**Project Report and Summary to the Northeast Climate Science Center**

**Section 1. Administrative Information**

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**Project title:** Incorporating Social Drivers to Optimize Conservation Practices that Address Gulf Hypoxia and Declining Wildlife Populations Impacted by Extreme Climate Events
**Agreement number:** MS3650
**Date of revised report**: 5 June 2018
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**Actual cost of project:** $154,060.43.

**Section 2: Public Summary**

With leadership and coordination provided by the Eastern Tallgrass Prairie and Big Rivers (ETGPBR) Landscape Conservation Cooperative (LCC), US Fish and Wildlife Service (USFWS) Landscape Conservation Cooperatives (LCCs), which collectively span the geographic extent of the Mississippi River Basin (MRB) (see https://lccnetwork.org/), have identified high nutrient runoff (a major contributor to Gulf of Mexico hypoxia), and declines in wildlife populations (especially grassland and riparian bird species), as major conservation challenges requiring collaborative action. This project focused on development and application of spatial decision support systems (DSSs), coupled with surveys of agricultural producers, to assist the LCC community and partner resource management agencies across the MRB in addressing these issues. The DSSs were designed to identify watersheds within the MRB, where application of select conservation practices can reduce nutrient export to the Gulf of Mexico hypoxic zone and enhance habitat and conservation for grassland and riparian bird species, based on understanding perspectives of agricultural producers who are willing and capable of effectively implementing these practices. The DSSs were intended to be used to identify appropriate conservation practices that could be implemented on the landscape, and to quantify resulting benefits for both reduced nutrient export and improved habitat for focal avian species. Informed by results and interpretations of surveys of agricultural producers in targeted watersheds, the application of the DSSs also benefitted from assessments of whether/how producer willingness to implement select conservation practices might be altered by perceptions of future climate change and extremes.

The most concrete findings and results from this project emerged from the agricultural producer surveys, and include:

Major findings:

- Agricultural producers are more willing to adopt conservation practices that improve soil health and prevent erosion, than practices that enhance other conservation priorities;
- The mean weight for reducing soil erosion was higher than for other criteria, indicating that on average, interviewees give more weight to reducing soil erosion when making decisions on practice adoption than to other decision criteria;
- Producers are willing to increase adoption of conservation practices which are already adopted widely in the watershed and which help prevent erosion (e.g., grass waterways);
- Reducing soil erosion and nutrient loss are more highly weighted by producers than decreasing risks of climate change or increasing biodiversity (wildlife) when making decisions about adopting conservation practices;
- Many of the practices that agricultural producers would increase are practices that interviewees were already willing to adopt; some of these could also decrease or stay the same. This indicates that climate change may not be a motivator for adoption of conservation practices; and

- Results imply that if interviewees are thinking of using conservation practices to address environmental issues (e.g., water quality), the fact that some practices have more concrete disadvantages may weigh more heavily than abstract benefits.

Recommendations that address significant concerns expressed by agricultural producers surveyed:

- Provide more outreach about off-farm benefits of conservation practices with a focus on water quality; and
- Highlight how adopting conservation practices can help to decrease the potential for future government regulation, reported as a concern by agricultural producers and documented in survey results.

**Section 3: Project Summary**

*Purpose and Objectives:*

With leadership and coordination provided by the Eastern Tallgrass Prairie and Big Rivers (ETPBR) Landscape Conservation Cooperative (LCC), US Fish and Wildlife Service (USFWS) Landscape Conservation Cooperatives (LCCs), which collectively span the geographic extent of the Mississippi River Basin (MRB) (see https://lccnetwork.org), have identified high nutrient runoff (a major contributor to Gulf of Mexico hypoxia), and declines in wildlife populations (especially grassland and riparian bird species), as major conservation challenges requiring collaborative action. This project focused on development and application of spatial decision support systems (DSSs), coupled with surveys of agricultural producers, to assist the LCC community and partner resource management agencies across the MRB in addressing these issues. The DSSs have been designed to identify watersheds within the MRB, where application of select conservation practices can reduce nutrient export to the Gulf of Mexico hypoxic zone and enhance habitat and conservation for grassland and riparian bird species, based on identifying agricultural producers who are willing and capable of effectively implementing these practices. The DSSs were intended to be used to evaluate appropriate conservation practices to be implemented, and to quantify resulting benefits for both reduced nutrient export and improved habitat for focal avian species. Informed by results and interpretations of surveys of agricultural producers in targeted watersheds, the DSSs were also intended to benefit from analyses of whether producer willingness to implement desired practices might be altered by perceptions of future climate change and extremes.

