MISSISSIPPI WATER RESOURCES RESEARCH INSTITUTE
FINAL TECHNICAL REPORT

Influence of wetland plant community types on water quality improvement in natural and restored wetlands of the Mississippi Delta

01 March 2015 to 28 February 2016

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ABSTRACT

In an effort to quantify the specific linkages between wetland plants and water quality in Mississippi Delta wetlands, we assessed vegetation and water quality in 30 wetlands, including 24 Wetland Reserve Program (WRP) restorations and six naturally occurring wetlands. Our goal was to examine interactions among water quality parameters and plant species to determine which plant species assemblages appear to most strongly influence nutrient and sediment concentrations in these wetlands. We found substantial differences in the hydrology of restored, versus naturally occurring wetlands, and these differences were correlated with differences in plant species diversity among wetlands. We did not see significant correlations between specific plant species and water quality parameters, but we did find that some plant growth forms were consistently correlated with such water quality parameters as pH, conductivity and nitrate concentrations. We will be working with the USDA NRCS in an effort to translate results of this work into information useful for the design of future restorations, such that they can yield the greatest improvements in water quality while also providing other benefits, such as wildlife habitat, for the Mississippi Delta.

INTRODUCTION

In the Mississippi portion of the Lower Mississippi Alluvial valley (i.e., the "Delta"), some 190,000 acres have been enrolled in the Wetland Reserve Program (WRP) since 1992 and over 23,000 acres are currently in CRP wetland restoration practices (Kevin Nelms, USDA NRCS unpublished data). The success of these wetlands in providing the desired ecological functions (e.g., wildlife habitat, water quality improvement) has been inadequately examined, but such studies are critically important for determining factors that may indicate potential success of future restoration or conservation efforts.

Conservation lands in the Delta are exposed to a relatively high intensity of agricultural land use, which has the potential to negatively impact the ecological function of these lands. For example, estimates based on current agricultural data indicate that watersheds in Mississippi experience nutrient loads in the range of 0.3 to 62 kg nitrogen per hectare and 0.3 to 45 kg phosphate per hectare within the Delta (Figure 1). These data are based solely on average inputs of N and P fertilizers per hectare of the three major MS crops (corn, cotton, and soybeans), which themselves range from 0.5 to 78 percent of the area of individual watersheds within the Mississippi Delta (USDA National Agricultural Statistics Service).

Figure 1. Wetlands examined during our research, plotted against USDA National Agricultural Statistics Service and USDA Economic Research Service data on estimated agricultural fertilizer inputs to corn, cotton, and soybeans. Boxed inset on left is shown in greater detail on the right, to indicate the distribution of our study wetlands across three categories of nitrogen loading, for purposes of our

Comprehensive assessments of restored wetland success are needed to determine the interactive effects among land use, wetland management, and water quality improvement. With this in mind, we set out to evaluate the linkages between water quality and wetland plant assemblages within the Delta. This work was part of an overall research program investigating the impacts of land use on water quality and wetland plant assemblages in natural and restored Delta wetlands.

Our specific objectives in this study were to:

1. Measure water quality parameters (changes in nutrient and sediment loads) and wetland plant species assemblages in restored and naturally occurring wetlands in the Mississippi Delta, across the available gradient of estimated nutrient loadings.
2. Quantify statistical linkages among nutrients, sediment, and wetland plant species, with the objective of determining which suites of species are most closely correlated with greater reductions in nutrient and sediment loads.
3. Translate these results into information that could be used to guide the design of future wetland restorations so as to optimize the likelihood of establishing wetland plant assemblages most likely to contribute to water quality improvements.

METHODS

Site selection

Twelve watersheds (HUC-12) containing WRP wetlands within the Mississippi Delta were selected for assessment (Figure 1). Fertilization and land use data from 2010-2012 were used to calculate approximate nitrogen loads (kg/ha) applied to each watershed, among the three most important crop species. From those data, watersheds were grouped into "high" (≥39 kg/ha), "medium" (17.9-39 kg/ha), and "low" (≤17.9 kg/ha) nitrogen fertilizer application loads (classified based on natural breaks approach in ArcMap 10.2). Those nitrogen loading groups were used to stratify study wetlands across the spectrum of nitrogen application conditions in Mississippi Delta (Figure 1).

