you're working a farm, you become like a servant. You work 24-7 at the farm because you live where you work. [After farmers sign onto the MWD program, workers work less overtime and have a day off] that's a great success."

Although campaigns like MWD have a powerful impact on the lives of workers, we have put these types of campaigns in the shielding category because they do not substantially change the position of workers or the relative power of companies within the food system as a whole. Because MWD is voluntary, the amount that companies pay to be a part of the program is a small share of their profits, and it does little to address the uneven distribution of wealth between companies, farm owners, and workers. Likewise, MWD faces an uphill battle in getting companies to willingly sign-on to the program and currently relies on a single company, Ben and Jerry's, which actively targets a socially-conscious consumer base. Finally, while the program makes substantial improvements in the day-to-day lives of many workers, it does not change the fact that many will continue to live in the shadows until they have substantive pathways to citizenship.

4.1.2 Nurture

Strategies that *nurture* agroecology are similar to shielding strategies in that, depending on the scale at which they are implemented, they do not necessarily dismantle social or governance structures that support the current agricultural system. However, they explicitly shift power by supporting farmer agency, community control, and self-determination (Anderson et al. 2020). Some nurturing strategies fell under the education category, including supporting farmer-to-farmer networks and building flexibility into government programs so that funding can be tailored to community needs. These actions are different from more common top-down methods of providing support to farmers because they support community agency. For example, one non-profit employee shared:

> "There's a lot of advocates advocating for instead of top-down grant funding opportunities, bottom-up funding opportunities, here community organizations or the people that are the most in need are dictating how that funding gets used so that it is culturally appropriate, so that it's making differences within the community."

Other nurturing actions overlap with fundamental elements of the vision, including supporting cooperative models of farming, marketing, and resource-sharing; and providing universal basic income or access to healthcare for farmers. As discussed, a number of these strategies address engrained social norms around land, the degree to which we value people within the food system, and the structure of rural communities, all of which are underlying issues that prevent transformative change. However, depending on the scale at which nurturing actions are implemented, they do not necessarily unsettle the current system. There are countries, for example, who provide farmers with wage protections and universal healthcare, but who also continue to provide a disproportionate share of resources to large commodity farms, failing to unsettle power dynamics at a systemic level.

4.1.3 Release and Anchor

Strategies that *release and anchor* agroecology are those that directly dismantle aspects of the current system (release) and replace them with agroecological practices (anchor) (Anderson et al. 2020). Through this process they institutionalize agroecology, transforming the dominant agricultural system so that it is structured around agroecological principles as opposed to supporting agroecology as a niche set of farming practices. Many examples of actions that could be releasing directly address the underlying issues inhibiting change. For example, interviewees proposed implementing antitrust legislation to reduce the monopoly power of agribusinesses companies and curbing financial speculation in farmland and limiting farm consolidation. Likewise, many interviewees discussed the importance of limiting crop insurance in terms of shifting power within the agricultural system. As a manager of a marketing co-op put it: "(Crop insurance is) giving [farmers] incentives to raise something that loses money. The government [subsidizes] tilling up the soil, pumping chemicals into it…spraying pesticides everywhere. Why are we incenting that system? …Because…big companies [are] making a living off that. I think that's the big thing that you need to change."

A number of people emphasized the impact of education in terms of releasing and anchoring agroecology. Specifically, interviewees discussed ways in which powerful corporate interests and agricultural policies that favor conventional agriculture influence the education system, and how this reinforces social norms about farm success and agricultural practices. One grazier talked about how "before ethanol and before crop insurance came along, Illinois was probably ahead of majority of the states in the Midwest doing grazing programs. But once that hit, the money [for grazing] left the University." Likewise, a University employee talked about the influence of corporate money on academia. He said:

> "[land grants are influenced by] very powerful corporate interests and [grazing] is essentially [striking] the heart of their business model. [At] Iowa State, and they do not allow dissenting voices…the Leopold Center for Sustainable Agriculture…was basically killed because…the word 'sustainable'…implied that the corporate industrial model is not sustainable. Power will kill anything that threatens its power"

A grazier and non-profit employee shared the impact this has had on academics at Iowa state in that she "got out of Iowa State thinking that animals could only eat corn and soybeans." More broadly, a Tribal farm manager emphasized how Universities reinforce a narrow interpretation of farm success based on yield rather than farm profit or the environmental and social benefits farms can support. He said: "[The benefits of grazing are] not getting out…through the universities [or] the tech schools, because so many of those instructors are still pushing yield, yield, yield…they're not looking at profits [or] the overall benefits of grazing versus conventional agriculture." Shifting the balance of agricultural education away from conventional agriculture and toward agroecological farming methods could thus have a significant impact in dismantling the power of the current system and anchoring agroecology by institutionalizing it in mainstream educational contexts. As interviewees pointed out, this could address underlying issues with social norms, shifting ideas about the type of agriculture that is valued and what we hope to get out of our agricultural system.

Likewise, as a number of interviewees emphasized in their visions, undoing colonial and racial policies can have a powerful impact in terms of reframing values around the purpose of agriculture, promoting agroecological farming, and shifting power toward those who have been marginalized by the dominant agricultural system. In this way, actions that seek to dismantle and repair legacies of colonialism are also examples of release and anchor policies. One non-profit employee linked the idea of redistributing land to the impact renewing Indigenous agricultural practices could have in terms of anchoring agroecology. He said:

> “I think [it] starts with understanding…the history of land management before the US was colonized…We forget that this land had been stewarded and preserved for many, many, many years. It's only in that short amount of time (since colonization) that we've seen these catastrophic changes to the landscape, to the water, and to our overall climate…remembering [this] can give us clues as to what…and who we might need to…learn from in order to move forward.”

To accomplish this, he emphasized acknowledging the role the U.S. government has played in creating inequities in land and resources, and dismantling these structures through land redistribution:

> “There were both legal and illegal transfers that were enforced by State-sanctioned violence against Native people and through the forced labor of Africans that [have] never been atoned for…Land didn't just pop up and exist, and people were like, 'Oh, it's yours. It's free.' That's a story that we're told, but that's not the reality in most cases. [Understanding this will] create the space for the actual transition of land that needs to happen to Black and Indigenous people…and [to] refugees.”

Members of the Onieda Nation in Wisconsin talked about the USDA FIDPR 638 Self-Governance Demonstration Pilot Program helps dismantle legacies of colonialism and anchor Indigenous agricultural practices. This program seeks to reorient a government food aid program, once used as a tool of colonization, to support Tribal food sovereignty. The U.S. government enacted colonial violence in part through systematically dismantling Native food systems and cultivating reliance on government food aid (currently the FIDPR program). Historically the U.S. government has controlled the sourcing and the type of food that is distributed through FIDPR, preferencing large farms off-reservation and commodity foods that have contributed to high rates of obesity and other health problems in Native communities. The

638 Program gives certain Tribes control over this process, enabling them to provide their communities with culturally appropriate foods sourced from Native farmers. This program is an institutional purchasing program, a category of programs that Anderson et al. (2020) classify as shielding because they often do little to change market structures that emphasize production while disregarding the impact of production methods. However, we would consider the 638 Program more transformative in terms of releasing the food system from colonial policies and anchoring agroecology through supporting the revitalization of Indigenous farming.

An example of a non-governmental anchoring strategy can be found in the Regenerative Agricultural Alliance (RAA). RAA seeks to build an alternative governance system based in agroecological farming practices (specifically grazed agroforestry systems), equitable distribution of power, and democratic governance. They primarily work with Latino/a farmers and former farm workers and are basing their system on Indigenous governance structures in Mexico and Guatemala, governing bodies that operate parallel to the State government. The emphasizes “horizontal…ownership, control, [and] governance” shared by farm owner and farm and food supply chain workers, with cooperatively owned supply chains and processing facilities and its own system of financial and technical support. While RAA is currently a young organization, their goal is to reach the scale necessary to anchor and institutionalize this governance system at a systemic level.

4. Discussion

We used interviewees’ visions for the future of our agricultural system to assess the underlying social and political factors inhibiting change. We then applied a framework developed by Anderson et al. (2020) to evaluate the transformative potential or actions interviewees proposed in responses to questions about the actions needed to support managed grazing. Across these analyses we found several key categories of underlying issue that inhibit transformative change. These include land and capital access, industry and farm consolidation, social norms, and a lack of support for farm owners and workers.

4.1 Visions for the future and underlying social issues

Interview questions related to the vision were much broader than questions focused on needs and opportunities for managed grazing. However, there was significant overlap in the types of issues interviewees discussed in response to both groups of questions. Many of the actions they proposed to support managed grazing were not specific to managed grazing or to the Midwest. Thus, it is clear many of our interviewees feel that to support managed grazing and other agroecological practices, it is necessary to address the broader, underlying structures that maintain the current agricultural system over its alternatives. This is consistent with political agroecology, which emphasizes that attending to these underlying structures is important in terms of facilitating transformative change (Anderson et al. 2020; Lawton and Murphy 2011; Robbins 2012).

Moreover, political agroecology posits that these underlying issues are revealed by understanding the broader social and political contexts of the problems at hand (Robbins et al. 2012). We found that focusing on interviewees' visons for the future prompts this broader focus; it illuminates what people want from the food system at a systemic level and thereby highlights the underlying elements of the current system that they would like to change. By asking what they would like to see, it gives them the freedom to dream about something that is profoundly different from where we are now and illuminates the path toward transformative change. Likewise, understanding issues within their broader context highlights connections between the social and environmental issues within our agricultural system (Robbins et al. 2012). This illuminates opportunities to build solidarity across movements, for example linking environmental and human health, or collaborating on advocacy efforts around labor, access to healthcare, or environmental justice.

4.2 Changes needed to achieve interviewees' vision for the future

Focusing more narrowly on what is needed to support managed grazing highlighted many of the same issues that interviewees discussed when they spoke of their vision for the future. However, it also prompted discussion of more technical issues around education, alternative markets, and processing, issues that are less directly tied to what interviewees expressed was needed to achieve the vision. Moreover, many of the specific actions that fall within the education, alternative markets, and processing categories are classified as shielding strategies within the Anderson et al. (2020) framework, indicating that they while they may support the change process, they have less transformative potential. This is not to say that these actions are unimportant. A number of researchers have suggested that actions such implementing education program that help farmers adopt agroecological practices on their farms can be an important factor for successfully scaling agroecology (Gliessman, 2019; Mier y Terán Giménez Cacho et al., 2018). Likewise, as many interviewees emphasized, these issues have serious implications for farm viability and on the ability of subsequent generations of farmers to enter the profession and addressing them can have a substantial positive on the lives of farm owners and workers. However, alone, these actions are unlikely to achieve transformative change as they do little to unsettle the power of the current system.

In contrast, strategies classified as nurture and anchor/release both address the underlying social and governance structures that maintain the current agricultural system, redistributing power to farmers, communities, and the environment. Nurturing strategies redistribute power through increasing the ability of agroecological farmers and communities to control how land and capital is allocated and creating space for dialogue that can help collective power, consensus, and shift social norms around food and agriculture. Anchoring and releasing strategies redistribute power through more equitable resource allocation and governance at a systemic level. However, conversations in the interviews and workshops indicated that a disproportionate share of effort across the Midwest sustainable agriculture movement is focused on these more technical issues (particularly education), and many workshop participants acknowledge that they would like to see more effort dedicated to addressing issues related to land and capital access, consolidation, supporting farm owners and workers, and social norms.

We applied Anderson et al. (2020)'s framework to a small subset of actions proposed by interviewees. However, in the future, this analysis could be extended to understand the transformative potential of a wide range of new or ongoing action strategies proposed across the Midwest sustainable agriculture movement. Likewise, the vision highlighted a number of underlying issue areas toward which efforts across the Midwest could shift to achieve more transformative change. Thus, this analysis can be used to guide the identification of priorities as activists, organizations, and farmers across the Midwest plan their next steps, a process that they have already begun through the workshops.

