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Leveraging Land Easements for Grassland Bird Habitat Conservation

Amy N. Marigliano
Gettysburg College

Hayden E. Dubniczki
Gettysburg College

Sarah W. Westrick
Gettysburg College

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Abstract

In addressing the decline of North American grassland bird populations, it is important to consider the various interdisciplinary approaches that can be employed in their conservation. OECMs, or “other effective area-based conservation measures” encompass a wide array of strategies which can be leveraged to conserve natural landscapes and species. Land easements implemented by the Land Conservancy of Adams County (LCAC) are an example of one such strategy. The LCAC seeks primarily to preserve the rural character of Adams County but has more recently turned their focus toward environmental conservation. In partnering with the Land Conservancy, this case study aimed to identify land easements within Freedom Township, PA that should be prioritized for grassland bird conservation, while also supporting the LCAC in applying for a Land Trust Grant through the Cornell Ornithology Lab. To fulfill these goals, the Eastern Meadowlark was chosen as a focal species. Surveys were then distributed to landowners engaged in LCAC land easements within Freedom Township to gauge their current agricultural practices and willingness to participate in grassland bird conservation. After preparing Eastern Meadowlark occurrence data and selected environmental variables in ArcGIS Pro, the software MaxEnt was used to produce models expressing the predicted probability of Eastern Meadowlark presence in Adams County, Pennsylvania. The first model used land cover data to identify where the birds were likely located, and the second model used crop cover data to relate presence to certain crops. By integrating these models with survey responses, we identified parcels (1) containing suitable habitat for the Eastern Meadowlark, and (2) owned by landowners interested in bird conservation as priority conservation parcels. The results of this study indicated that the Eastern Meadowlark was negatively correlated with tree cover and crops unfavorable for nesting, including soy and corn. A stronger presence was predicted on easements that self-reported growing crops conducive to nesting, such as grasses, wheat, or hay. Based on these findings, we make several recommendations for the focus of future grassland bird conservation efforts within Freedom Township.

Keywords

Land Easements, conservation, GIS, MaxEnt, Species Distribution Model

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Comments

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Leveraging Land Easements for Grassland Bird Habitat Conservation

Amy Marigliano, Hayden Dubniczki, and Sarah Westrick

Environmental Studies 400 Senior Seminar: Area-Based Conservation

Environmental Studies Department, Gettysburg College

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I affirm that I have upheld the highest principles of honesty and integrity in my academic work and have not witnessed a violation of the Honor Code.

Amy Marigliano, Hayden Dubniczki, Sarah Westrick

Abstract

In addressing the decline of North American grassland bird populations, it is important to consider the various interdisciplinary approaches that can be employed in their conservation. OECMs, or "other effective area-based conservation measures" encompass a wide array of strategies which can be leveraged to conserve natural landscapes and species. Land easements implemented by the Land Conservancy of Adams County (LCAC) are an example of one such strategy. The LCAC seeks primarily to preserve the rural character of Adams County but has more recently turned their focus toward environmental conservation. In partnering with the Land Conservancy, this case study aimed to identify land easements within Freedom Township, PA that should be prioritized for grassland bird conservation, while also supporting the LCAC in applying for a Land Trust Grant through the Cornell Ornithology Lab. To fulfill these goals, the Eastern Meadowlark was chosen as a focal species. Surveys were then distributed to landowners engaged in LCAC land easements within Freedom Township to gauge their current agricultural practices and willingness to participate in grassland bird conservation. After preparing Eastern Meadowlark occurrence data and selected environmental variables in ArcGIS Pro, the software MaxEnt was used to produce models expressing the predicted probability of Eastern Meadowlark presence in Adams County, Pennsylvania. The first model used land cover data to identify where the birds were likely located, and the second model used crop cover data to relate presence to certain crops. By integrating these models with survey responses, we identified parcels (1) containing suitable habitat for the Eastern Meadowlark, and (2) owned by landowners interested in bird conservation as priority conservation parcels. The results of this study indicated that the Eastern Meadowlark was negatively correlated with tree cover and crops unfavorable for nesting, including soy and corn. A stronger presence was predicted on easements that self-reported

growing crops conducive to nesting, such as grasses, wheat, or hay. Based on these findings, we make several recommendations for the focus of future grassland bird conservation efforts within Freedom Township.

Introduction

Since the mid-19th century, grassland birds have experienced “continental-scale population declines" driven by the estimated loss of more than 80% of North American grassland ecosystems (Brennan and Kuvlesky 2005). Audubon (2021) states that, relative to other North American birds, which have seen a sustained decline since 1970 overall, grassland birds have experienced the greatest total losses of priority birds across ecosystem types. This phenomenon is documented in data from the U.S. Geological Survey (USGS) North American Breeding Bird Survey (BBS), which monitors the breeding patterns of bird species across North America (Hill et al. 2014).

Two studies in particular have identified potential drivers for population trends of U.S. grassland birds. Mineau and Whiteside (2013) concluded that insecticide use and lethal toxicity were better correlates of observed BBS trends than agricultural intensification. In contrast, the results of Hill and colleagues (2014) did not support the insecticide-acute-toxicity hypothesis; rather, they pointed to habitat availability as the more plausible explanation for the population trends of grassland birds. Despite disagreement over the relative magnitude of impact, both studies acknowledged that pesticides and habitat loss were negatively related to grassland bird trends. Here, we focus on habitat availability for grassland birds in the Southern Adams County Grasslands. However, it is worth acknowledging that confounding factors such as pesticides may also be impacting these species.

In addition to habitat loss, other consequences of agricultural intensification have taken a major toll on habitat suitability of grassland birds. A reduction in the use of farmland for pasture and hayland, larger farm and field sizes, decreased crop and cover diversity, an increase in the production of corn and soybeans, and an increase in the use of agricultural chemicals have proved devastating for grassland bird populations (USGS 2022). During the breeding season, a variety of grassland birds use agricultural land as surrogate grasslands for breeding and rearing hatchlings (USGS 2022). Various agricultural landscapes can serve as surrogate grasslands, meaning they can still provide adequate conditions for nesting, including small grains, idled crops, and hayfields (USDA 1999) Crops such as wheat, barley, and rye resemble natural grasslands in terms of height and structure, so they provide more suitable nesting habitat for ground-nesting birds than do row crops.

Unfortunately, there has been marked increases in the production of row crops. Farmers are incentivized to cultivate more corn and soybeans due to high prices for those crops, as well as government subsidies. Additionally, funding for the Conservation Reserve Program, which compensates farmers for protecting wildlife and water quality by leaving grasslands undisturbed, has been in decline (Charles 2013). Increasingly large-scale, industrialized monoculture, coupled with weakened grassland preservation efforts is a foreboding trend for grassland birds. It is important to identify how agricultural lands can be used and managed in ways sensitive to bird conservation while also meeting the financial goals of landowners.

Even on agricultural land, small changes in practices can serve to benefit grassland bird conservation and may align with other management objectives. For example, mowing hayfields can produce desirable habitat features for grassland birds (i.e., reduced litter, vegetation height, and woody vegetation) (USGS 2022). However, mowing causes great harm during the breeding

season, as it has the potential to reduce available food sources, namely invertebrates, needed to provide for nestlings. It can also kill eggs or young through the destruction of nests (USGS 2022). Successful nesting may be fully prevented if haying occurs multiple times during the breeding season. There are a variety of solutions available to remedy this issue, ranging from rotational mowing to prescribed burning, and their relevance depends on the type of land in question.

Surrogate Grassland Conservation in Adams County

Adams County is one of the most historically and culturally significant regions of Pennsylvania, home to iconic rural landscapes which remain an emblem of American heritage. Although the county features numerous parks, trails, and game lands, the most widespread form of managed land in Adams County is farmland. As part of the Historic South Mountain Fruit belt, northern and western Adams County have ideal conditions for tree-fruit culture and is known for its highly productive apple orchards, as well as peach production (Agricultural Resources of Pennsylvania n.d.; Hendricks 2017). Dairy farms, livestock operations, and croplands constitute the character of the region (Gettysburg Adams Chamber of Commerce 2022). In this context, "character" refers to both the historical and cultural importance of this landscape, as well as to the notion that the land possesses an essence worth preserving.

One organization spearheading preservation efforts in the area is the Land Conservancy of Adams County (LCAC), a "non-profit land trust dedicated to preserving the rural lands and character of Adams County, Pennsylvania" (Land Conservancy of Adams County 2022). The Conservancy's work involves conservation easements- voluntary legal agreements which allows landowners to maintain land ownership while managing for certain agreed upon conservation

objectives and permitted uses (Land Conservancy 2022). In a land management context, *preservation* typically refers to the protection of an area from harmful human activities, whereas *conservation* involves the responsible use of natural resources (National Geographic Society 2019). Since its founding, the Land Conservancy of Adams County has "worked with over 130 local landowners to preserve more than 12,100 acres of farmland, meadows, forests, streams, and historical spaces (Land Conservancy 2022)."