Four watersheds in each of the three nutrient load categories were selected randomly following determination of easements with landowner willingness to participate in this study. Two restored WRP wetlands in each selected watershed were monitored throughout the study, for a total of 24 restored wetlands (eight each in high, medium, and low nitrogen load watersheds). A reference (naturally occurring) wetland was identified in six of the 12 watersheds, with two in high nitrogen application watersheds, two in medium, and two low nitrogen application watersheds (Figure 2). Selection of wetland sites via landholder willingness was facilitated with the assistance of Kevin Nelms (USDA, NRCS).

Data Collection

Water sample collection in each wetland took place along the "shoreline" of the wetland and within the wetland interior, with the number of samples collected depending on the size of inundated portion of the wetland on each sampling date. We collected four water samples from sites where the largest inundated area was less than 50m on its longest dimension (two shore and two interior samples) and six samples when the inundated area was larger than this (three shore, three interior samples).

Where obvious inflow points were present, the shore samples were collected from two or three of those locations, depending on wetland size. When obvious inflows were absent (which was most often the case), sample points were spaced at intervals of: approximately one-third the longest dimension (wetlands < 50m), one-fourth the longest dimension (wetlands ≥ 50m), or evenly distributed when the largest inundated area had an approximate diameter of 20m or less. We also sampled from wetland outflows when water levels were sufficient to generate flow through the outflow structures of restored wetlands (and from the major natural outflow for natural wetlands).

Sampling along the shore and within the wetland interior was expected to permit a wetland-scale evaluation of changes in nutrient and sediment concentrations as surface water passes through the vegetated zone of each wetland. Inclusion of samples from outflows, when present, was expected to permit an estimation of nutrient and sediment reductions for each wetland, relative to "inflow" loads and plant assemblages in each wetland.

Water chemistry

Water samples were analyzed for nitrate-N, ammonia-N, phosphate-P, dissolved oxygen (DO), conductivity, pH, and turbidity. We used in-situ data collection sondes (Hach Hydrolab DS5 sonde) to measure water temperature, conductivity, pH, DO, and turbidity. Concentrations of nitrogen and phosphorus were determined through analysis at the Mississippi State University Water Quality Laboratory.

All water samples were handled, collected, and transported according to EPA quality assurance/quality control guidelines (USEPA 2002). Water samples were transported (in coolers, on ice at ~4°C) from field sampling locations to the Mississippi State University Water Quality Laboratory for analysis. Unfiltered samples were analyzed for total inorganic phosphorus (TIP) using TNT 843 analysis kits (HACH, Loveland, CO, USA) according to methods described in APHA et al. (1998). All samples also were filtered through 0.45μm cellulose membrane filters to be analyzed for ammonia (NH_3), nitrate (NO_3^-), and nitrite (NO_2^-) using a Lachat Flow Injection Analysis (FIA) 8500 (Lachat Instruments, Loveland, CO, USA). Lachat FIA standard methods of automated cadmium reduction allow for analysis of NO_x^- and NO_2^- (APHA 1998), where NO_3^- values are calculated as the difference between NO_x^- and NO_2^-. Ammonia, NO_3^-, and NO_2^- were added together to calculate total inorganic nitrogen (TIN).

Sediment retention

Total suspended solids (TSS, a measure indicative of both inorganic sediment load and transport of organic particulates within and from the wetland) were measured by filtering water samples through pre-combusted (500°C), pre-weighed 0.7 μm glass fiber filters. The filters, along with the non-dissolved particulate matter from water samples, were dried at 105°C and re-weighed after drying to determine TSS concentration (APHA et al., 1998).

Wetland Plant Species

Floristic inventories (e.g., Ervin et al. 2006a) were conducted on plant species within the wetland sites in the spring (late May) and in the summer (early August). Fifty circular plots (0.5 m^2 each) were evenly spaced (~25m apart) along transects systematically covering each site, excluding portions of the site with standing water greater than waist deep. All plant species within the circular plots were recorded, and in the event of an unidentifiable specimen, voucher samples were collected and transported to the Mississippi State University Herbarium for expert identification.

Plant species are being analyzed for overall species composition, the composition of species based on growth form, and wetland indicator status. In this way, sites can be represented by dominant plant species, as well as by detailed species presence data, for analysis against water quality parameters.

Site Hydrology

Twelve water level loggers (Rugged Troll 100, In Situ Inc., Ft. Collins CO) were placed across nine of the twelve Delta watersheds. Within these watersheds, four loggers were placed in each nitrogen loading category. Of these four, one logger was placed in a reference wetland, while another was placed in a restored wetland within the same watershed. The remaining two were placed in two other watersheds within the same nitrogen loading category. The loggers recorded data every hour in a linear fashion over the duration of the study. This procedure captured hydrologic "fingerprints" of the wetlands and quantified site hydrology over the testing period.