4.3 The role of government policy

Another important consideration in terms of planning for the future is considering the role of government in future action strategies. In this analysis, government policy has a role in change strategies across the Anderson et al. (2020) spectrum. Moreover, government policy is also critical to maintaining—and thus may be important in transforming—the current food system (Anderson et al., 2021; Avelino & Rotmans, 2009; Geels, 2014; Klerkx & Begemann, 2020; Mier y Terán Giménez Cacho et al., 2018). However, it is important to note that many agroecologists as well as a number of our interviewees were skeptical about the degree to which the government could or would support transformative change. Agroecologists have emphasized that government policies can be unreliable in terms of sustaining change because support for agroecology can fluctuate widely with the political leanings of government administrations (Giraldo & McCune, 2019; Mier y Terán Giménez Cacho et al., 2018), and some people, particularly those who have been marginalized through government policy, are skeptical that governments who create and maintain the current system will shift toward something better. Moreover, Anderson et al. (2020) warn against the potential of change strategies being co-opted to reinforce the power of the current agricultural system. While this can happen with both governmental and non-governmental approaches, it is a particular issue for governmental policy because the policy process is so heavily influenced by powerful actors. The co-option of government programs that could support agroecology is evident in interviewees' frustrations with government conservation programs, as well as concerns many expressed around carbon markets, which many felt would primarily benefit the status quo.

In addition, the more transformative the change, the more difficult it is to achieve through government policy. For example, one policy advocate told us that advocacy campaigns around crop insurance reform have been active for 35 years but have made little progress. A number of years ago, legislation to limit crop insurance payments had passed the House and Senate, but it was removed at the last minute. This has led many policy campaigns to focus primarily on shielding strategies such as developing programs that support alternative agriculture, e.g., crop insurance program for graziers, while leaving the structures that disproportionately support the current system, such as the current crop insurance program, in place. Because of this, it is perhaps important to emphasize non-governmental change strategies on the more transformative end of the spectrum: efforts like creating space for dialogue about the future of rural communities and the values the food system should support, promoting agroecological education at all levels, providing resources to develop cooperatives and farmer-to-farmer networks, and identifying mechanisms like community land trusts that can be used to give communities greater control over the land around them.

4.4 Conclusions

Achieving transformational change would require a shift in focus toward activities that support redistribution of power within the food system. Currently most change strategies focus on actions that support agroecological farming practices but fail to address the underlying factors that the maintain the dominant food system. While these efforts are valuable, more attention should focus on underlying issues: access to land and capital, addressing consolidation in land and markets, supporting farmers and workers, and shifting social norms, and within all of these, addressing legacies of colonialism, racial equity, and social and racial justice.

Understanding that the current food system is maintained through such deep-seated social, economic, and political structures is daunting. However, it is also hopeful in that if the food system is created and maintained by design, it can also be changed. The future vision indicates that many people would like to see substantial change in our agriculture and food systems. This is a powerful sign of solidarity. Even within the alternative spaces occupied by most of our interviewees, some people were self-conscious about expressing the substantial changes they hoped to see. A number of interviewees prefaced their ideas with statements like “I might be a little more extreme than some people” or “I don’t want to get too hippy on you.” Yet the visions these people went on to express were widely shared by others. Their reticence is a powerful indicator of how dominant cultural narratives can make ideas seem more extreme than they actually are even within alternative spaces. However, the degree to which elements of the vision were shared across interviewees indicates that there may be more willingness to organize around truly transformative ideas than some people realize.

Overall, Anderson et al. (2020) emphasize that political agroecology is an iterative and reflective process that involves “many transformations.” Change happens non-linearly, and much of what results will not align exactly with ideal visions for the future. Yet progress is often made through “retrenchment, ‘blowback,’ or inimical shifts.” By selecting a wider range of change strategies, including those that address the more underlying issues, the Midwest sustainable agriculture movement has great potential to move us toward a different future.

Tables and Figures

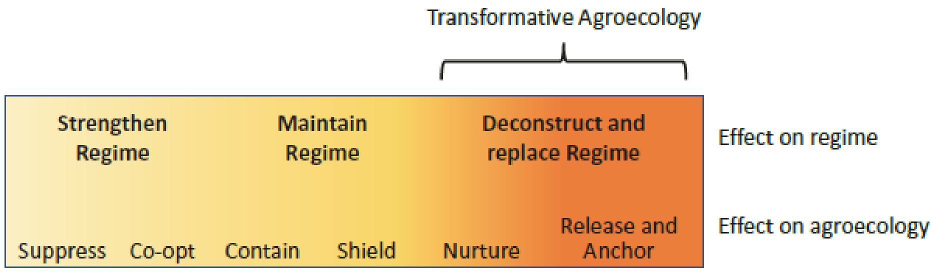

Figure 1. Anderson et al. (2020)'s framework for assessing the transformative potential of change strategies (figure reproduced with permission).

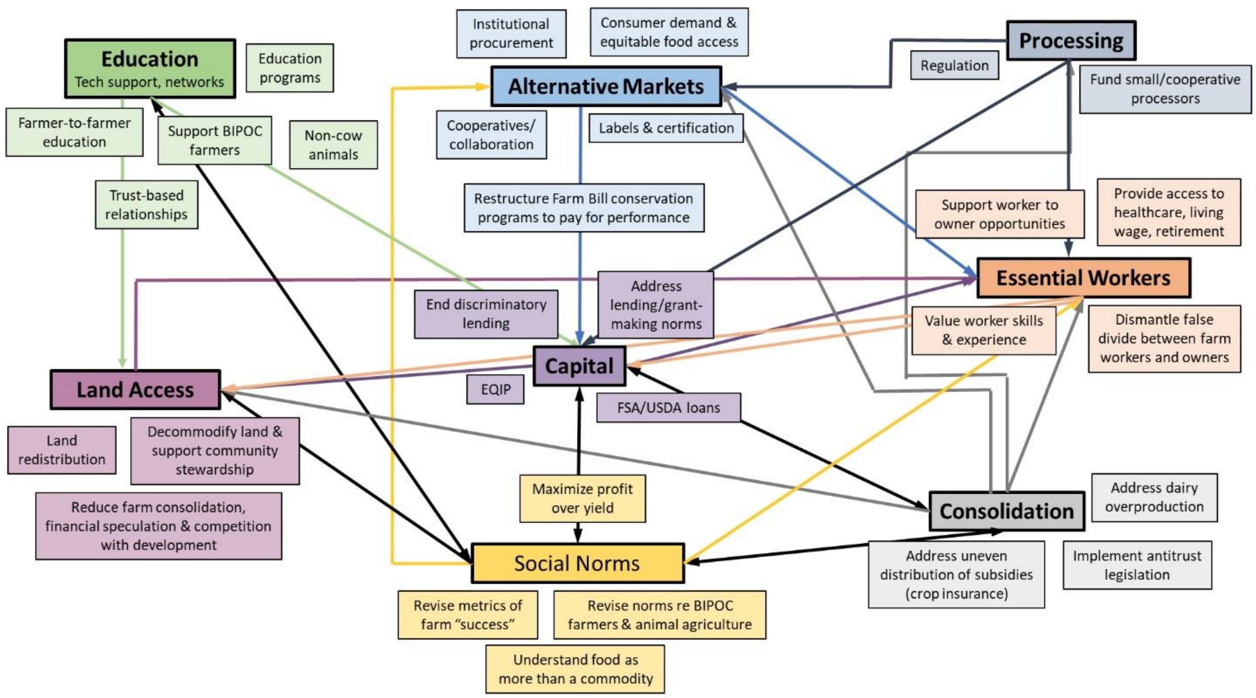

Figure 2. Diagram showing 8 categories of actions proposed by interviewees to promote change from our current agricultural system to one that supports perennial pasture. Lighter-colored boxes show broad examples of the types of propositions that fell within each category (for a more detailed summary, see Appendix C). Arrows indicate the direction of impact in the context of the actions proposed by interviewees. For example, an arrow goes from capital to land access because interviewees discussed how increasing land costs and lack of capital influence farmers' ability to afford land. The double-sided arrow between capital and consolidation indicates interviewees comments that more capital increases a farm or companies' ability to consolidate, which in turn influences their ability to gain more capital. More underlying issues are arranged at the bottom of the figure.

Table 1. Interviewees by state and profession. The 'miscellaneous' category includes people associated with colleges and universities, one person associated with the Farm Bureau, and one independent consultant. The state categories for organizations and companies represents the state in which the company or organization was based, however some operate across multiple states.

Profession	State							
	WI	IL	MN	MI	IA	MO	Other	TOTAL
Farmer	Dairy (7) Confinement dairy (3) Beef (6) Diversified (6) Goats (1) Pigs (1) Sheep (1) **Total: 25**	Dairy (1) Beef (5) Diversified (2) **Total: 7**	Dairy (1) Poultry (6) Diversified (1) **Total: 8**	Dairy (1) Sheep (1) **Total: 2**	Diversified (2) Diversified (aspiring) (1) **Total: 3**	N/A	N/A	**44**
Non-profit	People (12) Organizations (9)	People (7) Organizations (5)	People (5) Organizations (2)	N/A	People (3) Organizations (2)	N/A	People (5) Organizations (5)	**People: 32** **Organizations: 23**
Government	NRCS (3) State (4) County (1) **Total: 7**	NRCS (1) **Total: 1**	NRCS (2) State (1) **Total: 3**	NRCS (2) State (1) **Total: 3**	N/A	NRCS (1) **Total: 1**	NRCS (1) **Total: 1**	NRCS (10) State (6) County (1) **17**
Tribal government/ farms	10	N/A	N/A	N/A	N/A	N/A	N/A	**10**
Farmer education	4	N/A	N/A	N/A	N/A	N/A	N/A	**4**
Finance	3	1	1	N/A	N/A	N/A	N/A	**5**
Company	People (6) Companies (5)	N/A	N/A	N/A	N/A	N/A	N/A	**6**
Miscellaneous	3	1	1	2	N/A	N/A	2	**9**
TOTAL	**70**	**19**	**18**	**7**	**6**	**1**	**6**	**127**

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Appendix A: Interview Guides

1.1 Interview guide for graziers

Introduction
Introduce yourself and your farm:

- What kinds of animals
- How many animals
- How long have you been farming/grazing
- Do you come from a farming background?
- Do you rent or own land? How many acres?
- What county are you located in?

What do you think it means to be a successful farmer?

Benefits and drawbacks

1. What's something on your farm that makes you happy or something you're excited about for the future?
2. What motivated you to use managed grazing?
3. From your perspective, what are the benefits and drawbacks of managed grazing?
    a. How have you seen any of these benefits and drawbacks play out in your current work or on your farm?
4. Is there anyone else grazing in your area? Was there anyone when you started?
5. What do your neighbors think of you grazing? Are they supportive?
6. Do you know farmers who have converted a conventional operation to managed grazing? If so, how did it go for them? What do you think were their primary reasons for transitioning?
7. Do you know a farmer who tried grazing and then switched to conventional? If so, why?

Barriers and opportunities

1. What challenges did you face/are you facing in transitioning to or maintaining your grazing operation? Which are the biggest challenges?
2. Do you think your perception of barriers has changed over time (now compared to when you were newer to grazing/before you started grazing)?
3. Take a look at the barriers and opportunities document (see section *1.4* below), is there anything missing from this list?
    a. Which barriers on this list resonate the most with you and why?
4. What do you think would be needed to create a major transition toward managed grazing?
    a. If you had to prioritize, what seems most important?
    b. What seem the most changeable?
5. How do you think the types of changes needed to support new vs existing graziers differ?
6. Do you think there are unique barriers faced by farmers who come from historically marginalized backgrounds? If so, are there changes that would help address these barriers?
7. Have these barriers and opportunities changed recently due to the COVID-19 pandemic? If so, how?

Policies, programs, and networks

1. What specific policies or programs have helped you pursue managed grazing?
    a) Could you give an example from your experience of how this has made a difference?

b) How could these be improved?
2. What types of policies or programs would be helpful if they were to be introduced? Or eliminated?
3. Are there certain types of information or support networks that have been particularly helpful or that you wish you'd had better access to?
4. Have you interacted with a county, state, or federal agent, or with extension about grazing? Have they been helpful?
5. Do you have access to a grazing network or are there other farmers in your community who are grazing?
6. What should policy makers know about managed grazing and sustainable agriculture?
7. From your perspective, who would you identify as the most important entity or decision maker in the transition to managed grazing and/or sustainable agriculture?
8. What policies and programs are needed for beginning farmers, women, black, indigenous, and people of color farmers?
9. Has land access been an issue for you, personally? If not, do you know anyone who struggled to access land?
   - In a more general sense, how do you see land tenure and access factoring into this transition?
   - Are there specific actions or policies that might help with this issue?
10. Would you like to see more people farming? Who would you like to see compose the next generation of farmers and how would you like to see them farm?