This project has focused on developing analytical tools to help move current opportunistic conservation approaches to more strategic levels, by targeting conservation projects in critical watersheds to achieve the most tangible overall conservation benefits. While significant research is currently invested in decision support tools for designing alternatives for future adaptation of policies and management strategies for responding to climate change and extremes, limited research exists that improves understanding of how learning, attitudes, and decision making by agricultural producers shape adaptation and resilient farm-based livelihoods beyond climate risks. This project was designed to enhance understanding of what motivates producers to adopt conservation practices, filling what is presently a critical information gap.

*Organization and Approach:*
One component of this project involved development and application of the structure and components of the new UMESC DSS. This involved identifying focal watersheds for DSS applications in select regions of the MRB. Watershed selection was based on criteria provided by LCC staff and other resource managers, as well as on the location of groups of agricultural producers willing to participate in our detailed survey. The new DSS required developing two initial sub-models: (1) a species habitat sub-model for grassland and riparian bird species of concern, and (2) a surface hydrology sub-model. Two additional sub-models are in the conceptualization stage for future development, including (1) a best management practices (BMP) sub-model based on a subset of Natural Resources Conservation Service BMPs, and (2) a sub-model reflecting information on producer willingness and ability to implement desired BMPs, and how their willingness to apply conservation practices on the ground might change based on perceptions of future climate change and extremes.

The second project component involved developing conceptual links or interfaces between the UMESC developed habitat sub-model and WRESTORE (Watershed REstoration using Spatio-Temporal Optimization of REsources; http://research.engr.oregonstate.edu/hyrdroinformatics/wrestore), an existing interactive and participatory modeling framework developed for designing alternatives of conservation practices via web-based interaction with stakeholder communities. This was intended to be useful for fine-tuning or refining results from the new DSS to design spatially explicit plans for locating conservation practices in watersheds of interest.

The third project component involved completing detailed on-site surveys of agricultural producers (collectively referred to herein as producers) in carefully selected watersheds. The intent was to improve current understanding of what motivates producers to adopt specific conservation practices, and how their motivation and preference might change in the face of extreme climate events. This information was intended to inform sub-model design within the UMESC DSS.

*Project Results, Analyses and Findings: Conclusions and Recommendations:*
The complexity of this project, as well as problems encountered during project execution, prevented all components of the project from being completed as planned. Thus, we have not included the information requested in this section, synthesized for the entire project; instead, we provide the requested information for each of the individual project components in the following section.

## Section 4: Report Body

*Completion of Surveys of Agricultural Producers in Select Watersheds in the Mississippi River Basin (Purdue University)*. The MRB contains prime farmland that has produced high-value, nutrient intensive crops for food, fiber, and fuel. Prairie, forest, and river ecosystems that support diverse plant and animal communities are also present. The increase and intensification of agricultural production in the MRB has degraded plant and animal habitats. Aquatic and riparian ecosystems have been particularly impacted by intensive agricultural practices. Increases in sediment and nutrient loading, exacerbated in part by channelization and tile drainage, have resulted in impaired water quality throughout the MRB. Nutrient loading has led to extensive eutrophication that has contributed directly to the creation of the hypoxic zone in the Gulf of Mexico. Midwestern states within the MRB contribute the greatest nutrient loads to the Gulf of Mexico hypoxic zone. Recent implementation of tile drainage and reversion of Conservation Reserve Program lands to cropland in the Basin may increase effects of nutrient loading and further reduce wildlife habitat.