RESULTS & DISCUSSION

Hydrology differed markedly between the natural and WRP wetland sites (Figures 2 and 3). Natural sites maintained standing water on-site throughout a substantial portion of the year, but WRP wetlands exhibited shallower water overall, as well as a significant period of exposed sediments during each year. As discussed in a separate report, data suggested that this difference in hydrology may have resulted in a significantly higher plant species diversity in the WRP wetlands (Ervin & Kröger, 2016).

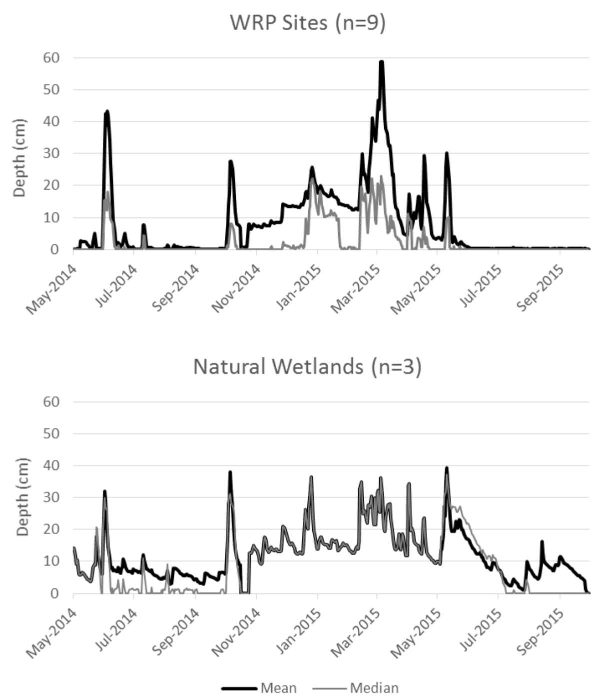

Figure 2. Hydrographs for sites on which water level loggers were installed. The data covered two research seasons for work funded by MS WRRI.

The management approaches used in WRP wetlands include annual drawdowns of water levels to stimulate spring and summer growth of desirable waterfowl forage plants. This is a major cause for differences observed in hydrology between wetland types. Local precipitation patterns also resulted in not only some differences among wetlands, but also periods of very dry conditions across all study sites (Figure 4, Table 1). This hampered our ability to examine plant-water quality interactions during portions of the year.

Despite the problems with water availability in August and October 2015, we were able to collect and process 177 water samples in March and 142 samples in May.

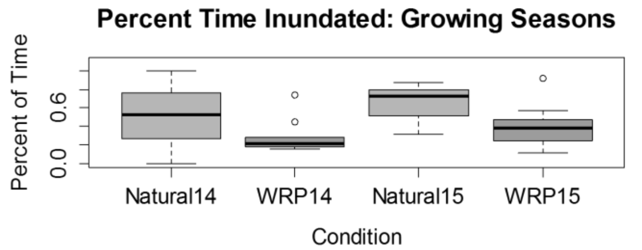

Figure 3. We found a general tendency (not statistically significant) for natural wetlands to remain flooded for a longer proportion of the growing season than did WRP wetlands.

One complicating issue with determining dominant plant species at water quality sampling locations in March was that sampling occurred before the majority of plants had emerged for the 2015 growing season. To facilitate a correlation of water quality sampling with dominant stands of vegetation within each wetland, we used plant survey data from August 2014 to determine water sampling locations. Maps of probable plant assemblages were interpolated using Thiessien polygons (in ArcMap GIS version 10.2) of dominant species from August 2014 surveys (e.g., Figure 5).

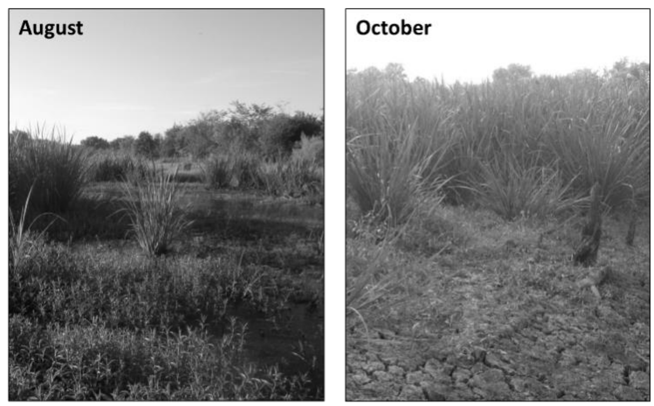

Figure 4. Example of the contrast in hydrology among seasons between late summer-early fall in some of the study sites.