10. What role, if any, does grazing play in your ideal vision of the future in the Midwest?
11. What is your vision for a just food and farm system?

12. Do you have anything to add?

1.2 Interview guide for non-profit employees

Introduction
1. What do you do in your current position?
2. How many years have you worked in your current position?
3. How many years have you worked in the food sector, agriculture, or natural resources overall?

Benefits and drawbacks
1. What is your understanding of the benefits and drawbacks of managed grazing?
2. Do you know farmers who have converted a conventional operation to managed grazing? If so, what do you think were their primary reasons for transitioning?
3. Do you know a farmer who tried grazing and then switched to conventional? If so, why?

Big picture transition
1. What are the biggest challenges that farmers face in transitioning to or maintaining a grazing operation?
2. Take a look at the barriers and opportunities document, is there anything missing from this list? Which barriers should be prioritized (see section *1.4* below)?
3. How do you think the types of changes needed to support new vs existing graziers differ?

4. Do you think there are unique barriers faced by farmers who come from historically marginalized backgrounds? If so, are there changes that would help address these barriers?
5. Have these barriers and opportunities changed recently due to the COVID-19 pandemic?

Policies and programs

1. What specific policies or programs help farmers pursue managed grazing?
2. What types of policies or programs would be helpful if they were to be introduced? Or eliminated?
3. What should policy makers know about managed grazing and sustainable agriculture?
4. From your perspective, who would you identify as the most important entity or decision maker in the transition to managed grazing and/or sustainable agriculture?
5. What policies and programs are needed to support beginning farmers, women, and BIPOC farmers?

Wrap up

1. What is your vision of a just food and farm system? What role (if any), does grazing play in this vision?
2. Do you have anything to add or other ideas you'd like to share?

1.3 Interview guide for Tribal government employees or farm managers

Food sovereignty, agriculture, and grazing

1. How would you describe your connection with agriculture/food in your community?
2. What does food sovereignty look like to you?
3. What is your ideal vision for the future of food and agriculture in your community?
4. Are there current food sovereignty efforts in your community that you're excited about?
5. Does grazing fit into what your conception of agriculture should look like? Does it fit into your conception of food sovereignty?
6. Do you have active grazing efforts? What kinds of animals?
    a) What have been some of the challenges to starting and maintaining those efforts?
7. Do you wish to expand grazing in your community? If so, what do you need to expand?
8. Is land tenure an issue for you or for members of your community? Are you interested in acquiring more land?
9. How has COVID-19 impacted you and your community?

Policies and programs

1. Are there specific policies, programs, or resources that have been helpful in supporting food sovereignty in your community?
2. Are there changes to existing policies and programs or additional resources that would be helpful in supporting these efforts?
3. Are there new policies, programs, or resources that could help support your vision of food sovereignty and/or support grazing in your community?

Wrap-up

1. What is your vision of a just food and farm system? What role (if any), does grazing play in this vision?

2. Do you have anything to add or other ideas you'd like to share?

1.4 Barriers and opportunities document

A document with the following categories was shared with all interviewees. They were asked to reference the document in response to the following questions:

1. What barriers or constraints do farmers face in transitioning to or maintaining a grazing operation? Which are the biggest barriers?
2. What do you think is needed to create a major transition toward managed grazing?
    a. If you had to prioritize, what seems most important?
    b. What seem the most changeable?

Here are a few categories to draw from, and please add to this list:

Economics & Finance
Debt, loans/credit
Insurance

- Consumer choices

Markets & Supply chains

- Brands, premiums, certifications, labels
- Processing facilities
- Industry consolidation
- Co-op policies

Social

- Identity
- Norms
- Values
- Lifestyle preferences

Education & Technical Support

- Farmer-to-farmer programs, pasture walks, extension, non-profits

Policy and governance

- Incentive programs (like Environmental Quality Incentives Program)
- Regulations, food safety standards
- Carbon markets
- Taxes
- Agency budgets
- Labor

Land tenure and land access

- Private land ownership
- Land redistribution, farmland transition programs
- Farmland preservation, planning/zoning
- Lease terms and conditions

Appendix B: Coding Schemes

1.1 Initial coding scheme

We aggregated everything coded as needs and/or opportunities based on our level 1 codes into 8 categories representing key themes that came up when people talked about what was needed to support managed grazing (Figure 2, main text). We used specific actions suggested within these categories (Appendix C) for the Anderson et. al. (2020) framework analysis in this paper.

Level 1 codes:

- **Benefits:** Any mention or reference to benefits of grazing; causes or reasons for wanting to transition to grazing
- **Drawbacks:** Discussion of drawbacks of grazing, experiences with challenges, or perceived challenges. Include any negative effects mentioned at the farm, community, regional level, and beyond
- **Barriers:** Barriers to establishing, transitioning, or maintaining a grazing operation. Code broadly, including barriers related to supply chain, cultural norms, education, access to resources, and any others mentioned
- **Opportunities**: Opportunities to help graziers establish, transition, or maintain a grazing operation including opportunities for systemic change; comments on how beginning farmers can or should get into farming (e.g. farmers can or should start by renting land, trialing a business, and then moving to land ownership); comments about programs that farmers have found helpful in their operation; comments about programs or policies that need to change
- **Governance** - Programs and policies (govt., NGO, or otherwise) that have been useful, not useful, should be eliminated (including grass-fed standards, labeling, regulations, etc.); existing and aspirational
    - **Programs** - government programs (except crop insurance because also coded as subsidies); including extension (should also be coded as academia)
    - **Tribal policy** -- government policy within Tribes
- **Vision:** Hopes and dreams for agriculture and grazing - farm level and beyond. Include all answers to the “successful farmer” question and the “vision” question. What is their vision for the future of agriculture, family, environment, economy, etc; Include instances when people talk about the future of family farms; *think about barriers/opportunities because often these come up in statements around vision*
- **Justice and Equity:** *Responses to questions about equity/justice including all questions about BIPOC farmers;* mentions of social justice, diversity, equity, inclusion, underrepresented/under-served/minority famers; statements about who is a farmer? E.g. graziers are white, farmworkers can or can’t be farm owners (*also coded as social norms*)
- **Human-environment relations:** Humans vs. nature, humans as part of nature, agriculture or any other category (e.g., markets, industry, human activities broadly) as inherently destructive or as conservation E.g., “win-win situation with the environment,” any mention of ‘inherent’ cost of ag or human activity, statements about farming practices being “more natural” or mimicking nature
- **Food culture:** cultural conception of food or ag - both farm-level practices and community or culturally important foods (including statements about Halal processing, etc.); statements about how religious norms influence land ethic/ag practices, etc.; *statements distinguishing culturally important foods or ag practices from others* (incl. comparisons to conventional ag)

  - **Indigenous agriculture**: statements defining Indigenous ag or distinguishing Indigenous ag from other types of ag; education around what Indigenous ag is (overlaps with education code, could overlap with certifications and others); traditional or culturally important practices around land stewardship, ag, or culturally important foods; Indigenous knowledge as it relates to agriculture; examples of specific initiatives
- **Key quote**: anytime anyone says something that's particularly eloquent or quotable, any key points that we think would be good to highlight in papers, on the website, etc.

Level 2 codes:
Most statements coded at level 2 codes were also coded with one or more level 1 codes

- **Grazing definition** - different kinds of gazing, e.g., managed, rotational, continuous, grazing cover crops - any comparisons between each
- **History of grazing** - references to how grazing culture/practices have changed over time due to structures, institutions, policies, economics, prices, etc. or changes in the number of people grazing, support structures for grazing, etc.; farmer stories of how policies affected their practices in the past
- **Grazing culture** - *current* amount of grazing in a community/community acceptance of grazing, support for grazing, cultural beliefs amongst graziers
- Grazing networks

Generally come up as benefits/drawbacks:

- **Lifestyle** - whenever people specifically use the term "lifestyle"; general statements about lifestyle, alt. lifestyle as a means of resisting the dominant system; statements about what they enjoy about farming or don't enjoy about other *types* of farming (including preferences around type of labor, etc.); statements about quality of life afforded by one type of farming over another
- **Labor** - statements different types of labor, enjoyment of different types of labor, statements about having time to do the labor (may sometimes overlap with lifestyle)
  Subnodes:
- **Farmworkers** - any hired help
- Slavery
- **Animal Health** - statements about animals being better-off, healthier, producing more milk, or living longer or the opposite in reference to a management practice (e.g. grazing, confinement, etc.)
- **Community health** - poverty, community revitalization/decline, examples of community capacity-building and resource development, community resilience
- Environmental health
- Subnodes:
- Soil
- Water
- Wildlife
- **Carbon & climate change** (including all refs to climate change, carbon sequestration)
- **Human health**: human health benefits of grazing; include statements about mental health; statements about healthcare *(also code as governance)*
  - **Nutrition** - nutritional health benefits e.g. health benefits of consuming grass-fed
  - **Disease** - human health risks of current ag system -- cancer, diabetes, etc
- **Family** - benefits/drawbacks of various farming practices to raising a family

- **Farm succession** - comments about succession planning, finding an heir, generational turnover, farm demographics (in terms of age); also statements like "I do this because this is how my parents/family did it" or statements about how younger generations are running their farms differently from their parents *(should also coded as identity);* statements about beginning farmers including comments about beginning farmers being more motivated to graze or specific challenges facing beginning farmers
- **Profitability** - profitability of grazing vs other operations; production vs profit or short vs long-term profit *(should also be coded as social norms)*

Generally come up as barriers/opportunities:

- **Social norms** - e.g., statements about production vs profit or short vs long term profit *(should also be coded as profitability*); definitions of "farmer," "farming," or "agriculture" (e.g. associated with technology or conventional practices, who or who shouldn't be considered a farmer)
- **Storytelling** - statements about the narratives/stories that create or recreate social norms
    - **Connection to food**: Stories of how a personal, family, or community experience with food or ag has influenced a person's or community's relationship to food or ag
- **Identity** - claims of identity, being and belonging; also identity markers including statements like "I do this because this is how my parents/family did it" or statements about how younger generations are running their farms differently from their parents *(should also coded as farm succession)*
- **Mindset** - mentions term "mindset"
- **Limited resources** - including limited funding due to budget cuts, limited staff/capacity or other resources for nonprofits, government agencies, grant funding, etc., statements about "it would be nice to have more resources for…"; code with capital if statement is about credit, loans, debt, up-front costs
- **Capital** - money, credit, loans, debt, other forms of financing (e.g. "the overhead to get started" or up front costs)
- Markets
    - Market access
    - Consumer demand
    - **Corporate control and consolidation** - in farms or to the supply chain; including statements about differential support for status quo vs alternatives (usually also coded as capital and barriers)
    - **Certification and labels** - certification programs including Organic or emerging certifications Indigenous, bird-friendly; any sort of labeling: grass-fed, country-of-origin; branding
    - **Ecosystem service markets** - carbon markets, markets for other ecosystem services
- **Subsidies** - any ref to farm subsidies incl crop insurance, commodity payments, lack of subsidies for non-conventional ag, etc.
- **On-farm infrastructure** - fencing, water, buildings, electricity
- **Infrastructure** - *not on-farm infrastructure -- that's it's own node;* large physical infrastructure that supports farms (public or commercial) e.g., transportation hubs, food hubs, cleaning facilities, distribution centers, broadband; *excluding* processing bc it has its own node
- **Processing** - meat processing facilities, permits, mobile processing
- **Education** - educating farmers (business, farming practice), consumers, communities, lenders, land owners

  - **Technical support** - farmer education on grazing practices, mechanics, etc.; statements about grazing being more complex than other practices
- **Relationship building** - technical support as a way of building relationships; the importance of relationships/relationship-building in accessing government programs/motivating change including issues around trust; how through relationships people are connected to programs and resources; things related to social support networks including farmer-to-farmer support networks, relationships between farmers and support organizations like WFAN; relationships between farmers and companies or conservation orgs
- **Land Access** - includes land dispossession
- **Social change** - emerging trends, movements, changes from accepted social norms/behavior patterns
- **Food sovereignty** - includes food security, the right to control the production and provisioning of culturally relevant food to your community
- **Politics** - direct references to politics, "political climate," "politics"
- **COVID** - when we ask questions about COVID or if people bring it up
- **Science and technology** -- direct refs to scientific innovation or technological innovation; statements of science as a driver of change; how science/tech/ag research (e.g. soil testing) has changed the way people think about farming, their ability to afford what they need for their farming operation, or their farming practices; technology diffusion and adoption; research/science as a way of validating agricultural practices
- **Academia -** direct mentions of "academia," "higher ed," "university," specific university institutions (e.g. UW), also mentions of extension *(cross-coded with programs)*
- **Biophysical:** statements about factors like weather, topography, geographic location that encourage/discourage certain farming practices, influence the amount of grazing, where people graze, how they graze, etc.
- **Genetics:** statements about breeding and genetics of animals

1.2 Vision coding scheme

The following coding scheme was applied to everything coded as "vision" under the level 1 codes above. We aggregated these codes into the 4 vision themes which we used to assess underlying issues preventing transformative change.