The meaning of preservation in Adams County is unique, however, because working farms are integral to the character of the rural landscape. Natural features and associated ecosystem services, which benefit agriculture and provide aesthetic value, must be supported while allowing concurrent land use. Pollination and biological control services are provided by local insects, birds, mammals, and plants, so preserving natural features as habitat for these organisms is central to the Land Conservancy's efforts (Land Conservancy 2022).

Although preserving farmland is the end goal, protecting and incorporating native species into preservation efforts is extremely important. Grassland birds have recently become one focus of the Conservancy. More than 5,750 of the acres within the Land Conservancy are part of the Southern Adams County Grasslands (Land Conservancy 2022). According to the National Audubon Society (2022), this open grassland habitat is ideal for a wide array of grassland birds, including various species of conservation concern. Although species conservation is not an explicit goal of the Land Conservancy, it goes hand-in-hand with the goal of preserving the rural character of Adams County. With current agricultural practices and residential development threatening bird habitat suitability, there is a need to pursue grassland restoration and alternative land management strategies in the Southern Adams County Grasslands (Audubon 2022).

Here, we aim to identify land easements within Freedom Township that should be prioritized for grassland bird conservation, while supporting the Land Conservancy in applying for a Land Trust Grant through the Cornell Ornithology Lab. To fulfill these goals, we crafted a case study that (1) assesses landowner attitudes toward grassland bird conservation, and (2) models habitat suitability for the Eastern Meadowlark in Freedom Township. We decided upon the Eastern Meadowlark (*Sturnella magna*) as our focal species. While this species was not listed as an Audubon 2021 priority bird, it has experienced general population decline in the Eastern United States and there is ample data on the bird's presence in Adams County (Audubon 2022). We developed two models to inform our goals, the first is based on land cover data and will help us to identify the areas in which we are most likely to find Eastern Meadowlark and the second is based on crop cover data and will provide insight into which crops this species prefers.

In terms of land cover data, we predicted that the most suitable habitat will be associated with impervious surfaces, as bird observations used in this study were sampled from roadsides. We predicted that low vegetation will yield the second highest habitat suitability value, as this category includes cultivated fields and the majority of available habitat in Adams County is agricultural land (Chesapeake Conservancy n.d.). We also predicted that Eastern Meadowlark presence will be positively associated with distance from tree canopy. Once you step outside the agricultural lands of Adams County, you encounter forest, and closed tree canopy does not resemble the open structure preferred by this grassland bird species.

In terms of crop cover, we predicted that the most suitable habitat will be associated with grass, as grassland is the Eastern Meadowlark's natural habitat. We predicted this cover type to be followed by grains, hays, and seeds, as these crops most closely resemble the structure of grassland habitat. We predicted that row crops (such as corn and soybeans) would yield a

relatively low habitat suitability value, as these do not resemble the structure of natural grasslands. Finally, we predicted that forest will yield the lowest habitat suitability value.

Methods & Research Design

I. Site Description and Grassland Bird Species of Concern

Freedom Township, Pennsylvania lies slightly southwest of Gettysburg National Military Park (GETT), and part of the Eisenhower National Historic Site (EISE), sits in the Township's top right corner. As part of the Southern Adams County Grasslands, EISE is home to over 100 bird species; and because it provides habitat for Loggerhead Shrikes, Short-Eared Owls, and Upland Sandpipers, it has been designated an "Important Bird Area" by Audubon and the State of Pennsylvania (National Park Service 2018). Two studies using point-count surveys and vehicular-road surveys (among other methods, such as nocturnal-owl survey protocol) sampled both GETT and EISE; but one study treated GETT and EISE as one area, called GETT-EISE. Keller and colleagues (2000) recorded 22 species of special concern in the boundaries of GETT-EISE, while Ross and colleagues (2003) recorded 15 species of special concern in EISE. Of the 10 species on Audubon's "watchlist" which remained within GETT-EISE to breed, three were grassland specialists: the Grasshopper Sparrow, Bobolink, and Eastern Meadowlark (Keller et al. 2000).

Shroeder and Sousa (1982) and Granfors (1992) identified four common variables which determine Eastern Meadowlark habitat suitability. These were: total herbaceous cover, relative grass cover, height of herbaceous vegetation, and proximity to perch sites. Additional variables were identified by Granfors (1992) such as distance to edge, shrub cover, litter cover, and

residual cover. We focused on assessing certain types of land cover and canopy cover rather than other habitat features.

II. Motivations and the Land Conservancy of Adams County

The Cornell Ornithology Lab Small Grant Program awards funding on the basis of an organization's ability to "accomplish or contribute to bird conservation on private lands through activities such as (but not limited to) strategic planning, outreach, habitat management, stewardship, bird monitoring, eBird use, capacity building, and land or easement prioritization" (The Cornell Lab 2022). As such, our research is designed to cater to the specific requirements of this grant program. Our methods – consisting of landowner survey dissemination and data analysis, as well as species distribution modeling – are structured to contribute to outreach, capacity building, and land or easement prioritization on behalf of the LCAC.

The goals and focus of our study were identified through discussions with the director of LCAC, Sarah Kipp. These discussions resulted in three outcomes that shaped the project: 1) the desire to apply for the Cornell Ornithology grant, 2) a focus on Freedom Township and a few parcels in Cumberland due to perceived interest of landowners in bird conservation, 3) the need for more information on landowners and their land practices.

III. Landowner Surveys

With approval from the Institutional Review Board at Gettysburg College (Appendix A), we created and disseminated surveys to 21 landowners within Freedom Township using both mail and email. Two versions of the survey were created, one which was intended for landowners in the area and another intended for farmers. The two asked almost identical

questions, save for wording tailored to the specific role of the receivers. However, only results of the landowner survey were used within our final analysis, as we only received one contact for farmers through the LCAC.

The landowner survey asked 19 questions pertinent to the overall research question and goals of our project (Appendix B). The survey first inquired about the current management of the land, including what the breakdown of the landscape on their property currently looks like (as best described by the landowners), what crops are grown on-site, current agricultural practices in use, and other current uses for the property. Questions then turned to the landowners' willingness to participate in conservation efforts. Such questions inquired about the landowners' individual willingness to set aside land to devote to grassland conservation, their willingness to delay the cutting of grass until later into the summer, and their willingness to begin growing hay on their land. These last two requests incorporate specific practices identified in our research to promote the survival of the Eastern Meadowlark, as grass and hay allow for secure nesting spots.

Finally, we inquired about obstacles standing in the way of the landowners' willingness to dedicate time, land, or energy into grassland restoration, including the impacts both generally and cost-wise of adopting new management practices, before closing with a segment allowing the respondents to share their personal thoughts or other relevant information to our study. We mailed the surveys to the landowners belonging to the Conservancy located in this area, as well as emailed the surveys to those who had email addresses on file with the LCAC.

All survey analysis and visualization was conducted using Excel (Appendix C). Additionally, we mapped the spatial distribution of selected survey results across land easements in Freedom Township using ArcMap 10.8.1, so that these results could be considered in the context of Eastern Meadowlark habitat suitability. These maps were created using a shapefile

acquired from LCAC, containing a polygon of 32 outlined parcels representing all land easements in Freedom Township (Table 1). As assured in our IRB contract, no names or identifying information were included in these charts and maps.

IV. Habitat Data Preparation in ArcGIS Pro

The second portion of our project was developing a species distribution model for the Eastern Meadowlark. We acquired bird occurrence data for south central Pennsylvania from the 2004-2008 bird atlas study (A. Wilson, pers. Comm.) (Table 1). These data included 2,095 point count locations with x-y coordinates (in decimal degrees) and 169 bird species. Each location was visited once and observations were made from roadsides. These data were superimposed on the boundaries of Adams County, Freedom Township, and LCAC land easements using ArcMap 10.8.1. For analysis in MaxEnt, we subsetted these data to include only locations with Eastern Meadowlark observations. We clipped observation data to the Adams County municipal boundary, as this was the extent of the environmental data we used and of our study area.

A high-resolution land cover layer representing the years 2013/2014 was acquired from the Chesapeake Conservancy. These data constitute a raster depicting land cover across the Pennsylvania portion of the Chesapeake Bay Watershed at a spatial resolution of one meter. This layer was derived from LiDAR and orthoimagery data sources (Chesapeake Conservancy n.d.). Once uploaded into ArcGIS Pro, we resampled the land cover data at a spatial resolution of 5 meters (based on the majority of cells). The purpose of these changes was to generalize land cover and minimize the road signature, which resulted from the sampling design of bird observation data. This layer was then reclassified according to Eastern Meadowlark habitat preferences (Table 2). We also extracted tree canopy data from this reclassified layer and created

a new raster showing the Euclidean distance to perch in meters. This variable was intended to test the importance of tree canopy (as potential perch sites) for the Eastern Meadowlark.