Table 1. Distribution of samples among sites and sample dates, during our 2015 water quality sample collection.

Sampling trip	Samples collected	Samples per site	Sites with samples collected
March	177	4-7	28
May	142	4-7	23
August	54	6	9
October	12	6	2

We are continuing our work on determining the full suite of plant species observed in our study sites. However, analyses for March 2015 water quality data are presented here (Figure 6). One important finding in these analyses (as well as preliminary analyses we have conducted for May 2015) is that plant species identity appears poorly correlated with water quality measurements in our dataset. Plant species assemblages varied quite widely among sites, with one consequence that we have found a set of roughly six species that are quite common across sites and a large number of species that occur at 2-6 sites each. This essentially resulted in relatively unique species assemblages for each wetland, which complicates efforts at finding broad-scale patterns of correlation between plant species, per se, and water quality.

On the other hand, when we grouped plant species into their representative growth forms (vines, broad-leaved, graminoid, and woody plant species), patterns emerged from the analyses (Figure 6). For the March 2015 sampling period, significant differences among plant growth forms for our measurements of pH, conductivity, and nitrate were found. However, no significant differences among growth forms with respect to reduction-oxidation potential (ORP), turbidity, total suspended solids (TSS), or phosphate were found.

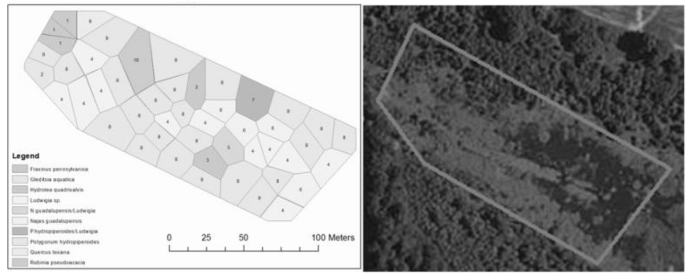

Figure 5. On the left, a map of probable plant assemblages at a site. On the right, satellite imagery of the same site at 1m resolution.

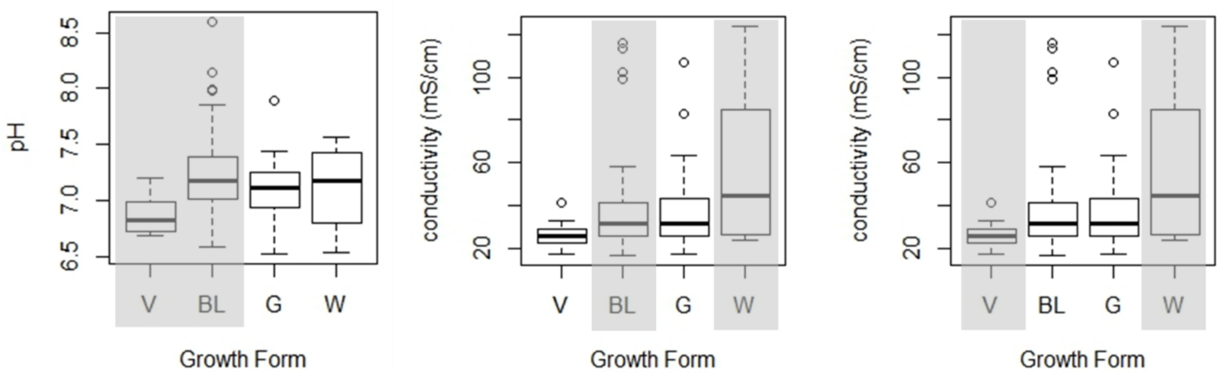

Figure 6. Plant growth form was found to be correlated with differences in some water quality parameters among wetlands. Left: stands dominated by vines exhibited significantly lower pH than stands dominated by broad-leaved species; middle: stands dominated by broad-leaved species exhibited significantly lower conductivity than stands dominated by woody species; and right: stands dominated by vines exhibited significantly lower conductivity than stands dominated by woody species.

We are conducting an additional experiment to look more closely at responses of wetland plant assemblages to nutrient and sediment inputs into Delta wetlands (Figure 7). In this study, we collected soil from three of our WRP sites and placed it into 378-L (100-gal) cattle tanks. The tanks then were randomly assigned to treatment groups receiving high or low level amendments of nitrogen fertilizer and high or level amendments of sediment, owing to the importance of nutrient and sediment serving as the most commonly cited water quality stressors for natural wetlands and those restored for conservation purposes. Sediment for this experiment was derived from the three wetlands selected for the study.