Relating to nature and ourselves – Farming that supports environmental and human health; incl general statements about caring for the land, etc.

- **Chemical-free** - incl. comments about reducing inputs, etc.
- Water quality
- **Climate resilience** - prepare/adapt for climate change, planning for perturbations, trade networks
- Climate-friendly ag
- Soil health
- Animal welfare
- **Wildlife** - incl biodiversity
- **Mimic nature** - perennialization, replicating the herds of buffalo, coexisting with nature
- Animal and Environmental health
- **Human and Environmental health** - note: don't confuse this with the human-environment relations code from our other coding scheme – I think that's more akin to the parent code; this should be about how a healthy environment also fosters human health, including community

health or subsequent generations (may come up as much or more than indiv human health) – could also be mental health - Happiness

- Economic and environmental sustainability

- **Local food:** building community resilience through local food / reconnecting people with their food
  - **Community resilience** - diversifying food grown within a given region, reducing dependency on outside support, food security/sovereignty, local markets, regional infrastructure
  - **Consumer education** - bringing people more in touch with food & where it comes from/the realities of farming; challenging the way people think about food

- **Community health** – broad statements about community wanting healthy, vibrant communities

- **Food security and sovereignty** - access to affordable, healthy, culturally appropriate food

- More diverse farms and farmers
- **Variety of farm types and sizes:** Greater variety of farm types and sizes - more small farms, family farms; comments about grazing
- **Tribal members back on the land** — add other groups inductively??
- Ownership for farmworkers
- Opportunities for Hispanic farmers
- More **cooperative/collective farming** – commons, co-operatives (formal and informal), collaborations, farmer-to-farmer
- Opportunities for **beginning farmers** - next gen of farmers, training/knowledge transfer

Racial equity: incl comments about deconstructing the racial caste system

- **Acknowledging dispossession** - history of genocide, slavery, ongoing racism/exclusion
- **Prioritizing opportunities** - prioritizing opportunities for people who have been excluded
- Reparations
- Representation/gatekeeping
- Whiteness
- Honoring Indigenous knowledge

Dignity for workers (incl farmworkers and ppl who work in food supply chains

Making a living (from farming); supporting farmers broadly e.g., making sure they have the ability to retire, have healthcare etc.

- **Equitable access to assets** (land, credit, capital, technology)
- **Living wage** - comments about ability to make a living, fair prices, price parity, taxes too high to make a living, etc.

Redistribute power & wealth: incl. comments about increase ownership & control

- **Corporate control & consolidation** – subsidies (also coded as “role of government”), farm consolidation, corporate consolidation (including in processing); help people understand where their taxes are going, even playing field for all farmers
- **Redistributing control** - redistributing control over land and other elements of food systems; democracy and democratic processes of participation

Role of government – EITHER quotes about the government needs to stop supporting x or needs to create a policy/program for y OR we need to build alternatives systems (can't rely on government) or we need it all to be market-driven

Build alternative systems: incl. comments about re-creating the current system, decommodifying food; an important theme under this is "scaling up" and "systems change"

Appendix C: Needs & Opportunities Report

The following report was shared with workshop participants after the workshops. We are in the process of collecting feedback from workshop participants and will be making edits accordingly.

Overview

This document is a draft summary of conversations with Midwest community members about what's needed to achieve a "just transition" in agriculture with a focus on expanding managed grazing. "Just transitions" encompass actions that allow those who work in agriculture and food systems to regain control over agricultural land, markets, and institutions; address inequities in the distribution of power and resources; and support healthy environments, communities, and livelihoods.

We interviewed 120 community members across the Midwest, primarily in Wisconsin, Minnesota, Illinois, Iowa, and Michigan. About 40% of interviewees were farmers (including farmworkers and aspiring farmers); 25% worked in non-profits; 14% worked for the US government; 10% worked in Tribal governments, mostly in WI; 6% in education; and 5% in other places such as financial institutions. Two out of five interviewees were people of color or worked in BIPOC-led organizations. We asked interviewees about their vision for the future of farming in the Midwest (see 4 vision themes in the main text) and about their understanding of barriers to managed grazing and pathways for change toward a more just system. We also organized a series of three participatory workshops with a subset of interviewees to explore the interview data in more depth. This document represents a summary of themes across both interviews and workshops.

The figure below (Figure 2 in the main text) is a visual depiction of these themes and how they relate to one another. The colors of each theme on this figure correspond to the references to the theme in the text.

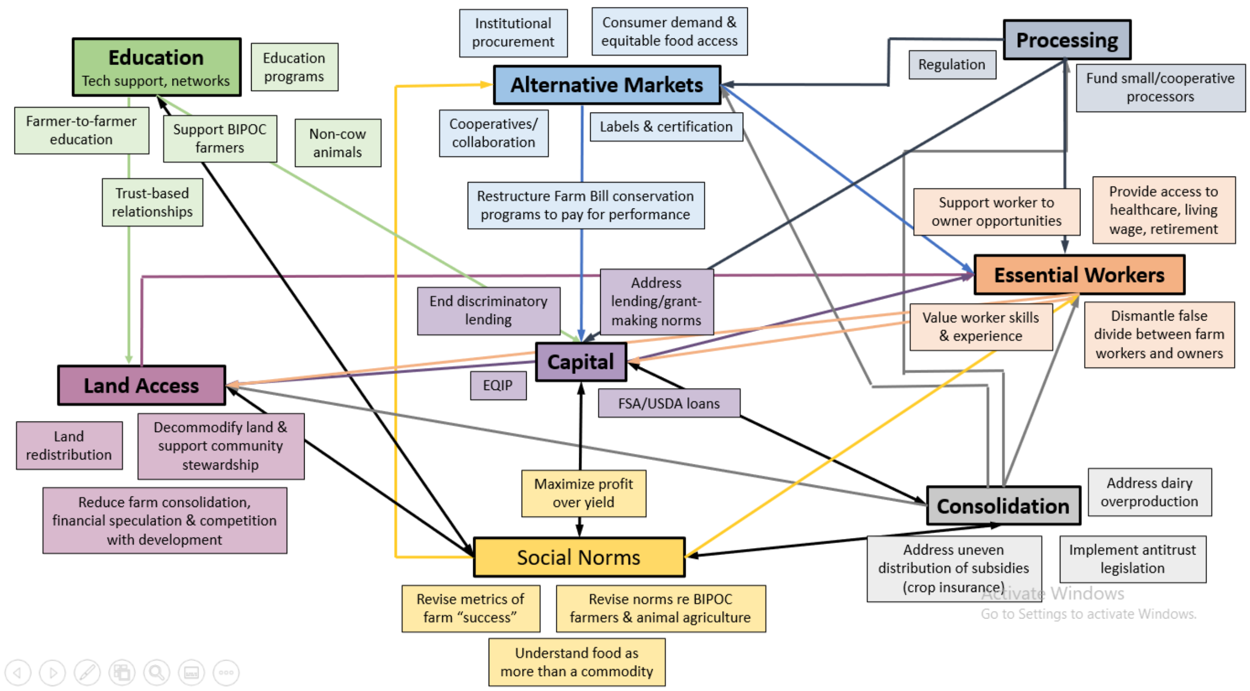

Figure 2. Diagram showing 8 categories of actions proposed by interviewees to promote change from our current agricultural system to one that supports perennial pasture. Lighter-colored boxes show broad examples of the types of propositions that fell within each category (for a more detailed summary, see Appendix C). Arrows indicate the direction of impact in the context of the actions proposed by interviewees. For example, an arrow goes from capital to land access because interviewees discussed how increasing land costs and lack of capital influence farmers' ability to afford land. The double-sided arrow between capital and consolidation indicates interviewees comments that more capital increases a farm or companies' ability to consolidate, which in turn influences their ability to gain more capital. More underlying issues are arranged at the bottom of the figure.

In this document, we use the term "BIPOC" – Black, Indigenous, and People of Color to highlight some similar needs and opportunities shared by these minoritized groups. However, we acknowledge that this also obscures important differences across communities, and have tried to highlight unique opportunities for specific groups (particularly Tribes and immigrant communities) throughout the document.

Takeaways:

The following represent some broad take-aways from what we've heard. We've divided the rest of the document into eight themes: education, alternative markets, processing, essential workers, consolidation, capital, land access, and social norms. Within these themes we explore more concrete opportunities for achieving these takeaways.

- Develop regional food systems composed of a variety of farm types and sizes; equalize support for smaller, sustainable farms
- Ensure farm owners, farmworkers, and food supply chain workers have access to basic necessities (e.g., adequate housing, healthcare, a living wage, and retirement)
- Create equitable opportunities for the next generation of farmers to access land and capital
- Create opportunities for BIPOC farmers and communities by supporting BIPOC leadership and enabling equitable access to land, resources, technical support, etc.
- Create pathways for farmworkers to build equity through their work and become farm owners

- Redistribute power and profits from large companies to workers and farm owners so that farmers can provide healthy and sustainable food at a price consumers can afford
- Provide more support for grazing animals other than cattle
- Support the development of cooperative and collaborative models of farming and marketing
- Advocate for Farm Bill policies and programs that pay-for-performance, and reroute funding away from industrial farms and towards sustainable farms of all types
- Reflect on what can and can't be achieved through the Farm Bill and policy work more broadly
- Support alternative economic systems that better provide for those who have been disenfranchised by government programs

Education

Needs at a glance:

- Increase support for farmer-to-farmer education networks including farmer mentors
- Increase the number of technical service providers with expertise in grazing, especially those with knowledge of grazing animals other than cattle
- Increase technical service support to BIPOC farmers by focusing on building trust and hiring staff from BIPOC communities
- Provide more education to farmers on business planning, marketing, lending, and government programs
- Invest in sustainable agriculture education at the high school and college level

Increase support for farmer-to-farmer education networks including farmer mentors

Many people emphasized the value of farmer-to-farmer educational networks (including grazing networks) and mentoring. Some said this was more important than investing in technical support providers and/or could make up for lack of capacity and knowledge within NRCS, extension, etc. They stressed that farmer-to-farmer networks are particularly important for beginning farmers (especially those not already connected with farm communities) and that they can encourage transitions to sustainable practices amongst existing farmers.

They emphasized programs that pay farmer-mentors for their time as well as the need for more people to support organizing farmer-to-farmer networks and connecting beginning farmers with those networks. Some people mentioned that many farmers refuse to mentor farmers of color. One black beginning farmer identified finding a mentor as his biggest challenge. Creating networks of BIPOC farmers and of farmers who are open to mentoring BIPOC farmers, as well as connecting people farming animals other than cattle would be helpful. IDEA Farm Network and Practical Farmers of Iowa's Labor for Learning, mentoring programs, and Beginning Farmer Summit were cited as useful examples.

Increase the number of technical service providers (TSPs) with expertise in grazing, especially those with knowledge of grazing animals other than cattle

Unsurprisingly, a large number of interviewees mentioned the need for more grazing planners and TSPs who are familiar with grazing, as well as more training for TSPs and more consistent support for grazing across NRCS offices. While access to educational resources has increased, there's no substitute for having someone coaching you through the steps, doing outreach to promote grazing, etc. This can be particularly important for helping beginning or transitioning farmers because grazing is a knowledge-intensive practice. Having people who can write grazing plans is also key to accessing funding through NRCS programs, and several interviewees mentioned that restoring funding for the Grazing Lands Conservation Initiative (GLCI) would help address the gap in grazing expertise (***see Capital***).