This project was conceived and designed to address the issues and concerns summarized above, and to investigate barriers and opportunities relative to adoption of conservation practices by agricultural producers in specific MRB sub-watersheds. This investigation also evaluated rates of adoption of different conservation practices which enhance water quality or wildlife habitat and that qualify for federal cost-share programs. Understanding what factors influence producers' management decisions can help researchers understand why practices are adopted, or why they might have a high likelihood of adoption now and in the future. Understanding decision-making as it relates to adoption of specific practices can also inform water quality and habitat models that predict what may happen to areas of hypoxia in the Gulf of Mexico in response to future climate and land use changes in the MRB.

Data developed in this component of the larger project resulted from in-person interviews conducted in Big Creek watershed located in Posey County in southwestern Indiana, and in Lime Creek watershed located in Buchanan and Benton Counties in northeastern Iowa. Interviews were conducted in Big Creek watershed with 18 agricultural producers in May and June of 2015, and in Lime Creek watershed with 16 agricultural producers in February and March of 2016. Agricultural producers were recruited with the help of the Soil and Water Conservation District in Big Creek watershed, and of Richard Sloan, an agricultural producer and coordinator of the Lime Creek Watershed Improvement Association. Delays associated with locating appropriate groups of producers willing to participate prevented a third set of interviews from being completed as originally planned.

The primary purpose of this portion of the overall study was to understand producers' motivations to adopt conservation practices, including perceptions of water quality and climate change. Results indicate that reducing soil erosion and nutrient loss as motivating factors are weighted more strongly by producers than decreasing risks of climate change or increasing biodiversity (wildlife) when making decisions about adopting conservation practices. However, there is wide variability in weights given to each criterion, indicating a lack of strong consistency in the weight interviewees give to one criterion in relation to another. For example, one interviewee may give more weight to reducing risks of climate change than reducing soil erosion when implementing a conservation practice while another interviewee may give more weight to reducing soil erosion.

We conducted semi-structured interviews with oral open-ended and closed-ended questions and written closed-ended questions using an interview guide developed prior to the interviews. Open-ended questions asked agricultural producers about the advantages and disadvantages of adopting different conservation practices on their property. Closed-ended questions asked producers to gauge their willingness to adopt conservation practices on a five-point Likert-type scale (1 representing least likely to adopt, 5 representing very likely to adopt). Conservation practices included in the interviews addressed either water quality, wildlife conservation, or both and included cover crops, constructed wetlands, drainage water management, filter strips, grassed waterways, no-till, riparian buffer strips, and strip cropping. Interviewees were asked to discuss their current use of conservation practices and their willingness to change their use of conservation practices in the future due to projected climate changes in the Upper Midwest.

Agricultural producers were also provided graphs of climate projections describing future temperature and precipitation changes in the Upper Midwest (developed by Dr. Alexander Bryan, NE-CSC staff, personal communication). The interviewer described how the graphs were developed and how to interpret the climate projections. Producers were then asked if they would increase or decrease their level of adoption (e.g., increase/decrease the extent of current use and increase/decrease the likelihood of implementing a currently unused practice), or if their level of adoption would stay the same. Near the conclusion of the interview, the interviewer asked the producer to fill out a form where producers chose between different decision-making criteria that may influence their adoption of conservation practices. We used the Analytical Hierarchical Process (AHP), which asked producers to make pair-wise comparisons between the following criteria: decreasing net costs, decreasing fertilizer losses, decreasing flooding, decreasing erosion losses, increasing biodiversity, and decreasing climate change risks.

Producers were asked to compare two criteria on an 18-point scale of relative importance of one decision criterion in comparison to the other. The purpose of the AHP is to understand how producers make trade-offs between different decision criteria and to assess which criteria have greater weight in their decision-making. Knowing the weight each criterion has on producer decision-making will help explain why producers are more willing to adopt a specific conservation practice over other practices.