The 2008 Cropland Data Layer (CDL) was acquired from the United States Department of Agriculture. These data constitute a raster depicting crop-specific agricultural land cover across the United States at a spatial resolution of 30 meters. Satellite imagery and ground truthing were used to collect data during the growing season (USDA 2008). The crop cover layer was uploaded into ArcGIS Pro and reclassified according to Eastern Meadowlark habitat preferences (Table 3). All data were saved to the same extent (the intersection of the BBS observation cell and the Adams County Boundary) and projection (WGS 1984) before being exported as .asc files for use in MaxEnt.

V. Species distribution model and MaxEnt

After data preparation, MaxEnt was used to model the geographic distribution of the Eastern Meadowlark. The Meadowlark observations and environmental layers were used to develop two species distribution models in MaxEnt (Phillips 2017):

1) Distribution – This model included categorical land cover data and continuous Euclidean distance to perch (tree canopy) data. It was intended to provide a baseline of where the Eastern Meadowlark may be present across Adams County.
2) Crop Preference – This model included categorical crop cover data. It is intended to identify the types of crops Eastern Meadowlark is likely to prefer and, therefore, to inform LCAC farming practices.

Model fit was assessed using area under the curve (AUC) and important variables were assessed using predicted probability of presence values. The cut-off for random results was an AUC of 0.5 or lower. The outputs of each model included a bar chart displaying the relationships between categorical variables and predicted probability of Eastern Meadowlark presence, as well as a raster depicting predicted probability of presence across Adams County (Figure 1 and Figure 2). The outputs of the first model also included a line graph displaying the relationship between predicted probability of presence and distance to perch (Figure 3). The raster from the first model was uploaded as an .asc file to ArcMap 10.8.1 (Figure 4). We calculated zonal statistics to find the average predicted probability of Eastern Meadowlark presence in each LCAC parcel (Figure 5).

Results

Survey Responses

Eleven of the 21 landowners provided some form of response to the survey, revealing what their land is used for and what management practices they are interested in; 72.7% of respondents said that their land is farmed (Figure 6). The most frequently reported crops were corn, hay, and grasses, followed by soybeans and wheat (Figure 7). In general, landowners responded positively to our survey: 81.8% said they were interested (or already involved in) managing their lands for grassland bird conservation, 63.6% said they would be willing to (or have already) set aside land for grassland bird habitat, and 54.5% said they would be willing to (or already do) delay grass cutting (Figure 6). When asked what bird species are frequently observed on their land, some landowners listed up to 33 species, but only one landowner listed the Eastern Meadowlark (Appendix C). Mapped survey results reveal that landowners who

responded to our survey own a cluster of properties in northeast Freedown Township (with an outlier in Cumberland Township) (N=11). Of these properties, all but one is farmed, and only one landowner expressed disinterest in managing their land to benefit grassland birds (Figure 8). The disinterested landowner owns a relatively large parcel in the center of the cluster (Figure 8).

Habitat Suitability

There were a total of 368 Eastern Meadowlark observations within the entire extent of bird observations, 53 of those observations were in Adams County, and about 4 of them were sampled near LCAC land easements (Figure 9). Two MaxEnt models assessed whether certain categorical and continuous variables were predictors of Meadowlark presence by running each model multiple times. In each run, the average sample values of all but one environmental variable were held constant. By doing this, the relationships between individual environmental variables and Eastern Meadowlark habitat suitability were tested.

The first model compared various categorical land cover variables, as well as the continuous variable of Euclidean distance to tree canopy. This model yielded an AUC of 0.797 (Figure 1). When the average sample values of all other environmental variables were held constant, impervious surfaces were the category with the highest predicted probability of Meadowlark presence (1.0), followed by shrubland (0.65) (Figure 1). Water/wetlands, low vegetation, barren, and structures yielded equally moderate values. Tree canopy yielded the lowest value (Figure 1). A positive relationship was found between distance from tree canopy and predicted probability of presence (Figure 3).

Using the same methodology as the first model, the second model compared various categorical crop cover variables. This model yielded an AUC of 0.760 (Figure 2). When the

average sample values of all other environmental variables were held constant, the category grains, hay, and seeds had the highest predicted probability of Meadowlark presence (0.760). Grass yielded the next highest value, followed by fallow/idle cropland, then other (Figure 2). Background, row crops, other crops, and tree crops yielded equally moderate values. Forest yielded the lowest value. This model output suggests that farms with grains, hay, and seeds as groundcover are most likely to support Eastern Meadowlarks.

Based upon categorical land cover, there is variation in the predicted distribution of the Eastern Meadowlark across the Adams County landscape (Figure 4). A scale of about 0.5 to 1 is represented by a color gradient of yellow to red, where yellow indicates the lowest predicted probability of presence and red indicates the highest (Figure 4). There was also variation in the mean predicted probability of Meadowlark presence across all LCAC parcels based upon categorical land cover (Figure 5), and this map ranges from a predicted presence of 0.1 to 0.3.

Discussion

To draw meaningful conclusions from our results, we conducted an integrated analysis of the survey results and the habitat suitability results. Information regarding Meadowlark distribution and various social and physical dimensions of the landscape (i.e., attitudes regarding grassland bird conservation and current farming practices) should be integrated to create comprehensive grassland bird management plans. To reiterate, our study sought to answer the questions of where the birds are, and how their preferences for crop cover may direct management decisions.

I. Where are the Eastern Meadowlarks in Adams County?

Our prediction that impervious surfaces would reflect suitable habitat was supported, but our prediction regarding low vegetation was not. Shrubland, rather than low vegetation, yielded the second highest predicted probability of presence value (Figure 1). This finding was unexpected, as studies by Shroeder and Sousa (1982) and Granfors (1992) converged at the same general conclusion – Eastern Meadowlarks prefer high herbaceous cover with an abundance of perch sites and low shrub cover. Perhaps in the case of Adams County, shrubland was the main source of ample perch sites. Additionally, the cultivated fields of low vegetation may have included more row crops than those preferred by the Eastern Meadowlark, like grass or grains, hay, and seeds (Figure 2). Therefore, shrubland was a better alternative to low vegetation overall. Our prediction regarding distance to tree cover was supported (Figure 3). Importantly, however, habitat suitability for this species is likely to be improved by nearby patches of trees that provide perch sites. Due to the spatial resolution of our datasets, tree cover in this study was indicative of non-farmed (i.e., forested) land rather than suitable perch sites.

There is clear variation in general habitat suitability as well as mean predicted probability of presence across LCAC parcels (Figure 4 and Figure 5). Excitingly, when overlaid with survey results, we found high potential for grassland bird conservation. Of the landowners surveyed, 81.8% were either interested or already involved in managing their land to benefit grassland birds (Figure 6). Many of the land easements containing moderate to high mean predicted probability of presence are owned by people who are interested or already involved (Figure 5). Only one landowner mentioned that Eastern Meadowlarks frequent their property, but this should not detract from targeting other land easements for conservation. The singular report of the Meadowlark could imply a number of possibilities; perhaps Meadowlarks were deemed not

worthy of mention, or else landowners genuinely do not see Meadowlarks on their property (Appendix C).

II. How can Adams County Land Easements Support Eastern Meadowlark Conservation?

The second model supported our prediction that row crops would yield a relatively low habitat suitability value. This finding was expected because Meadowlarks prefer tall grasses for secure nesting, and crops like corn or soybeans do not resemble a similar structure (Schroeder 1982). Given the reliance on tall grasses for nesting, we would expect grass to be the most suitable habitat, but our predictions about grasses and grains, hay, and seeds were not supported. Grains, hay, and seeds exceeded grass in terms of habitat suitability (Figure 2). Given the caveats associated with our study, more research would be needed to affirm or deny stronger suitability of surrogate over true grassland. Our prediction that forest would yield the lowest habitat suitability value was supported (Figure 2). In Freedom Township, most of the land that is not developed is heavily forested, making the management of agricultural easements all the more important.

Most of the land easements are farmed, and all landowners grow at least one crop conducive to Meadowlark nesting (i.e., wheat, hay, or grasses) (Figure 6 and Figure 7). However, five of the seven landowners that reported growing such crops also grew unsupportive crops, like corn or soybeans, in tandem. This finding is still encouraging, as it provides evidence that integrated management that allows for the satisfaction of human needs alongside conservation efforts is achievable. Similarly encouraging, many of the landowners that indicated willingness to manage their lands to benefit of grassland birds were the same landowners that indicated willingness to set aside acreage for habitat restoration, willingness to grow hay, and

willingness to delay cutting (Appendix C). This base of support for different management strategies will likely prove useful in the creation of cohesive management plans that span across easements.