All interviewees who farmed livestock other than cattle mentioned frustration with the lack of technical support (including TSPs, but also veterinary support and research/access to information on breeds and genetics). They also talked about how this manifests in difficulty accessing government funding (e.g. difficulty finding TSPs who have the expertise needed to write the plans they need to receive funding, being told they need to purchase materials unnecessary for their animals to receive funding) (*see* ***Capital***). Finally, they described how some government programs aren't designed for certain types of animals or that they don't cover them at all (e.g. non-ruminants are not considered grazing animals and don't qualify for EQIP funding for fencing).

Increase technical service support to BIPOC farmers by focusing on building trust and hiring staff from BIPOC communities:

Many interviewees talked about how few relationships NRCS, extension, and other technical support providers have with BIPOC farmers (which resulted, for example, in the 5% of funds set aside for "underrepresented farmers" often going unused) and the need to build *trusting* relationships with BIPOC communities. Several immigrant farmers mentioned that they were afraid to use government programs (or do things like apply for loans, see capital) because no one spoke their language and they were afraid of making mistakes. Interviewees at government agencies (including individuals on the USDA Civil Rights committees) admitted to having little to no relationship with communities of color and limited plans for outreach.

Interviewees suggested a number of ways to address these problems including:

- Addressing racism within government agencies and technical or financial support providers
- Hiring people from BIPOC communities. This means not just hiring one person to work with the entire community, but hiring multiple people across various areas of expertise (or at a minimum hiring people with language competency).
- Building relationships with trusted organizations in BIPOC communities (e.g. community centers, mutual aid associations); making resources available there and in other places where people get information (e.g., tribal newspapers)
- Providing better education on how to navigate Federal programs and identifying ways to reduce complexity of application processes, especially for non-English speakers: e.g., walking people through the paperwork (in their preferred language) or providing space to verbalize (rather than write) things like business plans; using pictures; reducing jargon and defining terms like "organic" that are not as common in other countries
- Listening to communities and engaging them in program development rather than consulting them after programs have been created
- Building more flexibility into programs so that they can be tailored to the needs of communities
- Recommendations specific to working with Native communities:
    - Develop cultural competency with Tribal agriculture
    - Understand Indian law and Tribal land and legal structures
    - Create more positions for Tribal Liaisons (within NRCS), strengthen pathways for students from Tribal Colleges and Universities to get jobs at NRCS, develop and supporting organizations like the Wisconsin Tribal Advisory Council (which helps interface between Tribes and NRCS) in other states
    - Increase coordination between the USDA and the Department of Interior Bureau of Indian Affairs
    - Connect with individual Tribal producers – even if a Tribe has a relationship with NRCS, members of the Tribe might not know about USDA resources

Provide more education to farmers on business planning, marketing, lending, and government programs:

Farmers are expected to wear many hats and it can be particularly difficult for those engaging in sustainable agriculture to piece together funding sources and access markets in what is currently a niche industry. Beginning farmers who lack experience and connections and those whose first language is not English face additional barriers. Many farmworkers interested in becoming farm owners, for example, have a lot of skill and experience farming, but haven't had the opportunity to learn to manage a business (*see* ***Capital***)

Invest in sustainable agriculture education at the high school and college level:

Interviewees talked about how high schools should have more practical skills classes in agriculture or how experiences with agriculture in high school were fundamental in cultivating their interest in farming. People also mentioned this as a way to connect the next generation of eaters with food production. A few people also mentioned making ag programs more accessible to people in urban areas, for example, developing USDA demonstration plots along bus and bike routes.

Interviewees emphasized how education at the college level reinforces conventional agriculture and that there's a need to expose students to alternatives.They also emphasized that there's an interest amongst students and young people to learn about sustainable agriculture: one interviewee shared that at the technical college she works for, the sustainable ag program remains popular while agronomy was cut and dairy science may face a similar future due to lack of interest. She also highlighted successful examples of programs that connect high school agricultural experience with pathways to agricultural programs at universities.

Alternative Markets

Needs at a glance:

- Improve certification processes and address the co-option of labels
- Cultivate consumer demand for grass-based products and make them accessible and affordable
- Support markets for less common meats by resolving education and supply chain issues
- Expand institutional procurement programs
- Develop and increase support for collaborative and cooperative farming and marketing structures (***see*** ***Processing*** and ***Essential Workers***)
- Restructure government programs and ecosystem service markets to pay for performance

Improve certification processes and address the co-option of labels:

Interviewees expressed that labels and certifications can be important tools for improving the economic sustainability of their farms and a number of people expressed specific optimism around grass-fed labels. However, others shared that they'd found that grass-fed wasn't enough and that Organic certification was necessary to get the premium prices they needed. Some expressed that the Organic certification process can be frustrating due to staffing limitations within USDA and certifying organizations. Finally, many interviewees expressed frustration with companies who have co-opted and diluted labeling claims. Country of origin labeling (COOL) was a particular issue. Many interviewees expressed the importance of amending the COOL Law so that labeling reflects where animals are actually raised rather than processed (***see*** ***Consolidation***)

Cultivate consumer demand for grass-based products and make them accessible and affordable:

Interviewees emphasized that one way to increase support for Organic or grass-fed markets is to teach the public about the realities of farming and the impacts (good and bad) that farming can have on the environment. Many believed that this would encourage consumers to pay more for their products. They also emphasized the need for a more nuanced discussion around meat and both climate and animal welfare. While increasingly people tend toward vegetarian or veganism for both reasons, managed grazing can also be a part of the solution. Some interviewees tied public education to their vision for developing regional food systems. They emphasized that increasing the variety of food produced across regions would bring consumers closer to the source of their food and help them understand what it takes to produce it.

While many stressed the importance of price premiums and consumer education as important to sustaining their livelihoods, others emphasized that everyone should have access to affordable, culturally-appropriate, and sustainably produced food – that an "apple [shouldn't] cost more than a doughnut" and that "pasture-based [should be] the norm at the Dollar General." Some explicitly expressed a need to resolve tension between farmers' ability to make a living and the community's ability to afford food by more equitably distributing profits made in the food system (***see*** ***Consolidation***).

Support markets for less common meats by resolving education and supply chain issues

Raising animals like goats and sheep provide an easier entrypoint into farming for many beginning farmers, and there is market demand for bison and goats, particularly from communities of color. Profits for selling these animals at the sale barn or through niche markets can also be higher than for cattle. This is particularly true for sheep farmers since lamb is considered an upper class food and consumers are willing to pay a premium for it. However, farmers raising these animals also face significant market access and supply chain issues.

For goat farmers in the Midwest, the best return on investment comes from auctioning animals off at the Halal Slaughter in Shannon, Illinois, the only Halal processor in the region. Farmers who wish to sell goats or other small animals direct-to-consumer face high costs at local processors. Some farmers reported paying the same amount per carcass no matter the size of the animal, making the cost of processing smaller animals considerably higher than for animals like cattle (***see*** ***Processing***). These issues are exacerbated by a dearth of information, lack of veterinary expertise, and little technical assistance on non-cow animals which creates many challenges on the farm (***see*** ***Education***). Providing more support and processing capacity for these animals would help create more viable markets, particularly for beginning farmers, and increase access to culturally appropriate meat for local consumers of color.

Expand institutional procurement programs:

Institutional procurement was mentioned as an important tool for supporting BIPOC farmers in particular. One powerful example of this is how tribes have been utilizing institutional purchasing to regain food sovereignty through the Federal Food Distribution Program on Indian Reservations (FDPIR). The US government used food as a tool for colonization, systematically dismantling Native food systems and cultivating reliance on government food aid. Tribes have never before been able to control the foods allocated through these aid programs. Normally, the FDPIR program sources food from large farms off-reservation and contributes to high rates of obesity and other health problems in Native communities. However, the FIDPR 638 Self-Governance Demonstration Project has given certain Tribes (including the Menominee and Oneida Nations in Wisconsin) control over what goes into FDPIR boxes, enabling them to provide their communities with culturally appropriate foods sourced from Native farmers.

Another example from cities across the United States is the adoption of the Good Food Purchasing Program. This program reforms lowest bid procurement regulations and establishes a metric-based framework that allows large institutions to make purchases based on five core values: local economies, environmental sustainability, animal welfare, a valued workforce, and nutrition.

Develop and increase support for collaborative and cooperative marketing structures:

Many people expressed an interest in developing more collaborative or cooperative methods of marketing as a way to support graziers, beginning farmers, and BIPOC farmers. Visions for what this could look like ranged from simply facilitating more collaboration across supply chains, to establishing marketing co-ops (e.g., Wisconsin Grassfed Beef Co-op), to creating opportunities for groups of farmers to both farm and market more cooperatively (either informally or through more organized systems like the Regenerative Agriculture Alliance). One interviewee emphasized how important joining a cooperative with existing marketing channels had been to his success as a beginning farmer. Most of our interviewees were not currently part of cooperatives but many expressed an interest in these models, emphasizing the need to increase support for developing new cooperative or collaborative marketing structures.

Supporting these marketing structures was highlighted by many as a way to return marketing power to farmers. However, a few interviewees also mentioned how cooperatives, like many dairy co-ops, can become subject to corporate capture or get so large that they limit the power of farmers to have a say in their markets rather than expanding it (***see*** ***Consolidation***).

Restructure government programs and ecosystem service markets to pay for performance:

Many interviewees expressed a desire to change the structure of more government programs to pay farmers for their performance rather than rewarding farmers for reducing harmful practices. This could help even the playing field both for beginning farmers who wish to start a sustainable farm and existing farmers who have been farming sustainably for many years. These frustrations also extended to carbon markets which many felt would disproportionately benefit large, conventional producers and companies selling carbon credits. One interviewee talked about companies who have used carbon contracts to exploit Tribes, collecting profits up front and leaving Tribes to bear monitoring costs for the duration of 100-year contracts. In light of this, the National Indian Carbon Coalition was developed to help Tribes establish fair carbon contracts.

Resources:
https://www.fns.usda.gov/news-item/fns-0010.21. https://civileats.com/2021/11/01/after-a-fraught-history-some-tribes-finally-have-the-power-to-rethink-commodity-foods/]

Processing

Needs at a glance:

- Create opportunities for more small and cooperatively owned processors and for more mobile or on-farm processing
  - Change regulations
  - Fund small processors/mobile and on-farm processing:
- Address labor exploitation/value labor (***see*** ***Essential Workers***)
- Address consolidation in the processing industry (antitrust) (***see*** ***Consolidation***)
- increase educational opportunities around processing

The issue:

Interviewees cited loss of processing capacity for meat in particular, but also for dairy and fiber, as one of the biggest issues related to processing. In the meat industry, this has been driven primarily by successful efforts to loosen antitrust laws around meat processing allowing for rampant vertical integration and consolidation in the industry (***see*** *Consolidation*). The consequences of processing consolidation have been severe. Interviewees talked about farmers having to sign up for meat processing slots before their animals were born, loss of dairy routes increasing their milk hauling costs, and worries about the welfare of animals having to travel long distances to processing facilities.

Access to facilities that process small animals is generally more difficult than for cows (with the exception of chickens in some locations in part due to on-farm processing exemptions). This is exacerbated by higher costs to process smaller animals, different technical skills needed to make cuts on smaller animals, lack of access to specialized processing facilities like Halal processing, and processors increasingly specializing in a single type of meat (***see*** ***Alternative Markets***). While access to processing for smaller animals is often more difficult, diversifying animal production can create an opportunity for processors by helping to reduce bottlenecks due to seasonality in processing for cows (especially in grazing systems).

Opening new, small meat processing facilities is costly because all processors are regulated the same way regardless of their size. This leads to high startup costs and small margins especially for smaller processors. In terms of access to processing facilities, only ~25 states allow state-certified facilities (as opposed to those certified by the USDA) which reduces the number of processing options. Certain markets require farmers to use USDA facilities. This includes farmers who wish to sell across state lines and institutional purchasing programs (e.g., Tribes who wish to supply meat to their communities through the FIDPR Federal food distribution program).

The primary solution proposed by interviewees was to create opportunities for more small and cooperatively owned processors and for more mobile or on-farm processing.