Interviewees were asked about their perceptions of climate change. Most interviewees expressed skepticism about human contributions to climate change but acknowledged that climate changes over time. After being presented with climate scenarios of precipitation and temperature changes, interviewees were asked if their use of conservation practices would increase, decrease, or stay the same. Many of the practices that would increase habitat potential and mitigate nutrient runoff were practices that interviewees were already willing to adopt; some of these could decrease or stay the same. This indicates that climate change may not be a strong motivator for adoption of conservation practices.

Producers' discussions of the advantages and disadvantages of conservation practices primarily focused on on-farm benefits while off-farm benefits were secondary. For example, when producers spoke of grassed waterways, they spoke of more immediate outcomes (e.g., soil erosion or forage for livestock), while discussions of constructed wetlands focused on outcomes that are more removed from the producer’s farm, such as wildlife or water quality. This distinction is consistent with the weight given to reducing erosion control and loss of nutrients rather than to benefits to biodiversity. Interestingly, many of the advantages discussed with those interviewed were more abstract (e.g., wildlife benefits), whereas many of the disadvantages mentioned for each practice focused on problems with implementation or management of those practices or the requirement to change farming operations (e.g., delayed spring planting). This difference implies that if interviewees are thinking of using conservation practices to address environmental issues (e.g., water quality), the fact that some practices have more concrete disadvantages may weigh more heavily than abstract benefits.

These results will inform the future work of researchers at Purdue, Oregon State, or USGS as they develop applications that tailor information and advice provided through DSS. These applications will help in the understanding of what practices may be of value to farmers at the field scale and how to measure on-farm and off-farm benefits of those practices. By understanding the barriers, constraints, and motivations for adoption of conservation practices, we will be able to provide better suggestions and advice when farmers are using these tools.

### Major survey findings include:

- Agricultural producers are more willing to adopt conservation practices that improve soil health and prevent erosion than practices that enhance other conservation priorities;
- The mean weight for reducing soil erosion was higher than for other criteria indicating that on average, interviewees give more weight to reducing soil erosion when making decisions on practice adoption than other decision criteria;
- Producers are willing to increase adoption of conservation practices which are already adopted widely in the watershed and which help prevent erosion (e.g., grass waterways);
- Reducing soil erosion and nutrient loss are more highly weighted by producers than decreasing risks of climate change or increasing biodiversity (wildlife) when making decisions about adopting conservation practices;
- Many of the practices that producers would increase are practices that interviewees were already willing to adopt; some of these could also decrease or stay the same. This indicates that climate change may not be a strong motivator for adoption of conservation practices; and
- Results imply that if interviewees are thinking of using conservation practices to address environmental issues (e.g., water quality), the fact that some practices have more concrete disadvantages may weigh more heavily than abstract benefits.

### Recommendations that address significant concerns expressed by agricultural producers surveyed:

- Provide more outreach about off-farm benefits of conservation practices with a focus on water quality; and
- Highlight how adopting conservation practices can help to decrease the potential for future government regulation, reported as a concern by producers and documented in survey results.

*Modification and Application of the DSS WRESTORE to Select Watersheds in the Mississippi River Basin, in Order to Simulate and Optimize Placement of Conservation Practices (Oregon State University)*

One of the primary goals of this component of our project was to couple the underlying simulation-optimization model and algorithms in the existing DSS WRESTORE (Watershed REstoration using Spatio-Temporal Optimization of REsources; http://research.engr.oregonstate.edu/hydroinformatics/wrestore) with the avian habitat model and data contained in the USGS Gap Analysis Program (GAP) database, hosted on the USGS GAP website (https://gapanalysis.usgs.gov). The resulting integration provides decision makers with the ability to examine a range of conservation practices and their spatial implementation, for the purpose of managing co-benefits related to flood mitigation, water quality abatement, and avian habitat restoration. In this component of the project, we focused on examining how such a coupling would impact the design of wetlands in a test-bed agricultural watershed. However, the approach is transferrable to other practices, and also to a combination of multiple conservation practices. We investigated the following specific objectives focused on the design of wetlands using a coupled WRESTORE-GAP approach.