Figure 7. Tank experiment designed to test responses of wetland vegetation to nutrient and soil inputs. Soil from three WRP sites was used to establish the experiment.

This experimental study – although still underway – has suggested that there are significant differences among the three wetlands in both the plant species assemblages establishing in each but also the rates of removal of nutrients and sediment from the water column over time. These results support our finding in the field study that plant species assemblages among the individual wetlands are quite dissimilar, complicating our efforts at teasing out interrelationships among plant species and water quality. It remains to be seen, however, whether relative differences in removal rates in the experiment will correlate with relative differences in measured water quality parameters among the three wetlands in the field and whether dominant plant species in the experimental tanks may be correlated with similarly low or high levels of water quality in the field. Regardless, it appears that we may be able to draw conclusions about the role of wetland plants in water quality mediation, via the differential effects of growth forms such as vines and broad-leaved plant species on water quality parameters we have measured.

Two graduate students continue to work on aspects of this project related to their thesis projects. We anticipate one thesis, one dissertation, and at least a small number of papers to be published based on this work (Table 2). We also will be producing reports for each individual site that will be distributed to the land owners and to Kevin Nelms, of the USDA NRCS.

REFERENCES

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PROGRESS RELATED TO STATED OBJECTIVES

1. Measure water quality parameters (changes in nutrient and sediment loads) and wetland plant species assemblages in restored and naturally occurring wetlands in the Mississippi Delta, across the available gradient of estimated nutrient loadings.

We completed four sampling trips to collect water quality data during 2015, along with two complete wetland plant surveys. The main obstacle to fully completing the objective as stated was that we found limited occurrences of outflows in our wetlands. This complicates efforts at quantifying changes in water quality parameters as water moves through the wetlands. This was one impetus for the experimental tank study that was established and is still underway. We do have data from two nutrient amendment treatments, the data for which are currently being analyzed.

2. Quantify statistical linkages among nutrients, sediment, and wetland plant species, with the objective of determining which suites of species are most closely correlated with greater reductions in nutrient and sediment loads.

We have completed analyses examining suites of species and individual species and have found few indications of consistent roles of individual species across the 30 study wetlands. However, we followed up those analyses with an examination of whether growth forms (groups of similar species) may influence water quality, and we have found indications that this is the case.

3. Translate these results into information that could be used to guide the design of future wetland restorations so as to optimize the likelihood of establishing wetland plant assemblages most likely to contribute to water quality improvements.

Individual reports on our findings for each wetland will be prepared and delivered to cooperating landowners. We anticipate having these reports delivered during Fall 2016. We have made contact with the coordinator of the Gulf Coastal Plain and Ozarks Landscape Conservation Cooperative about developing a project page to host data and information about this work. We also will be working with Kevin Nelms, of the USDA NRCS, to incorporate our findings into any potential improvements for the USDA ACEP (formerly WRP).

SIGNIFICANT FINDINGS

Information gained so far in this research project indicates that:

- Relatively large differences exist in plant species composition among Delta wetlands, even when experiencing similar management strategies.
- Individual plant species composition is relatively uninformative about water quality in Delta wetlands.
- Some water quality attributes do appear to be influenced by species mixtures or types, rather than by individual species themselves.

We will build upon these findings to develop plans for future research that could use these insights to help direct future restoration/conservation efforts in the Delta.

CONTINUED RESEARCH

Although the project performance period has ended, much of the analyses of data collected remains underway. We have collaborated with Dr. Charles Bryson and Mr. John McDonald to identify the more difficult plant species from the field surveys, and plant identification is nearing completion. We currently are engaged in data analysis for one Master's student thesis that should result in at least one peer-reviewed publication, and we anticipate at least two publications to result from the doctoral dissertation that is still in progress.

Table 2. Anticipated products not yet completed from this project.