Visions for cooperative processing ranged from a group of farmers or Tribes owning a plant together to worker-owned cooperatives to improve workplace conditions. Interviewees also talked about how small and/or cooperatively owned processing plants could create opportunities for people farming non-cow animals and open avenues for reconceptualizing waste within the processing sector. One interviewee emphasized the significance of her Tribe owning a processing facility in that it would allow the Tribe to harvest animals in accordance with cultural teachings, including making sure that no part of the animal is treated as "waste." To create more opportunities for small and cooperative processors, interviewees proposed:

- Changing regulations:
  - Regulating small processors differently from large processors
  - Reducing record-keeping/paperwork burdens for small processors

    - Hiring more inspectors
    - Building more USDA-certified facilities, easing restrictions on state/local facilities, and easing restrictions on which facilities farmers can use based on their end-consumers
    - Supporting the PRIME act which would ease regulations, allowing farmers to process meat sold on farms or at farmers' markets at "custom exempt" facilities (now used mostly by hunters). This is a start, but it's an incomplete solution because these facilities are often already at capacity and because farmers who use these facilities would be limited to a subset of potential markets.
    - Easing regulations through the Local Processing Act
- Funding small processors/mobile and on-farm processing:
    - Federal: Food Supply Protection Act, Value-Added Producer Grant program
    - State: rural development enhancement funds, tax dollars (already used to fund ethanol plants in some states), in WI: Department of Financial Institutions platform to crowdsource funding to start/expand a business (seldom used), in MN: the Local Food Advisory Committee which partners with the Minnesota Department of Agriculture has helped advocate for processing funding. Interviewees also highlighted discrepancies across states in providing funding to address processing issues.

In addition, some interviewees emphasized the need to address labor exploitation (***see Essential Workers***) and consolidation in the processing industry (***see Consolidation***), as well as to increase educational opportunities around processing at community colleges and other learning institutions to address labor shortages.

Essential Workers

Needs at a glance:

- Farmworkers and workers in processing plants:
    - Create more programs to educate workers on their rights
    - Provide workers with adequate housing, healthcare, job security, workplace protections, and living wages
    - Provide pathways for wealth-building and farm ownership if desired
    - Develop worker-cooperatives to achieve better outcomes for workers in the processing industry
    - Reform immigration laws including advocating for changes in the H-2A Program and amending state ID laws for those who are undocumented
- Farm owners:
    - Provide for farmer well-being: healthcare, retirement, living wages, student loan relief
- Develop/increase support for collaborative and cooperative farming and marketing structures (***see*** ***Processing*** and ***Alternative Markets***)

The issue:

Interviewees emphasized the need to place greater value on farm owners, farmworkers, and food supply chain workers. This includes both valuing the labor required to provide food to communities and to care for the environment, and supporting the people who do it. Providing access to basic supports like housing, healthcare, a living wage, and retirement is crucial. But people also expressed the need to shift the way we think about professions in the food and farm system. To this end they emphasized breaking down the false division between farm owners and workers: farmworkers are farmers and both farm owners and farmworkers are "essential workers. They also suggested removing the term "unskilled labor" from our vocabulary since it legitimizes low wages and doesn't describe the work being done.

While there may be some avenues for change within the Farm Bill, some interviewees emphasized that truly addressing these issues will require thinking beyond the Farm Bill, at least as it's currently structured. There are many active advocacy campaigns around affordable housing, healthcare, wages, retirement, and immigration and there is potential for more collective organizing to address these issues. Many farmworker advocacy groups and labor campaigns circumvent policy altogether, focusing instead on raising public awareness and pressuring large companies to ensure worker dignity throughout supply chains. This strategy works by exerting pressure where the most money and power lies within the food system (***see*** *Consolidation*).

Provide for the well-being of farmworkers and workers in processing plants:

On farms across the country, worker exploitation is rampant, with most of the agricultural industry staffed by undocumented workers living in slavery-like conditions. Workplace abuses often go unreported by workers who have not been made aware of their rights and/or fear deportation. There is a crucial need for adequate housing and housing stability. Many workers live in cramped, substandard houses provided by farm owners. Because housing is often tied to their jobs, many workers are in jeopardy of housing insecurity if they are fired. As a result of market shocks due to the COVID-19 pandemic, many farms laid off workers, leaving them without housing in the midst of the pandemic.

Another coping strategy for farms during the pandemic was to take on more animals to make ends meet. We heard from interviewees that many of these farms then asked employees to work harder and faster for the same pay. Farmworkers do not qualify for overtime pay like other workers under OSHA, opening opportunities for exploitation, particularly in crisis situations.

Many workers can't get IDs because of their legal status. Because of the isolated location of most farms, this means many workers lack control over their own lives. They must depend on farm owners just to fill basic needs like going grocery shopping or attending doctors appointments. It is important to amend state ID laws so that workers can access driver's licenses.

While most meatpacking workers are not tied to on-farm housing in the same way that farmworkers are, the processing industry is also primarily staffed by undocumented workers who face many similar challenges. OSHA is notorious for poor enforcement of worker protections in processing plants. The extent of workplace abuses was exacerbated during the COVID-19 pandemic under the Defense Production Act, which allowed plants to increase line speeds and put workers' safety in jeopardy without liability. The loss of middle-class jobs in processing has also led to a labor shortage, exacerbating processing capacity issues (***see Processing***). At one point butchering and other jobs provided middle-class wages, but since the 1980s butchering has seen a 40% reduction in salary adjusted for inflation. This is also in large part due to consolidation in the processing industry (***see Consolidation***) which has left workers with few options.

Interviewees discussed a range of solutions to these problems including:

- Creating more programs to educate workers on their rights
- Ensuring that farmworkers have access to adequate housing and healthcare (see spotlight on Milk With Dignity, below)
- Finding tangible ways to value the labor done on farms and in food supply chains (***see Capital** and **Land Access***). This could include:
    - Increasing wages and worker protections
    - Identifying ways for workers to build financial equity, and developing pathways to farm ownership for farmworkers who wish to own their own farms
    - Developing worker-cooperatives to achieve better outcomes for workers in the processing industry
- Reforming immigration laws includingadvocating for changes in the H-2A Program and amending state ID laws for those who are undocumented. This would need to be at the heart of any of the above solutions since in many states undocumented people can't access capital or own land.

Provide for the well-being of farm owners:

Farm owners expressed that grazing animals alleviated the amount of labor needed on the farm. They described how in sustainable agriculture systems much of the labor is done by nature. However, they still expressed being overworked and underpaid which limited their quality of life in many ways: it hindered their ability to apply for grants and access extension resources, to meet their own standards for environmental stewardship, to be creative, to take time for themselves, and to spend time with family. To address this issue, interviewees expressed a need to ensure farm owners have access to the basic necessities for a dignified life including healthcare, a living wage, and retirement. Classifying farmers as public servants and relieving student loan debt would also make a big difference for both beginning and existing farmers. A few interviewees also mentioned the need to address the mental health crisis amongst farmers. Providing access to healthcare *including* mental healthcare as well as resolving issues with wages and retirement would go a long way toward resolving this crisis which is exacerbated by financial instability (***see Capital***).

Develop/increase support for collaborative and cooperative farming and marketing structures:

Many were interested in more collaborative or cooperative ways of farming (***see*** ***Processing*** and ***Alternative Markets***). Farming in this way can help ease access for people with fewer resources, reduce risk, and allow farmers to ride out crises together rather than going through them alone. Visions for what this could look like ranged from developing formal cooperative structures, some of which included integrated cooperative models of farming, processing, and marketing; to collectively stewarding land, animals, and/or farm equipment; to simply normalizing collaboration and resource-sharing across independent farms within a given region. Specifically, one farmer expressed an interest in inviting other farmers to farm collaboratively on her family's land, and another has been searching for ways to allow his workers to build equity through their labor.

Many of our interviewees expressed interest in developing these types of models, however most were unsure how to begin. Collaborative and cooperative modes of farming and marketing are no longer as common in many farming communities in the Midwest. However, collaborative farming is a recent memory for many farmers, and within many BIPOC communities, collaboratives continue to thrive. There is a need to both highlight and support existing collaboratives and cooperatives as well as to provide more guidance on how to develop these models.

Consolidation

Needs at a glance:

- Increase equity in agricultural subsidies (crop insurance)
- Level the playing field by more equitably distributing profits made in the food system
- Institute policies to stabilize dairy prices

The issue:

Every interviewee who mentioned farm structure agreed that they wanted to see more farms, not fewer, and that there should be equitable opportunities for all farm types and sizes. Many specifically imagined a future with more small, diverse farms. Proponents of this vision emphasized that regional diversity would increase resilience in the face of crises like COVID and climate change. Consolidation directly inhibits this vision. People expressed concerns over both industry consolidation and farm consolidation. They talked about how consolidation is enabled by agricultural agricultural subsidies and antitrust laws. It's also reinforced by agricultural education, research funding, and lenders who all disproportionately support the needs of large, conventional farms (***see Education** and **Capital***). The result of industry consolidation is to concentrate power in the hands of large agribusiness companies, which primarily support large, commodity farms to the detriment of other types of agriculture. These companies have little interest in grazing or other ecological farming practices as these practices minimize the need for the inputs they sell.

Increase equity in agricultural subsidies (crop insurance):

Interviewees talked about how subsidies lock us into the current agricultural system, compounding the many issues this system causes for community and environmental health. By benefiting only commodity crops, subsidies drive other farmers out of business, consolidating the land into larger and larger farms growing corn and soy. This in turn drives patterns in animal agriculture, as low corn prices incentivise consolidation into CAFOs. Interviewees specifically discussed the role of subsidies in decreasing farmland availability and increasing its cost, increasing the price disparity between grass-fed and grain-fed meat and dairy, and harming the livelihoods of farmers worldwide by flooding foreign markets with excess products (***see Land Access***).

Every interviewee who talked about row-crop subsidies agreed that it would encourage a rapid shift in agriculture to remove them. However, a number of interviewees also stressed how difficult it has been to make change because of the entrenched power of industry. One policy advocate talked about how there have been efforts for 30-35 years to cap subsidies to no avail. These interviewees emphasized the importance of providing subsidies for alternatives like grazing or making changes to crop insurance policy as a more viable way to shift the status quo.

Several farmers expressed interest in an insurance program for pasture. While the Pasture, Range, and Forage program theoretically supports grazing, few thought it was useful. They discussed how difficult it was to use and how the payout wasn't enough to cover insurance costs. Other interviewees suggested changes to crop insurance policy like allowing farmers transitioning to grazing to keep their base acres and tying more conservation programs to crop insurance.

Level the playing field by more equitably distributing profits made in the food system

Several interviewees emphasized the need to level the playing field by more equitably distributing profits made in the food system. They pointed out that retailers, corporations, and agribusiness companies make increasingly massive profits, but that these profits aren't shared with most farmers, consumers, or farmworkers. As an illustration of this issue, bacon is now more expensive than it was in the 40s and 50s (adjusted for inflation), yet farmers take home a smaller amount of every food dollar than they ever have. This creates a false tension between farmers and consumers and farm owners and workers. When farmers don't make a living wage themselves, they struggle to pay their workers and rely on price premiums that many consumers can't pay (***see Alternative Markets and Essential Workers***).

Interviewees proposed increasing corporate taxes, promoting cooperative ownership at all levels of the food system, and implementing antitrust legislation as ways to address this issue. One interviewee mentioned that antitrust issues were once addressed through legislative action, but today this happens primarily through the courts. Because the fines imposed through antitrust lawsuits are minimal in comparison to companies' profits, legislative action is necessary to make any real difference on consolidation.

Helpful legislation would include policies that:

- Prevent vertical integration, e.g., companies can no longer own the animals they slaughter or they can only slaughter one type of meat
- Prevent companies from merging with others after they own a certain number of market shares
- Phase out CAFOs
- Update the legal frameworks for cooperatives to ensure new cooperatives aren't subject to corporate capture as in the dairy industry

While judiciary action is limited in terms of what it can accomplish, there is also a need to encourage attorney generals to hire antitrust attorneys at a state level as many states lack this kind of judiciary capacity.

Institute policies to stabilize dairy prices:

Overproduction and industry consolidation is driving low prices and price instability in the dairy industry. As a result, small dairies are driven out of business, promoting the consolidation of farms into CAFOs. Supply management was cited as a policy to address oversupply, and amending regulations that prohibit direct-to-consumer sales of milk would give small dairies freedom from having to take whatever prices are offered by dairy companies.