Prior to taking the first species distribution model into account, conservation efforts should concentrate on areas where landowners are interested in grassland bird conservation and willing to change their management practices. These easements are where conservation efforts are possible in the first place. The continuation and adoption of bird-friendly agricultural practices (such as growing grains, hay, seeds, and grasses) should be promoted. Once management plans are established for these easements, focus can be shifted toward easements where landowners did not express interest in grassland bird conservation, especially those which overlap with high mean predicted probability of presence. Further outreach can be done to establish connections with landowners who did not respond to our survey.

III. Caveats and Limitations

Some of the survey responses were indecipherable as the majority of surveys were returned handwritten. Rather than guess meanings and thus inadvertently provide misleading or incorrect information within our results, these words and/or phrases were replaced with the phrase “indecipherable” (Appendix C). Questions containing variable or indecipherable answers were largely omitted from analysis. In addition, two of the email addresses provided were either non-existent or unable to be sent, limiting the scope of our survey.

In regards to our modeling, it must be noted that the years of the Eastern Meadowlark observations, land cover, and crop land data do not coincide. The bird observations were taken during the years between 2004 to 2008. Our land cover data were valid for the years 2013 and

2014 and our crop data was produced in 2008. Lastly, in analyzing our results and drawing conclusions, it was imperative to remember that bird observation data was taken from roadsides, which skewed our results and limited the ability of our data to provide a true sense of where the Eastern Meadowlark is predicted to be found. We attempted to account for this by resampling the data with a spatial resolution of 5 meters. However, a correlation between bird presence and roadsides can still be seen (Figure 4). Despite this bias, our model results in meaningful variation due to other land cover types.

IV. Future Recommendations

There are many actions which owners of farmed land can take to encourage the survival of grassland birds. Farmers can cut their fields in strips, rotating which patches are cut when, whether earlier or later in the season, or even left to natural succession for the season, a practice called rotational mowing (Michigan State University Extension 2012). Like hayfield mowing, harvesting small grains and row crops can negatively impact the nesting success of grassland birds. Practices like no-till, minimizing equipment passes, contour buffer strips and strip cropping, Integrated Pest Management, alternative crops and cropping practices, and idling sensitive cropland can reduce this impact (USDA 1999).

In addition to rotational mowing, prescribed burning and grazing can be employed on grassland and rangeland in order to maintain various stages of simultaneous succession as well as diversity of vegetation (USDA 1999). By reducing concentrated areas of livestock, well-managed grazing systems can benefit birds *and* cattle operations by improving the health of key forage species, reducing soil erosion, and increasing water quantity and quality (USDA 2020).

More specifically to the Eastern Meadowlark, research suggests that the birds prefer habitats with high levels of disturbance. Without human intervention, this is accomplished through natural fires or ground trampling by native animals. On multi-use lands, disturbances can be artificially created through the use of strategically timed hoeing and/or mowing (Török et al. 2021). In addition to breaking up the land, these practices also clear woody vegetation congregated at the edges of grassland habitat. Removing this vegetation from the perimeter of the habitat is crucial, as it destroys travel corridors used by at least 10 different known predators of the Eastern Meadowlark (Hull 2002). Furthermore, brown-headed cowbirds (*Molothrus ater*) prefer woodland habitat edges because more host species are found there. Hubbard and colleagues concluded that Meadowlarks' selection of nesting sites farther away from habitat edges may have been influenced by cowbird parasitism (Hubbard 2006). This result supports our finding that Eastern Meadowlark habitat suitability was positively related to distance from tree canopy (Figure 3). As explained in a comprehensive study on management and Meadowlark survival, efforts to restore Meadowlark populations need not simply restore degraded habitat, but aid in natural mitigation of threats such as predation and parasitism (Hull 2002).

Conclusions

The findings of this survey and subsequent modeling hold great significance for the formulation of future grassland bird conservation initiatives within Freedom Township. To affirm our conclusions, both environmental and bird observation data should be updated to more accurately reflect the current presence of Eastern Meadowlark in the area, as well as the status of native and surrogate grassland habitats. Collection of new data should be thorough and extensive, gathering sightings from both public and private lands, instead of just by roadsides, to

build a more holistic picture of Meadowlark occurrence. As well, transect lines could be employed for the purpose of ground truthing the tree and crop cover data used. Through our survey, many landowners expressed willingness to allow data collection on their lands, and most provided complete contact information, so more extensive studies should be feasible moving forward.

While we chose the Eastern Meadowlark as a focal species for this study, new data should be collected regarding the presence of other grassland birds within Adams County, especially for more greatly threatened birds such as the Grasshopper Sparrow, the Northern Bobwhite, and the Bobolink (Keller et al. 2000). The results of such observations can be used in tandem with the findings of this study to build more inclusive and all-encompassing plans for grassland bird conservation efforts. As well, studies should be extended to include the entirety of the LCAC's easements across Adams County, as management practices in other areas will affect bird displacement across the county.

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Tables, Figures, and Appendices

Table 1. Data Sources analyzed using ArcGIS Pro, ArcMap 10.8.1, and MaxEnt software.

Name	Creator	Time Valid For	Description
Adams County Municipal Boundary	Adams County GIS Hub	2022	Boundaries of Adams County, PA
Meadowlark Observations	Dr. Andrew Wilson	2004-2008	Points with coordinates showing locations of meadowlark observations
Pennsylvania State Boundary	Pennsylvania Department of Transportation	2022	Boundaries of Pennsylvania and counties
Land Cover	Chesapeake Conservancy	2013-2014	Land cover within the area of interest. Includes tree canopy, low vegetation, and shrubland
Land Conservancy Parcels	Land Conservancy of Adams County	2022	Land Conservancy properties within Freedom Township
Crop Cover	United States Department of Agriculture	2008	Crop cover within the area of interest. Includes tree canopy, corn, hay, soybean, wheat, and grassland/pasture

Table 2. Land cover data reclassified in ArcGIS Pro and the features included in each category.

Category	Features Included
1 - Water/Wetlands	water, wetlands
2 - Tree Canopy	tree canopy, tree canopy over structures, tree canopy over impervious surfaces, tree canopy over impervious roads
3 - Shrubland	shrubland
4 - Low Vegetation	low vegetation
5 - Barren	barren
6 - Structures	structures
7 - Impervious Surfaces	impervious surfaces, impervious roads

Table 3. Crop cover data reclassified in ArcGIS Pro and the features included in each category.

Category	Features Included
0 - Background	background data from original dataset
1 - Row Crops	corn, sorghum, soybeans, sweet corn
2 - Grains, Hay, Seeds	barley, winter wheat, dbl, wheat/soy, rye, oats, speltz, alfalfa, other hay
3 - Other Crops	dry beans, potatoes, other crops, misc. fruits and vegetables
4 - Fallow/Idle Cropland	fallow/idle cropland
5 - Tree Crops	cherries, peaches, apples, christmas trees, other tree crops
6 - Grass	sod/grass seed, pasture/grass, herbaceous grassland
7 - Other	clover/wildflowers, wetlands, open water, developed/open space, developed/low, developed/med, developed/high, barren, woody wetlands, herbaceous wetlands
8 - Forest	Forest, deciduous forest, evergreen forest, mixed forest