Type	Tentative title	Anticipated completion
Dissertation	*Assessing drivers of wetland plant community dynamics in the Mississippi Delta*	December 2017
Thesis	*Functions of Wetland Plant Assemblages in Water Quality Improvement in Natural Wetlands*	August 2016
Reports	Individual site reports to be delivered to landowners who provided access to their property	Fall 2016
Online documents	We have made contact with the coordinator of the Gulf Coastal Plain and Ozarks Landscape Conservation Cooperative regarding development of a "project page" to host data and information related to this work	Fall 2016
Paper	Experimental assessment of nutrient and sediment removal by Mississippi Delta wetland communities	Fall 2016
Paper	Correlation of wetland plant assemblages with water quality in Mississippi Delta wetlands	Fall 2016

FUTURE FUNDING POTENTIAL

Dr. Ervin made contact with Florance Bass and Doug Upton, at Mississippi DEQ, regarding future research projects that could expand on the findings resulting from this work while also contributing to wetland needs within Mississippi. Plans are to continue discussions with MS

DEQ and to develop research plans that could be used to pursue potential funding opportunities that could take advantage of the information gained in this WRRI-funded project.

STUDENT TRAINING, OUTREACH, AND INFORMATION TRANSFER

Two graduate students are continuing work towards their degrees, with one planning to graduate during 2016, the other potentially as early as December 2017. These students have presented work from their projects at a number of regional conferences, resulting in one award for Best Student Presentation. The following are some of the products resulting from this research thus far.

Student Training

Name	Level	Major
Cory Shoemaker	Doctoral Student	Biological Sciences

Cory won the award for Best Student Oral presentation at the 2016 Mississippi Water Resources Conference, for a presentation on this work.

Name	Level	Major
Evelyn Windham	Master's Student	Biological Sciences

Evelyn was selected as the Department of Biological Sciences Teaching Assistant of the Year for the 2015-2016 academic year.

Publications/Presentations

Ervin, G. N. and C. M. Shoemaker. 2015. Water quality-land use interactions in restored wetlands of the Mississippi Delta. Mississippi Water Resources Conference, Jackson, MS, 08 April 2015.

Shoemaker, C.M. 2015. Drivers of wetland plant communities in the Mississippi Delta. Department of Sciences and Mathematics, Mississippi University for Women, Columbus, MS, September 9, 2015. (Invited lecture)

Shoemaker, C. M. and G. N. Ervin. 2015. Drivers of plant community composition in Delta wetlands. Mississippi Water Resources Conference, Jackson, MS, 08 April 2015.

Shoemaker, C. M. and G. N. Ervin. 2015. Drivers of plant community compositionin restored wetlands. Society of Wetland Scientists annual conference, Providence, RI, 03 June 2015.

Shoemaker, C.M. and G. N. Ervin. 2015. Drivers of wetland plant assemblages in restored and naturally occurring wetlands in Mississippi. MidSouth Aquatic Plant Management Society Conference, Mobile, AL, September 16, 2015

Windham, E.L., C. M. Shoemaker, and G. N. Ervin. 2015. Functions of wetland plant assemblages in water quality improvement in natural wetlands. MidSouth Aquatic Plant Management Society Conference, Mobile, AL, September 16, 2015.

Shoemaker, C.M., E.L. Windham, and G.N. Ervin. Effects of land use on wetland plant diversity in Mississippi. Mississippi Water Resources Conference, Jackson, MS, 06 April 2016.

Windham, E.L., C. M. Shoemaker, and G.N. Ervin. Functions of wetland plant assemblages in water quality improvement. Mississippi Water Resources Conference, Jackson, MS, 06 April 2016.

In the Mississippi Delta, agriculture and wetlands are often seen as different, separate systems. This and other projects in which we are engaged attempt to blur the boundaries of the two types of systems by considering wetlands within their landscape context. A better understanding of how wetlands function in agriculturally dominated landscapes is of interest to wetland scientists but also to producers with land in conservation programs or those who are considering enrollment. Information developed through this project will provide new data that may affect how various Delta stakeholders manage land and prioritize enrollment ACEP sites.

Planned web-based hosting of data and information

Final products from the project will be made available to scientists and the general public through Ervin's membership in the Gulf Coastal Plain and Ozarks Landscape Conservation Cooperative (GCPO LCC). In particular, geospatially referenced data products resulting from this work can be made available, with landowner permission, via the GCPO LCC Conservation Planning Atlas (http://gcpolcc.databasin.org/).General information about the project and findings will be hosted through a GCPO LCC project page (gcpolccapps.org). All products made available in this manner will adhere to the data management best practices developed by the GCPO LCC.

Collaboration with Kevin Nelms of the USDA NRCS.

We have cooperated directly with the USDA NRCS in determining sites on which to conduct the research, but we also plan to maintain that collaboration to aid in information dissemination. Incorporation of our findings into the USDA NRCS WRP ranking tool will ensure that the most complete information is being applied to assessment and prioritization of WRP efforts within the region.