Capital

Needs at a glance:

- Expand ways for farmworkers to build equity
- Provide relief from student loan debt
- Move beyond loans as the primary tool for financing beginning farmers
- Streamline funding sources across government agencies
- Provide education to lenders and grant-makers
- Adjust lending and grant-making norms
- Amend USDA and FSA loan programs
- Amend the Environmental Quality Incentives Program (EQIP)
- Create a program to help fund basic operating expenses for farmers
- Develop and expand financial mechanisms that support small farm businesses

The issue:

Debt and equitable access to capital were seen as critical problems by many interviewees. Some people mentioned that farm loans are much more difficult to attain than other types of credit. They also emphasized the degree to which debt and access to capital influence how we do agriculture. Lenders preferentially grant loans to large, conventional farms both because that's the type of farming they understand, and because they see large farms as "too big to fail." Meanwhile, debt from capital and infrastructure investments lock conventional farmers into their production practices, while cash-flow and farm viability issues exacerbate this problem. When profits are good, farmers have little incentive to change their production practices, and when they're bad, they have the incentive, but little ability to do anything differently (***see*** *Consolidation*). This also has serious implications for farmers' mental health, with higher suicide rates among those with debt and financial insecurity (**see** ***Essential Workers***). People talked about how managed grazing offers a relatively low-cost way for beginning farmers to get into agriculture, at least as compared to conventional models like row-crops or CAFOs. However, many also emphasized that farming animals requires far more up-front land and capital than farming vegetables, meaning that grazing is out of reach for many. Smaller animals provide a less costly entry-point than cattle, reinforcing the need to support other types of livestock (***see Education, Alternative Markets, and*** *Processing*).

General needs expressed by interviewees included expanding ways for farmworkers to build equity and providing relief from student loan debt (***see Essential Workers***). Some also discussed moving beyond loans as the primary tool for financing beginning farmers because many people who are interested in farming, particularly young people and BIPOC folks, don't qualify for business loans. Finally, one interviewee emphasized the need to streamline funding across government agencies, concentrating it into fewer, larger, and more flexible pools rather than underfunding many small programs.

Lender and grant-maker education:

Many interviewees shared that lenders often have a poor understanding of non-conventional agriculture, making it difficult for other farmers to access loans. They emphasized that there's a need for lender education around managed grazing and other sustainable farming practices that emphasizes how these practices can mitigate long-term risk. Likewise, some people wanted to see lenders who are better versed on beginning farmer loan programs and more able to help beginning farmers who might not currently qualify for a loan determine how to do so in the future.

Overall, there is a need for lenders and grantmaking institutions to expand their cultural and language competency. By far the best way for them to do this is to increase representation within these institutions by hiring folks from BIPOC communities. However, at a minimum, educating staff on cultural differences and Tribal governance structures, and hiring people who speak languages other than English would be helpful.

Adjust lending and grant-making norms:

A few interviewees emphasized the need to change the way lenders assess risk including incorporating how different types of agriculture can increase or mitigate this risk into risk assessments. One interviewee told us that in the philanthropy sector, grant reviewers often ignore grants with small mistakes like grammatical errors. This denies capital to many farmers with limited education or experience applying for grants and loans particularly those who didn't grow up in the US. Several immigrant farmers spoke about how they pay cash for everything, are afraid to apply for grants or loans, or avoid making certain business decisions because they fear making a mistake. Similarly, many lending institutions may ask for farm business information that farmers in other countries do not traditionally keep written records of. Adjusting these expectations or providing more education on how to navigate the system is important.

One interviewee shared that despite a good track record on paying back loans, many Tribes are assessed by lenders as "high risk," and turned away or charged exorbitant interest rates. Similar attitudes extend to other BIPOC communities. Redlining is often viewed as an urban issue, but one Black farmer shared that redlining is also an issue in her rural community which has a large number of Black farmers.

Finally, changing policies that govern lending institutions, such as the requirement that clients provide immigration papers or provide land and other assets as collateral would be helpful. Using land as collateral is a documented cause of land loss amongst Black farmers and other farming communities (***see Land access***). To address this issue the Indian Land and Capital Company has established a "full faith and credit" model where Tribes must show they can back the loan but do not have to put up assets as collateral. Implementing similar models in traditional financial institutions would be helpful but this is currently prohibited by bank regulators.

Reform FSA and USDA loan programs:

While a few interviewees had positive experiences with FSA's Beginning Farmer Loan Program, many also suggested improvements:

- Increasing loan limits to keep up with land costs and covering leases as well as land purchase
- Adjusting requirements for the Beginning Farmer Loan program so that farm labor counts as valid farm management experience (***see Essential Workers***)
- Reducing income requirements for loans to eliminate trade-offs between access to capital and healthcare. One interviewee mentioned that to qualify for a USDA loan they had to make enough money that they lost access to state-sponsored healthcare, even when healthcare continued to be unaffordable to purchase on their own (***see Essential Workers***)
- Making Tribes eligible for USDA grants for capital projects like other US territories. The fact that tribes are not eligible for the same grants as these territories represents a failure to acknowledge that tribes are sovereign nations.

Amend the Environmental Quality Incentives Program (EQIP):

Many interviewees expressed how helpful EQIP had been in supporting infrastructure investments on their farms. This was particularly important to cover fencing costs, a particular issue in Midwest states where fencing has been largely removed. However, many interviewees also suggested changes to EQIP, particularly from an equity and justice standpoint.

- Make EQIP easier to use: Many interviewees talked about speeding up the EQIP application process and making it less complicated. They also expressed that many of the infrastructure standards, particularly for fencing, are more robust than they need to be. They recommended changing these standards so that they are less over-engineered and therefore less costly. Hiring more staff, particularly people with the expertise to write grazing plans would also be helpful in terms of speeding up wait times (***see Education***).

- Eliminate requirements for up-front capital: Interviewees recommended making changes that help farmers access up-front capital needed for EQIP projects and eliminating the requirement to pay TSPs to develop grazing plans or other assessments in order to access funding.
- Interviewees emphasized the need for EQIP to better support livestock farmers, especially those farming animals other than cattle, raising crops and livestock, or utilizing less common systems like silvopasture. Farmers are currently unable to receive funding for both crops and livestock (e.g., cover crops and fencing). They also expressed frustration with the fact that EQIP doesn't cover infrastructure for grazing non-ruminant animals like chickens or pigs and that many TSPs don't understand the needs for animals beyond cattle (***see Education***). Finally, some interviewees felt that people farming row crops could get funding more easily than those using less common practices, particularly things like silvopasture. They expressed the need to educate service providers on these types of practices or at least encourage them to be more helpful when faced with practices with which they're less familiar.

Develop a new program to provide capital for basic operating expenses

Many people also expressed frustration that programs like EQIP only provide funding to address resource concerns. This left many farmers, particularly beginning farmers and farmers with limited capital, at a loss for how to cover a range of expenses. These farmers expressed a need to either change EQIP or develop other programs that could cover things like building exterior fencing, purchasing animals and basic infrastructure like trucks or freezers, and covering repairs to roads, houses, and farm equipment. While FSA provides microloans to cover these types of expenses, it was notable no one mentioned using this program. It is unclear if interviewees were unaware of this option or if the program was inaccessible because they didn't meet loan requirements. Minnesota's Rural Finance Authority provides flexible funding for some of these expenses at very low interest rates and could be a useful model

Develop and expand financial mechanisms that support small farm businesses

There are a host of economic development and financing tools that could be applied to support the local food system. Some states have mechanisms where businesses can crowdsource for equity capital to start or expand their operations (e.g., the Department of Financial Institutions in WI, see ***Processing***). It is important to develop platforms like this where they don't exist and expand outreach around ones that do. States also need to provide more support for rural planning and economic development since communities often lack the staff capacity, expertise, and funding to implement local economic development tools (e.g., Tax Incremental Financing Districts, which could help subsidize local food and farm infrastructure).

Land Access

Needs at a glance:

- Recognize that BIPOC farmers have experienced land theft and exclusion from land ownership, and repair this damage via land return, land policy, debt relief, and worker-to-owner programs
- Increase availability and affordability of farmland by reducing farm consolidation, financial speculation, and urban development
- Increase support for succession planning and decouple farmers' ability to retire from land sales
- Improve infrastructure to connect beginning and BIPOC farmers to land that becomes available
- Shift dominant ways of thinking about land and return jurisdiction over land to communities

Land access was one of the most critical issues to many interviewees -- 90 mentioned it was an important issue and 30% explicitly stressed that it as one of the biggest barriers to transition. While land access is a problem for many current farmers, many interviewees emphasized that land access particularly affects beginning farmers and BIPOC farmers. Likewise, land represents a greater barrier to grazing which requires more land than to other types of agriculture such as vegetables.

Recognize the causes of inequitable land distribution and create pathways for people of color to reclaim a place of dignity within agriculture and food systems

It is important to recognize that the inequitable distribution of land we have today is due to a long history of land policy in the United States. This needs to be addressed to repair the harm that has been done. Many farmers who have inherited land from their families either don't understand or don't acknowledge how previous generations acquired that land. As one interviewee put it, "'Land just didn't pop up and exist, and people were like, 'Oh, it's yours. It's free.' That's a story that we're told, but that's not the reality in most cases." The reality tells a story of colonial violence whereby the U.S. government systematically removed Native peoples from their homelands, redistributed the land to white farmers, and excluded other BIPOC groups from land ownership. These policies built on global displacement through colonization and the slave trade, which was used to fuel the US agricultural economy. Today, many people around the world continue to lose their livelihoods to international policies including those related to agriculture. Many of these people are forced to migrate to the US, where they face slavery-like conditions working in the agricultural sector (*see* ***Essential workers***). Both land loss and labor exploitation has inhibiting many BIPOC communities from building wealth, exacerbating issues with access to capital (***see Capital***)

Repairing this damage starts with creating pathways through which people of color can reclaim a place of dignity within agriculture and food systems. As this intersects land access, interviewees talked about land reparations including returning land to Native communities, developing land redistribution policies, providing debt relief for BIPOC farmers, and developing pathways for farmworkers to become farm owners (***see Capital*** *and* ***Essential Workers***). As with many of these issues, the needs of specific BIPOC communities differ widely based on their unique histories. Doing justice to the complexity of this issue requires its own report, however, we've briefly highlighted an example of some of the land access challenges specific to Tribes in the spotlight below.

Increase availability and affordability of farmland by reducing farm consolidation, financial speculation, and urban development

Today, land is increasingly out of reach for most farmers because of decreasing availability and skyrocketing costs. Interviewees discussed the role of large farms, financial speculation, and urban development as drivers of this trend.

Subsidies and lending norms disproportionately increase the profits of large, commodity farms, fueling farm consolidation. This is a problem both for land purchases and leases – some interviewees gave specific examples from their communities in which large CAFOs were outbidding small farmers by offering twice the going rental rate. Consolidation creates a vicious cycle where farms gain land, increase their assets and in turn use those assets to leverage even more capital, allowing them to acquire more land and driving smaller farms out of business (***see** Consolidation and **Capital***). Increased interest in farmland as a financial asset has also led to a proliferation of landholding by companies, funds, and wealthy individuals. This has resulted in a large amount of land held by people with limited knowledge of or stake in the communities where that land is located, and with little understanding of farming. There is a great need both to quell financial speculation in land and to educate existing absentee owners on both sustainable farming and appropriate lease terms.

A smaller number of interviewees also mentioned urban development as a factor increasing the cost of farmland adjacent to cities. This is a particular issue for smaller, sustainable farmers who often rely on niche markets and for many immigrants whose communities are centered in urban locations. Zoning laws are one of many ways to address this issue.

Increase support for succession planning and decouple farmers' ability to retire from land sales

Lack of support for both farmers' retirement and for succession planning, fuels land consolidation and speculation. When farmers' ability to retire is linked to land sales, it becomes difficult to pass land on to beginning, BIPOC, or sustainable farmers. Rather, land often gets sold to the highest bidders – the largest conventional farms, those interested in land for financial speculation, or developers. Interviewees emphasized that identifying ways to support farmers' retirement plays a critical role not only in supporting farmers themselves, but also in determining the future structure of farms and rural communities. State-level tax incentive programs and the Federal Conservation Reserve Program's Transition Incentive Program (CRP-TIP) help incentivise farmers to transfer their land to beginning farmers. However, more direct policy is needed to successfully transition farmland on a large scale.