Objective 1**:** Use a multi-objective optimization approach in WRESTORE that considers four objective functions together – minimize Wetland Area (WA), maximize Peak Flow Reduction (PFR), maximize Sediment Reduction (SR), and maximize Nitrate Reduction (NR) – to identify a non-dominated set of watershed scenarios for restoring and/or implementing wetland restoration or creation. The peak flows, sediment loads, and nitrate loads were estimated using the Soil and Water Assessment Tool (SWAT; Arnold 1998).

Objective 2: Develop a fifth objective function related to avian habitat restoration - maximize Habitat Index (HI) (species-habitat relationship) – using the GAP habitat model, and re-optimize watershed scenarios of new wetlands based on the previous four, as well as the new fifth habitat objective function.

Objective 3: Compare trade-offs between objective functions of non-dominated solutions found via the two previous experiments in Objectives 1 and 2.

This component of the study employed five related steps in its overall approach, as described in the following text.

First, before parameterizing and validating the SWAT model of the watershed, the river/stream, watershed, and sub-watershed were delineated using ArcMap. Sub-watershed divisions were delineated by overlaying, to the extent possible, HUC-12 boundaries. The resulting vector files served as input for the SWAT model.

The SWAT model was calibrated using delineated watersheds, with land use and soil data from the Geospatial Data Gateway database (https://gdg.sc.egov.usda.gov/), slope categories, weather information at appropriate monitoring stations, stream gauge records, and appropriate SWAT parameters at the outlet of sub-watershed #39 in Big Creek Watershed. The Nash-Sutcliffe Efficiency (NSE) and $R^2$ criteria were used to determine that the model calibration was acceptable.

Second, species-habitat relationships were obtained based on GAP data for current conditions of the watershed (baseline), considering four forested riparian birds: American Redstart, Wood Duck, Red-eyed Vireo, and American Woodcock. The GAP analysis uses a Python script, and for this study, two additional scripts were developed in Python in order for it to iteratively run GAP analysis from outside ArcMap. These scripts were later assembled into a Java code for use in the Non-dominated Sorting Genetic Algorithm (NSGA-II) optimization algorithm.

Third, existing wetlands were considered as baseline. A list of existing wetlands was obtained from the National Wetlands Inventory (https://www.fws.gov/wetlands/). Identified wetlands were delineated in ArcMap, and further formatted for inclusion in the SWAT model.

Fourth, following the methodology and concepts described by Babbar-Sebens et al. (2013), potential sites for new field-scale wetlands were determined.

Fifth, in order to determine which potential wetlands could bring more benefits for Big Creek Watershed regarding PFR, SR, NR, and HI, for the smallest possible total wetland area in the entire watershed (i.e., WA), an optimization model was run using the NSGA-II algorithm. Objective functions for SR and NR were taken from Piemonti et al. (2013), whereas the objective function to estimate PFR was taken from Babbar-Sebens et al. (2013), and the function for estimating increase in HI was taken from Garrison (2015).

The application of the revised WRESTORE was focused on Big Creek Watershed, one of the watersheds selected by Purdue for landowner surveys, and also in Bayou Creek Watershed; both are located in southwestern Indiana.

Restoring wetlands has been proposed as a potential strategy to reverse watershed impairments such as poor water quality, loss of natural habitats, and changes in natural flow regime of rivers. This study focused specifically on determining optimal solutions for wetland size and location that simultaneously optimized all five objective functions -- potential WA, PFR, SR, NR, and HI, through a spatial, multi-objective optimization of new potential wetlands at field scale. Hydrologic, sediment yield, and water quality processes were simulated using SWAT; and avian habitat benefits were estimated using the GAP tool. The four avian species listed earlier were considered collectively as a surrogate of avian biodiversity.