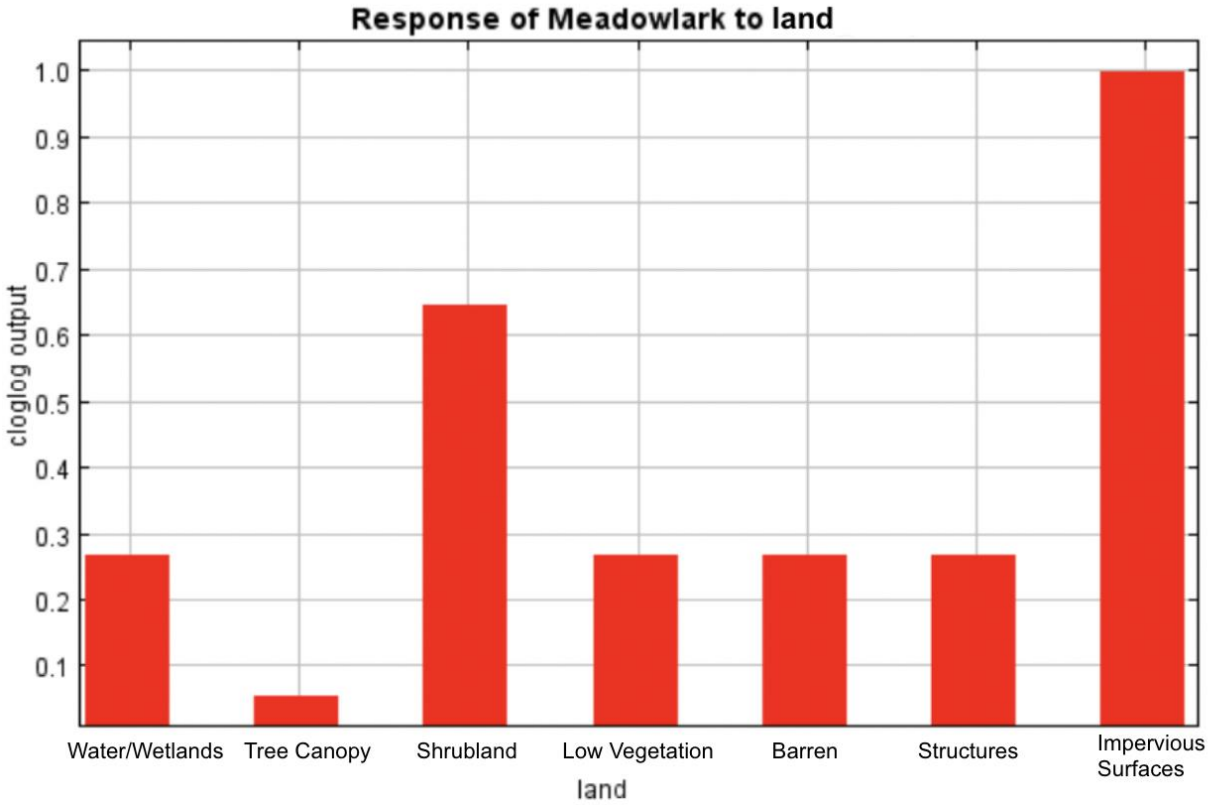

Figure 1. Comparison of Eastern Meadowlark habitat suitability across certain land cover types. The x-axis displays 7 classes of categorical land cover. Features included in each category are described in Table 2. The y-axis displays predicted probability of presence values yielded for each category when all average sample values for other environmental variables remain constant. AUC (Area Under the Curve) = 0.797.

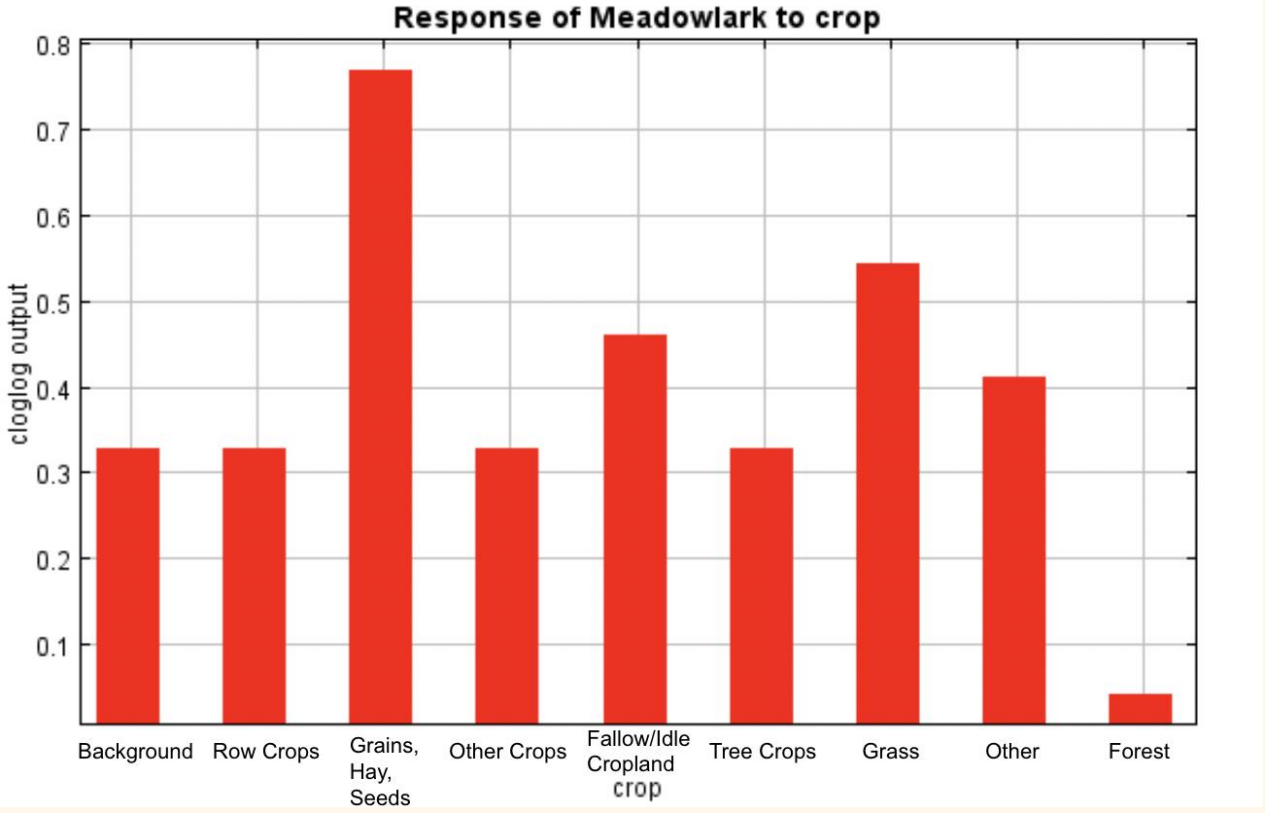

Figure 2. Comparison of Eastern Meadowlark habitat suitability across certain crop cover types. Features included in each category are described in Table 3. The y-axis displays predicted probability of presence values yielded for each category when all average sample values for other environmental variables remain constant. AUC (Area Under the Curve) = 0.760.

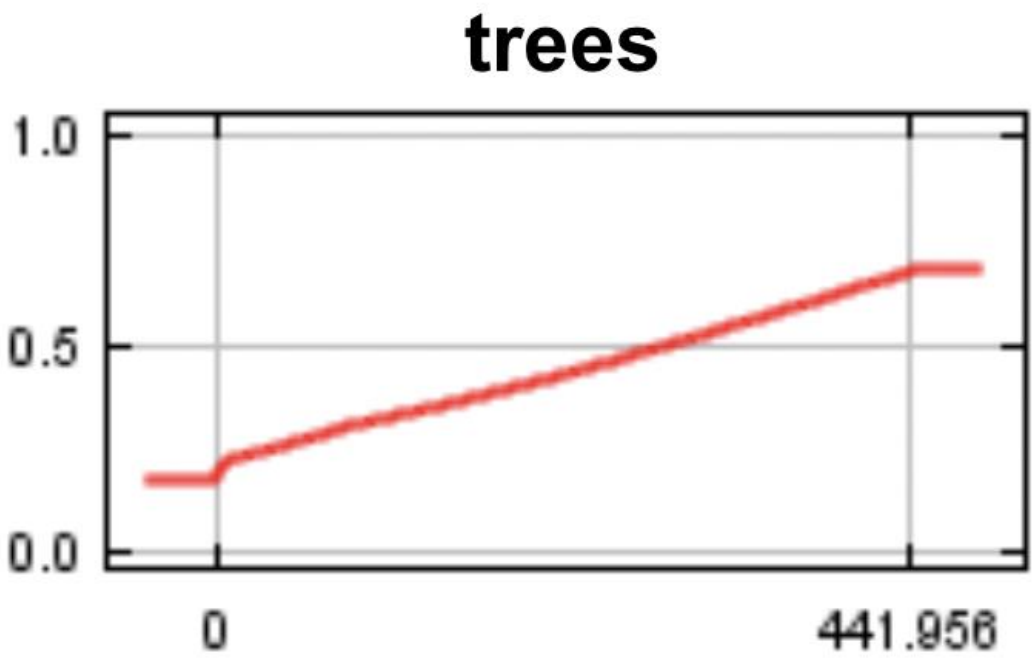

Figure 3. Response curve showing how the predicted probability of Eastern Meadowlark presence changes with variance in distance (meters) to tree canopy (perch). The average sample values for other environmental variables are not omitted from this curve.