Land owned by farmers who pass away without a succession plan often meets a similar fate. Many shared that farm succession is often a highly emotional topic which makes it difficult to have conversations about retirement. Many farmers deed land to family members without determining if they'll continue to farm, resulting in heirs selling the property to other interests. Even farmers fortunate enough to have family land face challenges due to family dynamics. Farmers shared stories of being prevented from inheriting because they were women, having to rent land from non-farming family members at market rates, and disagreeing with parents over the value of sustainable farming practices. When farmers die without a will, family members who wish to farm are often deprived of the opportunity through a legal issue known as heirs' property. Land under heirs' property isn't eligible for USDA loans or disaster relief and cannot be used as collateral, making it difficult for farmers to hang onto. Moreover, the inheritance structure for heirs' property can create property titles co-owned by hundreds of people. This makes it difficult to clear titles but easy to sell land without the consent of other heirs. For this reason, predatory developers often target financially vulnerable heirs and encourage them to sell out without the consent of heirs who are farming the land. Due to historic and ongoing discrimination in the court system, a large number of BIPOC, and particularly Black farmers die without wills, perpetuating historic legacies of land theft and dispossesion. For these reasons, there is a critical need to create more positions for people who can support succession planning and resolve heirs' property disputes, as well as a need to amend the laws governing heirs' property.

Improve infrastructure to connect beginning and BIPOC farmers to land

People also expressed frustration with how difficult it is to locate available farmland, particularly for those who are marginalized within rural communities. It's common for land to get passed down within families or sold by word-of-mouth. Racism complicates this process even more for BIPOC farmers. Records of who owns land are difficult to find in many areas, making it challenging to identify who to ask about land sales or rentals. Addressing racism, developing widely-available and digitized records on landholdings, and creating programs that support land access navigators and land-linking services could help address these issues.

Shift dominant ways of thinking about land and return jurisdiction over land to communities

Importantly, a number of interviewees voiced that to solve these issues, there needs to be a fundamental shift away from thinking about land as a commodity and a financial asset. The idea of land as a commodity that could be bought, owned, and sold, came to the US with European settlers and was one of the ideas used to enable colonial land theft worldwide. There are many ways to think about land beyond a tool for wealth-building. In other places, land is seen as something that should be stewarded by communities and for communities, as a vital source of life, as a resource critical to our survival, and as a living being. Yet in the US, land as a financial commodity remains the dominant paradigm. This is compounded by financial speculation in farmland. When land is concentrated in the hands of distant individuals and institutions, communities lose control over what happens to the land around them. This has exacerbated inequities in farmland ownership and further concentrated wealth and power outside of rural areas.

To address this issue, interviewees stressed the importance of returning jurisdiction over land to farmers and local communities. Many were interested in cooperative or collective land stewardship. This also has the benefits of decreasing the cost per person and reducing risk in financing, as well as enabling more shared infrastructure and building community. Other interviewees emphasized the role that land trusts can play in removing land from the market and placing it under community control. They also discussed policies that are being implemented elsewhere in the world, like community rights of first refusal on land sales. Purchase of development rights and conservation easements are common tools for protecting farmland and reducing its cost. One interviewee pointed out that while these tools are helpful, they don't address the root causes of the affordability problem. However, they could be used to promote more transformative change if they enabled land trusts or communities to acquire land and remove it from the market in perpetuity.

Spotlight: Tribal Lands

Colonial land theft and subsequent government policies not only forced Native people from their homelands, but also led to the loss of land within reservation boundaries. Under the **Dawes Act**, the US government sold scattered plots of reservation land to non-native land owners, depriving some Tribes of most of the land within their reservations. The resulting **checkerboard pattern** of land claims makes means that for some Tribes, much of their remaining land is non contiguous, making it challenging to govern, steward, and use for activities like grazing. Some of this land is also held in trust by the Federal government. The Secretary of Interior must review nearly all land use decisions on trust lands, creating additional headaches for land management.

The Dawes Act also created an issue called **"fractionation"** where land titles were subdivided with each generation. This lead to some titles split between thousands of heirs. To farm that land, heirs must have the consent of half their co-owners, a near impossible task. While the Federal government is working to resolve these claims, the pace is far too slow, meaning that many people die waiting for resolution. Overall the Dawes Act resulted in the Federal Government confiscating 90 million additional acres of Native land.

During the 1950s and 60s, over 100 Tribes were also **"terminated"** by the Federal government, meaning that their legal status as a Tribe, and with it, all their land was taken. While some Tribes have regained Federal recognition, many are still struggling to restore their legal status and even more have been unable to regain the land they lost.

It is important to note that the situation for each tribe is unique. A small number of Tribes like the Menominee Nation in Wisconsin have retained nearly all their reservation land while others such as Standing Rock retain as little as 2%. Specific factors like geographic location (e.g., to what degree the reservation land allotted to the Tribe is capable of supporting agriculture), are also highly variable. However, a priority for many Tribes is to regain land within their reservation boundaries as well as control over particular sacred sites.

"We have one woman who has 345 different land interests on four different reservations. Collectively, they total less than 100 acres. We have a nine-month-old little boy, I guess now he would be almost two years old, but he had nine interests. He's two years old and he has nine interests of land that he's inherited." –Non-profit employee, 114_MN

For more information on Native land issues, see The Indian Land Tenure Foundation: https://iltf.org/.

Social Norms

Needs at a glance:

- Normalize profitability (rather than production) as the economic metric of farm success
- Measure farm success by the degree to which the farm supports farmers and the community it's feeding
- Understand food as medicine
- Expand notions of what agriculture looks like
- Normalize grazing by building communities of graziers and supporting the next generation
- BIPOC farmers are an important part of the future of animal agriculture

Normalize profitability (rather than production) as the economic metric of farm success

Interviewees emphasized the necessity of moving toward farm profitability, rather than production, as the primary economic measure of farm success. The emphasis on productivity is reinforced by media, agribusiness, farm consultants, universities, lenders, and even conservation groups, among others. Yet in many cases the problem is producing too much, rather than too little. Interviewees talked about how dairy overproduction drives price fluctuations causing many dairy farmers to lose their livelihoods, and how overproducing corn and soy undermines grazing and fuels the consolidation of smaller farms into CAFOs (***see*** ***Consolidation*** and ***Land Access***). They also talked about how loss of production is used as an argument against the viability of managed grazing, even though grazing can be more profitable than other forms of animal agriculture. Focusing on profitability would emphasize what really matters for farm viability, and could create avenues for discussing overproduction and the role that subsidies play in determining what type of agriculture is profitable.

Measure farm success by the degree to which the farm supports farmers and the community it's feeding

A few interviewees discussed the need to re-define metrics of farm success through the lens of decommodifying agriculture. Using farm productivity as a sole metric of success has reduced farms to factories producing commodities. "Decommodifying" agriculture creates space to acknowledge that farming is so much more. Instead of measuring farm success on the basis of productivity, these interviewees emphasized that the success of a farm should be measured by the degree to which it supports its farmers and the community it's feeding. Farm profitability is a part of this, but community and environmental health are critical to success as well. This sentiment was echoed by nearly all of the farmers we interviewed who shared how all of these elements are an important part of what being a "successful farmer" means to them.

Understand food as medicine

Some interviewees also talked about decommodifying food itself. While food is a product that is bought and sold, for many it's also a cultural experience, a medicine, and a gift from the earth. Many people expressed that the way we steward the land and the food that we produce is linked to our health, and some of our Native interviewees in particular, talked about the idea of food as a medicine. Food is medicine from the perspective that what food we put in our bodies affects our physical health outcomes. But for some communities of color in particular, food is medicine in a more holistic sense that encompasses cultural and spiritual well-being. Just as depriving Native communities of access to their traditional foods was a tool of colonization, one of our Native interviewees shared that reconnecting with these foods provides a means of healing and reclaiming her culture.

The concept of food as medicine also has important consequences for the way some Tribes are thinking about agriculture and food systems planning. Within the context of Tribal government, it has opened opportunities for collaboration across departments of environment, health, and agriculture. This idea could be implemented within the context of the US government as well, and has important ramifications for building connections across movements (*see* ***How do We Make Change?***).

Expand notions of what agriculture can look like

Through the process of colonization, Europeans sought to replace Native ideas about food and agriculture with their own vision of what food systems should look like. Some Native interviewees talked about how many Tribal members don't see themselves as farmers because they don't "milk cows or slaughter pigs." However, many Tribes are now reclaiming what agriculture means to them. Decolonizing agriculture requires making space for the many forms that agriculture can take, from raising bison, to cultivating wild rice, or tapping maple trees for syrup. Some tribes have made inroads with NRCS in terms recognizing these practices, but far more work is needed to create equitable support for Native agriculture.

Normalize grazing by building communities of graziers and supporting the next generation of farmers

Many interviewees mentioned that peer pressure often dissuades farmers from grazing. On the flip-side, interviewees talked about how reaching a critical mass of graziers in a region can persuade conventional farmers to alter their practices. Likewise, many interviewees saw hope in the next generation of farmers. Logistically, new farmers are less locked into the current system by infrastructure investments, and many also expressed that the next generation is more open to doing things differently. Many current farm support programs are focused on current farmers, and while these programs are important, there is also a critical need to support the next generation as well.

BIPOC farmers are an important part of the future of animal agriculture

In some cases, preconceptions about certain groups of future farmers inhibit understanding their needs. Over the course of this project, we talked with some people who assumed that BIPOC farmers are not involved in or interested in animal agriculture because many beginning BIPOC farmers farm vegetables. However, our conversations with BIPOC farmers and people who work with them proved otherwise. Most dairies are staffed by immigrant workers highly skilled in working with animals. Many other immigrant communities are interested in raising animals for cultural reasons and have experience farming animals in their home countries. Many Tribes are interested in raising animals to support food sovereignty or to reintroduce culturally important foods like bison, and Tribes across the U.S. manage a large amount of grazing land, which makes up the majority of Tribal agriculture.

Our conversations with these groups made it clear that the reason many beginning BIPOC farmers begin with vegetables is less about interests and more about systemic barriers such as access to land and capital. The fact that we encountered false assumptions about BIPOC farmers' interest in animal agriculture underscores the importance of hiring BIPOC folks into leadership roles and to building stronger relationships with BIPOC communities (***see Education***). It also emphasizes the need to address more deep-seated issues with land and resources and to support smaller animals which provide a less costly entry-point to animal agriculture than cattle.

How do we make change?

Address root causes

Interviewees and workshop participants shared many examples of the critical work being done to address the major barriers being faced in the Midwest. However, they also emphasized the importance of focusing more collective effort on difficult problems at the root of these barriers such as racism and racial inequity, industry consolidation, agricultural subsidies, labor justice, and access to land and capital, particularly for beginning and BIPOC farmers.

Many organizations are experts in providing education and technical support and connecting farmers and others within rural communities. People emphasized the importance of leveraging these strengths to build capacity to address more deep-seated issues. Part of this means creating spaces where people can process their struggles within the food system: both historic and ongoing violence against BIPOC folks and the current and historic struggle of rural poverty. There is also a need to build transparency and trust by bringing together rural neighbors, farmers, urban farmers, and consumers to talk about the current food system and what a better future could look like.

In addition to providing space to process historic harm, current needs, and imagine a different future, many people also emphasized the need to broaden current efforts to address the root causes of problems more directly. Policy advocacy around the Farm Bill is crucial, but there are other food system issues that do not encompass the Farm Bill e.g., immigration issues that affect farm and food-chain workers (***see Essential Workers***). Cooperatives and collaborative farming arrangements need more support from civil society as well as state-level support through funding and policy reform.

Broaden coalitions & build connections across movements

Building broader coalitions is key to achieving change. This includes restructuring institutions to prioritize and empower BIPOC voices and centering BIPOC communities and farmers in developing solutions. In the workshops, a number of people expressed a specific desire to learn more about how they could best support farmworker movements. Work around processing, supply chains, and co-ops were mentioned as specific points of connection between these movements and existing or aspirational projects.

There are also many connections between stated needs and opportunities and other areas of advocacy. These include health, the climate and conservation movements, as well as campaigns around immigration policy, fair wages, housing, retirement, and healthcare. Similar connections could also be made across government agencies – there are many opportunities for better coordination across departments of labor, agriculture, health, and environment.