Two cases of potential wetland optimization were completed. Case 1 considered four objective functions: WA, PFR, SR, and NR. In Case 1, HI for optimized design alternatives of the spatial distribution of potential wetlands was completed post-optimization. In contrast, Case 2 considered HI as a fifth objective function and was completed within the optimization process. Hence, HI, along with the other 4 objective functions, simultaneously influenced the search process of the NSGA-II algorithm. At the end, trade-offs among the objective functions were established and further examined for all optimized design alternatives.

Before conducting optimization, GAP analysis was carried out for baseline watershed condition (i.e., current condition with no new wetlands added to the landscape). The analysis of the baseline condition showed that the study area is more suitable for Red-eyed Vireo, followed by American Woodcock, Wood Duck, and American Redstart. This order was expected to remain the same if potential wetlands are implemented.

In addition to calculating habitat area for the baseline condition, the GAP model was also used to simulate the effect on habitat area if all potential wetlands identified for the watershed were actually implemented/created on the landscape. Results show that Wood Duck habitat area would increase by 135.1%, followed by American Woodcock (18.2%), Red-eyed Vireo (4.7%), and American Redstart (0.5%). This suggests that Wood Duck habitat is more likely to benefit from addition of wetlands than the other three species. American Redstart habitat is not likely to improve significantly if all potential wetlands were added to the landscape. It also suggests that in future considerations of wetland optimization, when considering avian habitat as the objective function, species for which habitat is less likely to improve significantly following implementation of a conservation practice (i.e., less sensitive) should not be taken into account as part of further analyses focused on identifying optimized conservation plans for the watershed.

Trade-offs between the HI objective function and each of the hydrologic-water quality objective functions (PFR, SR, NR) were estimated for final sets of optimized design alternatives produced in Case 1 and Case 2 optimization experiments. Results indicate that there is generally a weak conflict between HI and other objective functions in Case 1 and weak redundancy in Case 2; however, trade-offs between HI and WA were the opposite, weak redundance in Case 1 and weak conflict in Case 2, albeit with a low level of confidence in both cases.

Trade-offs between WA and the physical hydrologic-water quality objective functions (PFR, SR, NR) showed strong conflict for both Cases 1 and 2, with high negative correlation coefficient values. This result suggests that minimizing WA does not lead to optimal solutions for PFR, SR, and NR.

On the other hand, trade-offs among the objective functions (PFR, SR, and NR) demonstrated strong redundancy for both Cases 1 and 2, with strong positive correlation coefficients. These objectives increase and decrease together based on a corresponding increase and decrease in amount of WA to be implemented.

Including HI as a fifth objective function in the optimization process (Case 2) did not result in significant improvement of total habitat area values across all avian species. In fact, the HI values across all avian species for optimized designs in Case 2 were slightly lower than for the case in which HI is not included in the optimization process (i.e., Case 1). But in both cases, HI showed a weak association with the other objectives, with HI being very similar for dissimilar values of PFR, NR, and SR objective function values. This indicated that optimal values of HI, or close to optimal values of HI, could be obtained by a range of dissimilar configurations of restored potential wetlands.

Analysis of HI for optimal scenarios at sub-basin scale in both cases (i.e., Case 1 and 2) showed a positive association between WA and HI; however, there was no pattern of intensity of association between WA and HI. In other words, Pearson Correlation Coefficients varied from 0.05 (weak association) to 0.92 (strong association). In several sub-basins, it was observed that different amounts of WA produced the same or nearly the same HI.

Regarding the decision space, in the tradeoff curve of optimized PFR, SR, and NR values, design alternatives provided noteworthy sub-basin-scale PFR, SR, and NR benefits mainly at downstream sub-basins and in the main channel. In these optimized watershed plans for potential wetlands, the restored WA were placed primarily in uplands, indicating that upland wetlands in upstream locations can considerably benefit downstream sub-basins.

Four avian species were considered in this study based on USGS-UMESC priorities. However, since these species provided limited help in identifying an optimal configuration of new potential wetlands due to a weak "Habitat-Wetland area" association, other species should also be considered in future analyses.