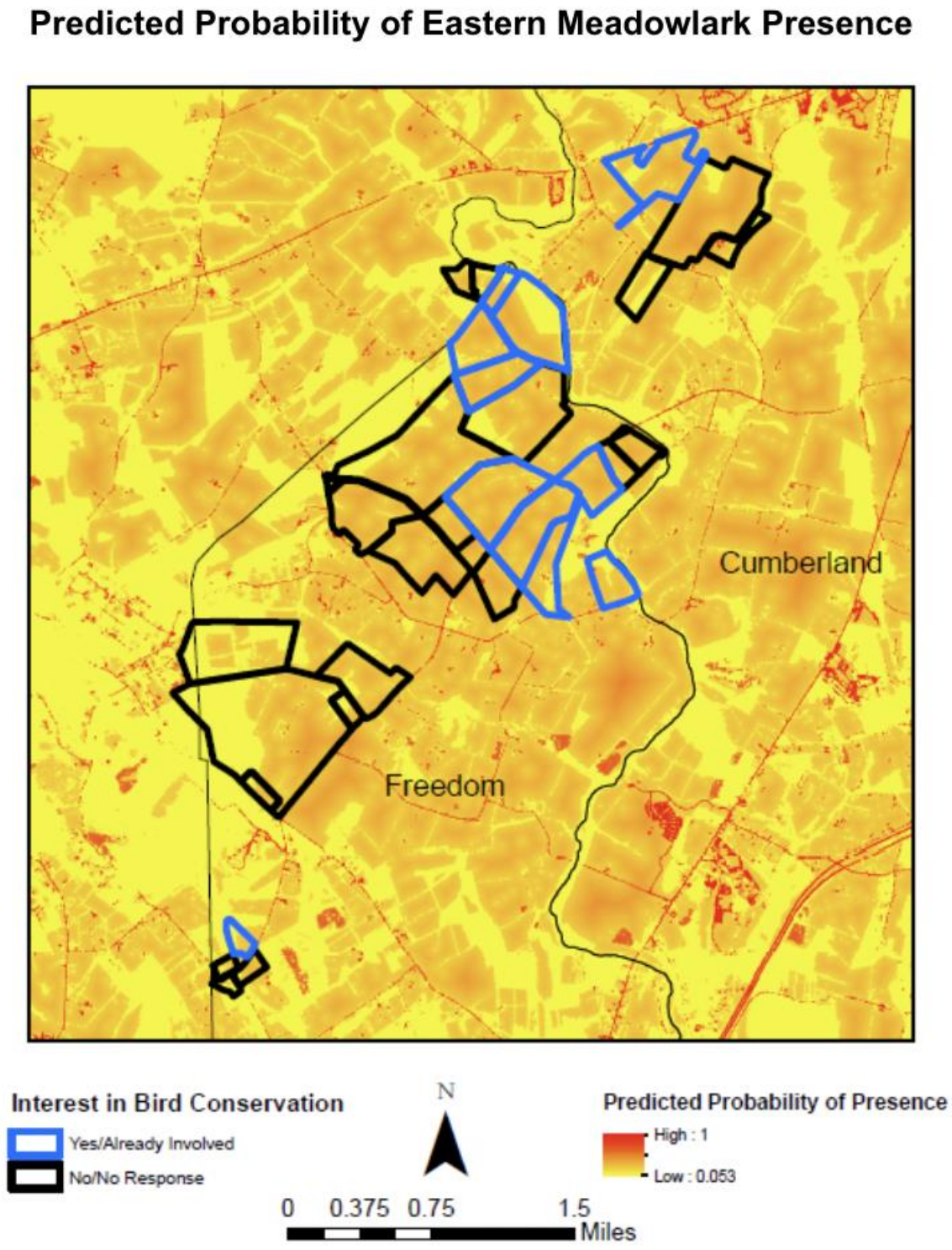

Figure 4. Species distribution model for the Eastern Meadowlark (*Sturnella magna*) based upon categorical land cover variables and a continuous environmental variable, Euclidean distance to perch. Features included in each category are described in Table 2.

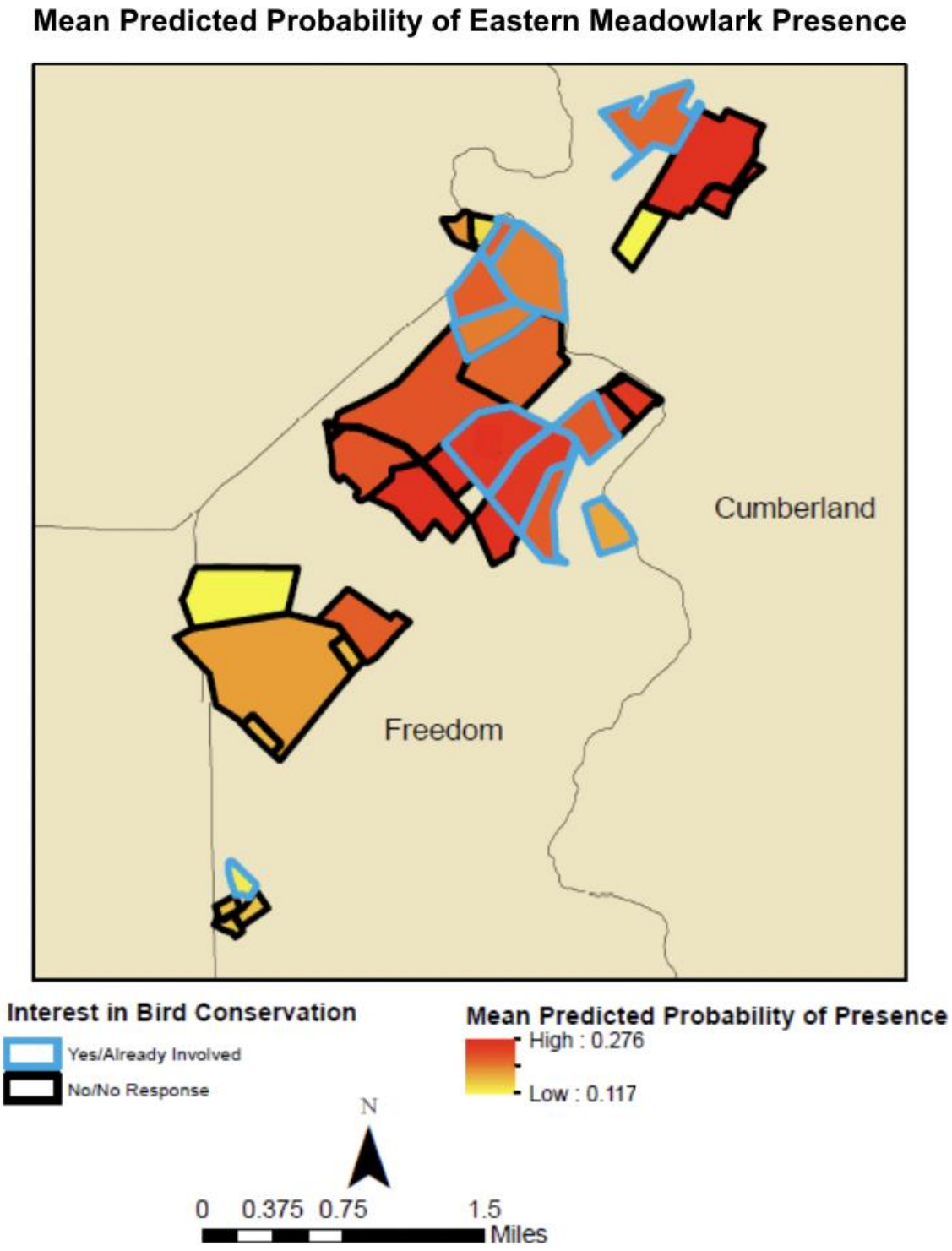

Figure 5. Mean predicted probability of Eastern Meadowlark (*Sturnella magna*) presence within LCAC parcels, calculated using zonal statistics. This figure is based upon the species distribution model incorporating categorical land cover variables and Euclidean distance to perch. Features included in each category are described in Table 2.