*Development of new UMESC DSS for Application to Select Watersheds in the Mississippi River Basin (USGS UMESC)*: Scientists at UMESC worked to develop the components of a new DSS to assist resource managers in identifying geographic areas (i.e., watersheds at specific spatial scales) where the spatially-targeted application of select conservation practices (BMPs) would reduce nutrient export to the Gulf of Mexico hypoxic zone, while simultaneously increasing the quantity and quality of habitat for grassland and riparian bird species. The long-term goal was to help opportunistic conservation move to a more strategic, stakeholder-driven approach that identifies project locations in critical watersheds to achieve the largest overall conservation benefit.

We initiated the development sub-models to be used to identify locations on the landscape where the implementation of BMPs could reduce nutrient run-off and enhance grassland and riparian bird habitat. The avian sub-model was developed as a derivative of the GAP species habitat models. They were recreated in Python script and were intended to be delivered to the user as an ArcMap Add-in. We intended to provide an easy to understand, broadly applicable tool that leveraged previously existing models and data. This sub-model included an overall influence weight identified by the user to adjust the relative significance of each sub-model. The user then selects which of the grassland, riparian forest, and/or bottomland hardwood bird species habitat models found in GAP to include in the analysis. Each species model has an associated weight value that can be edited to adjust the species influence over the composite model. The land cover types used in the model are presented to the user, and the habitat suitability values linking each land cover type to each bird species being modeled can be edited by the user. The user can also identify which land cover classes are available to be altered and which should be removed from consideration (e.g., urban areas are unlikely to be converted into a different class and should be masked from the composite model). The user can also identify a range of values within the final composite model that are considered marginal and have the potential for conversion into a land cover class of greater benefit to the selected species.

The nutrient sub-model identifies patches of potential nutrient pooling and prioritizes patches by concentration, size, shape, and up-slope proximity to flow lines. Again, this sub-model also has an overall influence weight identified by the user to adjust the relative significance or influence of each sub-model. This allows the user to perform sensitivity analysis by adjusting the relative weight/significance of each model. For this model, the user defines the influence of land cover on nutrient loading and nutrient uptake (zero = neutral, positive values = nutrient load, and negative values = nutrient uptake). The user then specifies a topographic surface and flow line dataset. We utilized NHDPlus data for both of these inputs. Flow lines in this model identify the runoff endpoints. Runoff that reaches this feature is considered to be exported out of the system. There are two basic flow model types: weighted flow accumulation and a weighted topographic convergence index. Weighted flow accumulation tends to emphasize channelization whereas the weighted topographic convergence index emphasizes broad areas of pooling. The patch selection criteria help to restrict areas of interest by evaluating areas of high nutrient load while taking into consideration patch shape, patch size, and proximity to flow line. This model was created with ESRI ArcObjects libraries and needs to be updated to be compliant with the most current version of these libraries.

To assist in placement of BMPs, the tool WRESTORE, described in the previous section, was to be used. It includes several key features important to linking it to the newly developed UMESC DSS to accomplish the main objectives of this project. WRESTORE is a web-based, participatory design tool for planning conservation practices in a watershed. It uses a crowd-sourcing (bottom up vs. top down) planning process to accomplish this. WRESTORE contains a user-friendly interface for engaging stakeholders in viewing and providing feedback on alternatives for placing conservation practices and has the ability to include both stakeholder's unquantifiable and quantifiable goals in the planning process. Within this tool, stakeholder feedback is used to detect preferences and guide optimization algorithms to develop new alternatives for BMP placement.

This new DSS was also intended to consider information on the willingness and preferences of landowners to apply select conservation practices (BMPs), and how such preferences might change in response to future climate change scenarios. Colleagues at Purdue University structured and executed interviews to develop an understanding of the motivations and barriers to adoption of conservation practices in light of a changing climate. These semi-structured interviews and interpretations of outcomes are discussed above.

Critical to the success of this project was the formation of a 'technical advisory team' of experts who could provide advice and guidance on various issues requiring resolution as the DSS was being developed and applied. Among various tasks, the advisory team was to assist in (1) finalizing the list of focal grassland and riparian bird species to be included in the DSS; (2) scoring the 'habitat suitability' of land cover types/geographic cells being modeled for each of the avian species under consideration [the GAP data bases contain very coarse suitability information -- basically presence/absence information -- which needs to be enhanced, but a wealth of other relevant geographic information that can be used as is]; and (3) selecting 3-4 priority clusters of watersheds in different regions of the MRB for initial proof-of-concept model application and testing. Ongoing technical advice from knowledgeable experts was fundamental to the successful development and implementation of this new DSS.

Based on various efforts over the last several years to identify avian species of conservation concern, a list of candidate grassland and riparian bird species to be included in the DSS was assembled and is included below.

**Grassland:** Upland Sandpiper, Bobolink, Grasshopper Sparrow, Dickcissel, Henslow's Sparrow, Horned Lark, Greater Prairie Chicken, Eastern Meadowlark
**Riparian:** Prothonotary Warbler, American Redstart, Wood Duck, Acadian Flycatcher, Green-Winged Teal, Mallard, Pectoral Sandpiper, Marsh Wren, Virginia Rail

Due to delays and difficulties encountered in other components of this multi-component project, especially in the completion of landowner interviews, we were not able to fully complete all intended components of the new UMESC DSS, nor has the system yet been applied to any watershed or landscape. Further development and implementation of this DSS is contingent on future project and funding opportunities.

**Outreach and Products:**

*Publications and Reports:*

Garrison, S. 2016. Determination of Trade-offs Between Wetland Ecosystem Services in an Agricultural Landscape. M.S. thesis, Oregon State University.

Singh, Ajay S., Belyna Bentlage, and Linda S. Prokopy. 2016. Agricultural Producer Perspectives on the Adoption of Conservation Practices, Water Quality, and Climate Change in the Lower Wabash River Watershed, Posey County, Indiana. Natural Resources Social Science Lab, Department of Forestry and Natural Resources, Purdue University.

Singh, Ajay S., and Linda S. Prokopy. 2016. Agricultural Producer Perspectives on the Adoption of Conservation Practices, Water Quality, and Climate Change in the Lime Creek Watershed, Buchanan and Benton Counties Iowa. Natural Resources Social Science Lab, Department of Forestry and Natural Resources, Purdue University.

Singh, Ajay, Francis Eanes and Linda Prokopy. In Press. Assessing Conservation Adoption Decision Criteria Using the Analytic Hierarchy Process: Case Studies from Three Midwestern Watersheds. *Society and Natural Resources.*

Yarasca, E.N., S. Garrison, and M. Babbar-Sebens. In preparation. On the inclusion of bird habitat goals in multi-objective optimization of wetland placement: An Examination of redundancies and tradeoffs.

Yarasca, E.N., and M. Babbar-Sebens (2017). Multiobjective Optimization of Wetlands for Attaining Flood, Water Quality and Bird Habitat Benefits. In: ASCE's World Environmental & Water Resources Congress, Sacramento, CA, May 21-25.

Yarasca, E.N. (2017). Multiobjective Optimization of Wetlands for Attaining Flood, Water Quality and Bird Habitat Benefits. M.S. thesis, Oregon State University.

*Presentations:*
Fox, Timothy, Jason Rohweder, Jack Waide, Meghna Babbar-Sebens, Linda Prokopy, and Gwen White. Incorporating social drivers to optimize conservation practices that address Gulf Hypoxia and declining wildlife populations impacted by extreme climate events. 75th Midwest Fish & Wildlife Conference, February 2015, Indianapolis, IN

Singh, Ajay, Belyna Bentlage, Meghna Babbar-Sebens, and Linda Prokopy. Ag producers' motivations for adopting conservation practices. Annual Meeting of the American Fisheries Society, August 2016, Kansa City, MO.

[In addition, Jack Waide made presentations on project progress and results at several meetings of the Steering Committee of the Eastern Tallgrass Prairie and Big Rivers LCC.]

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