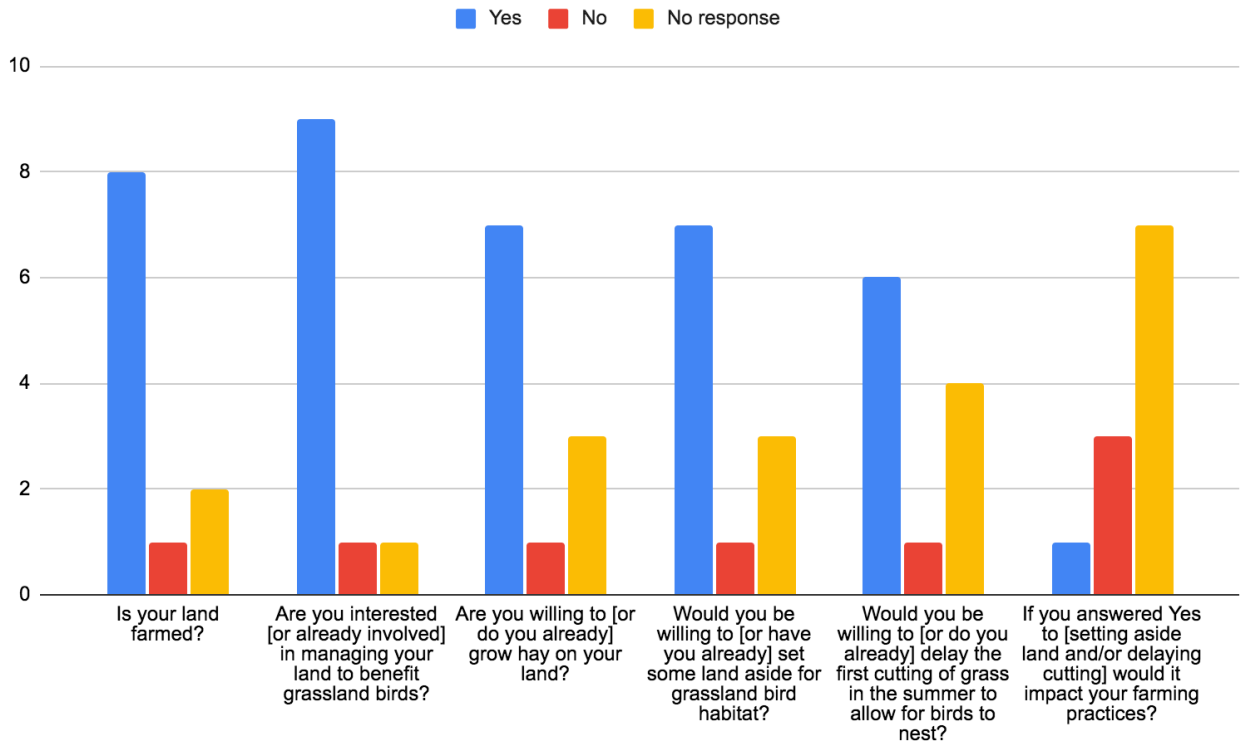

Figure 6. Bar chart displaying the breakdown of landowners' responses to a subset of survey questions. There were 19 questions total, and surveys were sent via mail and email. Eleven out of 21 survey recipients responded. Those who wrote that they were already involved in the practices mentioned were grouped into the "yes" category, and the questions have been slightly altered on this graph to include prior involvement without changing the nature of the question.

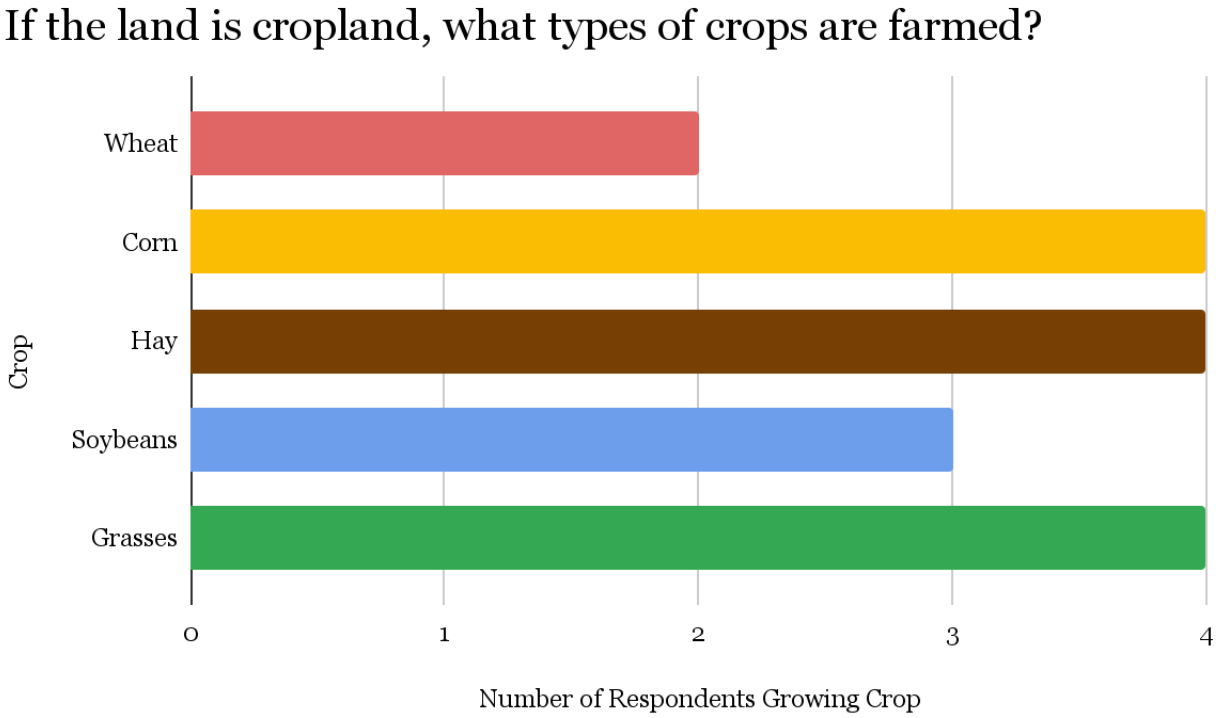

Figure 7. Bar chart displaying the frequency of different crop types grown by Freedom Township landowners (N=11). This survey question (10) allowed open-ended answers. Blank answers and the response “N/A” are omitted from this visualization.

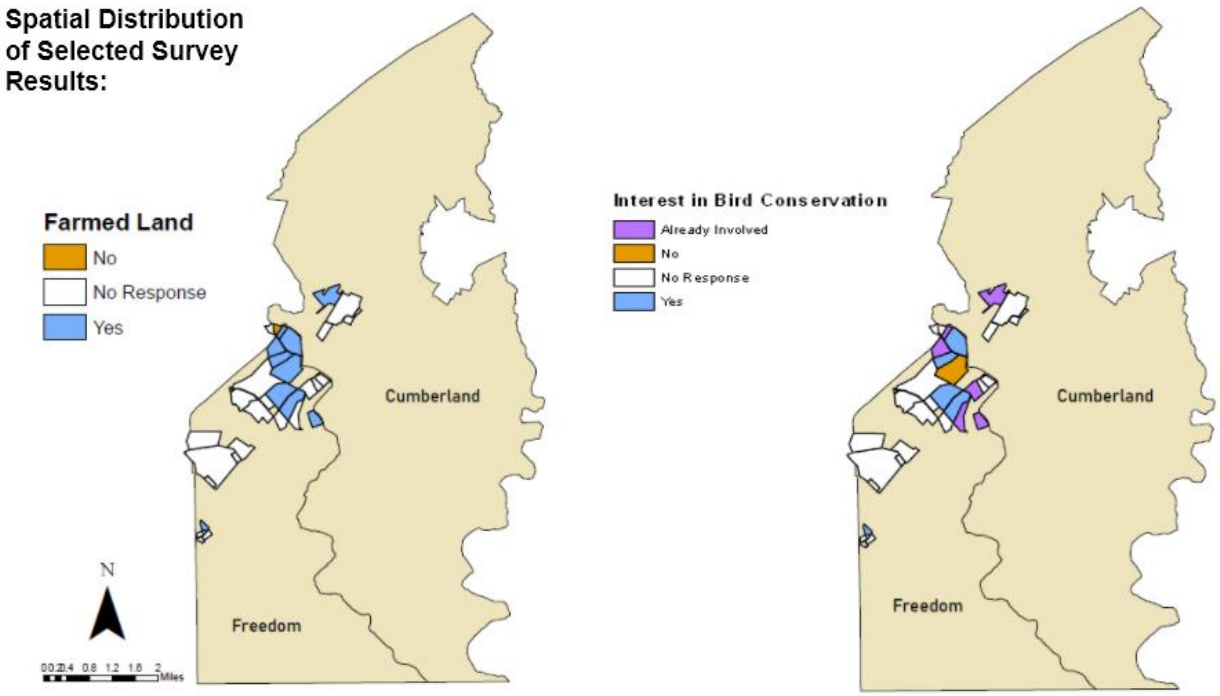

Figure 8. Mapped survey results showing the spatial distribution of farmed land easements of the Land Conservancy of Adams County, as well as landowner interest in managing their land for bird conservation as assessed by a landowner survey (N=11).

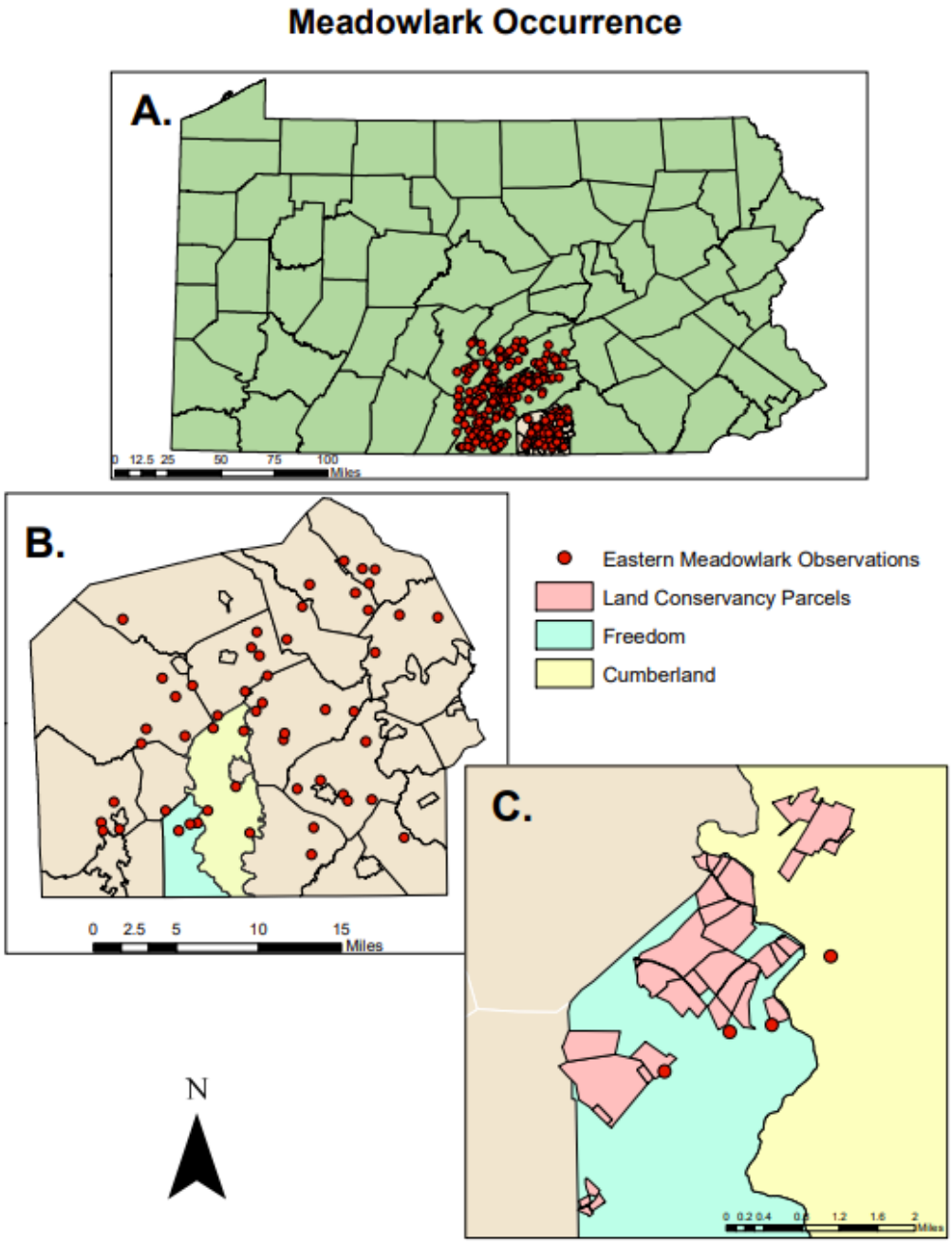

Figure 9. The geographic distribution of Eastern Meadowlark observations in Adams County. These 2004-2008 observation data are from the "Second Atlas of Breeding Birds in Pennsylvania". A: N=368, B: N=53, C: N=4. Produced in ArcMap 10.8.1.

Appendix A

Gettysburg COLLEGE

Funds for Senior Projects Application

Submit Date:	Sunday, February 13 2022, 1:47 PM
Faculty Instructions:	Indicate your approval by forwarding this e-mail to [redacted] having typed 'I approve' in the message section of the e-mail.
Department/Program:	Environmental Studies
First Name:	Amy
Last Name:	Marigliano
Student Email:	[redacted]
Student Campus Mailbox:	[redacted]
Student ID Number:	[redacted]
Student Home Address:	[redacted]
Expected Graduation:	Saturday, May 14 2022
Faculty Sponsor:	Natasha Gownaris
Faculty Sponsor Email:	[redacted]
Project Title:	Assessing Grassland Bird Habitat Suitability in Freedom Township, PA
Project Description:	The goals driving this project are twofold. Our long-term goal is to support the Land Conservancy in applying for a Land Trust Grant through the Cornell Ornithology Lab. Our short-term goal is to enact change in the land management practices of Freedom Township to restore and/or maintain grassland bird habitat. Fulfilling these goals will require the achievement of two main objectives: creation of a case study modeling the habitat suitability for grassland birds in Freedom Township, as well as an educational pamphlet for landowners and farmers explaining how they can alter their agricultural practices to benefit local bird species.
Amount Requested:	$500
Supplies:	$160- Envelopes, stamps and postage, pamphlet printing
Transportation:	$320- Gas, vehicle rental and driver
Acknowledgements:	FundingPurposeAcknowledgement,EthicalReviewAcknowledgement,SummaryAgreementAcknowledgement
CC:	[redacted]

Appendix B

Land Conservancy of Adams County Landowner Survey

Purpose and intent: Gettysburg College students Hayden Dubniczki, Amy Marigliano, and Sarah Westrick are conducting research for their Senior Capstone project that is focused on assessing habitat suitability for grassland bird species in Freedom Township, PA for the Land Conservancy of Adams County. We are interested in better understanding which farming and land use practices are amenable to grassland habitat restoration and preservation.

Data and Privacy: Any personal and identifiable data will be shared only with the researchers, a faculty advisor (Natasha Gownaris), and the Land Conservancy of Adams County.
.
Deadline: The deadline for this survey is March 14, 2022. If you are unable to meet this deadline, please still send this survey back to the researchers at your earliest convenience. Please mail this survey back to the researchers with the address below (a stamp has been provided for you):

Hayden Dubniczki
300 N. Washington St
Gettysburg College- CB # 0688
Gettysburg, PA 17325

Your participation in this study is voluntary. This study will not provide compensation for participation. We do not expect you to benefit from being in this study, but your participation may help the Land Conservancy and grassland bird populations in the future. You must be 18+ years of age to participate in this study.

The Land Conservancy has contact information for the landowners they are currently in collaboration with. However, they have mostly mailing addresses rather than emails, and they do not have contact information for the farmers actively engaged in agricultural practices related to land management. If you, the participant, so choose, the researchers who crafted this survey will share your contact information with the Land Conservancy. This will allow the organization to have emails and mailing addresses for landowners and their farmers (in the event the landowner and farmer are not the same person). Researchers will contact farmers personally with a separate survey, and in that survey we will ask for their permission to share their contact information with the Land Conservancy.

If you are not comfortable with your contact information being shared with the Land Conservancy, you can still answer survey questions to help with our grassland bird conservation

research. By checking “No” below, you will opt-out of sharing your name, mailing address, and email with the Land Conservancy, and this contact information will be limited to researchers only. If you check “Yes”, you are giving researchers permission to contact you in the event they have further questions regarding your land use practices or would like to discuss ground truthing on your property.

If you have questions about this survey or this study please email Hayden Dubniczki (dubnha01@gettysburg.edu) or Sarah Kipp (skipp@adamscounty.us).

If you agree to participate in this study, we ask that you answer these questions. If you do not wish to participate, you may disregard the survey. If you have already participated in this survey via email, please disregard this mailed survey.

Name(s):

E-mail:

Phone number:

Address:

Do you give researchers permission to share your contact information with the Land Conservancy of Adams County?

O Yes
O No

Survey Questions:

1. Is your land farmed? If you answered Yes, who is your farmer?

   O Yes
   O No

   a. Farmer contact information:

      i. Email:

      ii. Phone number:

2. If you answered No to #1, what is your land used for?

3. How involved are you in the management of your land?

4. What type of land cover is present on your property (e.g., horse or cow pasture, cropland, grassland, forest, open yard, etc.)? If possible, please provide a rough estimate of the percent land cover in each relevant category.

5. Are you familiar with which bird species are frequently present on your land? If so, what species have you observed?

6. Are you interested in managing your land to benefit grassland birds?

   O Yes
   O No

7. Are you willing to allow us on your land to conduct bird count surveys and to inform our habitat suitability study?

   O Yes
   O No

The following questions apply if you/your farmer farm your land.

8. What are your current agricultural practices?

9. If the land is cropland, what types of crops are farmed? (e.g., wheat, soy, grass, apple trees, etc.)?

10. Are you willing to grow hay on your land?

11. Would you be willing to set some land aside for grassland bird habitat?

    O Yes, with appropriate compensation
    O No

12. If you answered Yes to #11, how much acreage would you be willing to set aside?

13. Would you be willing to delay the first cutting of grass in the summer to allow for birds to nest?

O Yes, with appropriate compensation
O No

14. If you answered Yes to #13, how long would you be willing to delay cuttings?

15. If you answered Yes to #11 and/or #13, would it impact your farming practices?

O Yes
O No

16. If you answered Yes to #13, what would the impact be cost-wise to your practice?

17. Do you have any questions for us?

18. Please use this space to add anything that may be relevant but is not covered above.

Appendix C

Excel file containing raw Landowner Survey Responses (identifying information has been redacted): https://docs.google.com/spreadsheets/d/1ezZ1sU-tvpncQ2uy-tqkjpxmkd_WqtuO4Hzm0T8XH2U/edit?usp=sharing