Evaluating the 4R Nutrient Stewardship Concept and Certification Program in the Western Lake Erie Basin

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Abstract:

Since the mid-1990s, the frequency and extent of algal blooms and loadings of dissolved phosphorus (P) in the Western Lake Erie Basin (WLEB) have been on increasing trends. Agricultural crop management has been identified as a primary source of P to the Lake. Over the past 2-3 years, educational programs directed at growers and nutrient service providers (e.g., agricultural retailers, crop advisers) have emphasized principles of 4R Nutrient Stewardship, and a 4R certification program for nutrient service providers in the WLEB has been developed and planned for roll-out in March 2014. The overall goal of the proposed project is to evaluate the specific impacts of the adoption of practices associated with 4R Nutrient Stewardship, and the impact of the WLEB 4R Certification Program itself, on crop productivity and profitability, water quality, and perceptions of growers, nutrient service providers, and residents in the WLEB. A multidisciplinary approach is proposed involving monitoring, modeling, and measurement of the impacts at the field, watershed, and lake scales.

Background:

Lake Erie is part of the Great Lakes System, which contains 20% of the surface freshwater in the world. Annually, tourism associated with Lake Erie generates more than $7.4 billion in direct sales, while Lake Erie seaports generate approximately $1 billion in revenue (USDA-NRCS, 2005). Sport fishing within Lake Erie has also been estimated to generate hundreds of millions of dollars annually. Unfortunately, over the past five years there has been an increased incidence of algal blooms and proliferation of aquatic weeds. Not only are algal blooms aesthetically unappealing, but they also can cause the formation of hypoxic zones in stratified waters. In some instances, algal blooms contain toxins that are harmful to humans and aquatic life. The increase in nuisance and harmful algal blooms (HABs) in Lake Erie has led to greater water treatment costs, reductions in fish populations, and poor water quality that has negatively impacted fishing and tourism industries within the Great Lakes region.

The primary cause of water quality impairment and algal blooms within Lake Erie is the input of excess nutrients, such as nitrogen (N) and phosphorus (P), often transported from agricultural lands. Many growers have accepted responsibility and are taking action to improve soil health and reduce nutrient losses from their fields. However, there are still additional opportunities through scientific and technologic advancements to help growers keep nutrients in their fields to benefit both crop growth and watershed health. 4R Nutrient Stewardship is an innovative approach to nutrient management that considers the economic, social, and environmental dimensions of nutrient management. Although the concept is relatively simple (apply the right source of nutrient, at the right rate, at the right time and in the right place), following the 4R principles has the potential to significantly reduce the amount of nutrients transported to Lake Erie as well as increase crop nutrient use efficiency.

One way to encourage adoption of the 4R principles is to first define key actions that characterize nutrient and water stewardship and to recognize good stewardship through a credible certification program. The 4R Certification Program Advisory Committee, led by members of the agricultural industry, grower representatives, and supported by The Ohio State University, state government, and facilitated by The Nature Conservancy, have been meeting since the spring of 2012 to create a program that identifies best management practices (BMPs) and encourages nutrient service providers (e.g., agricultural retailers, crop advisers) to adopt the 4R Nutrient Stewardship concept. The 4R Certification Program will help these nutrient service providers tailor 4R principles to each grower's unique needs, while minimizing nutrient losses and maximizing crop uptake. This program represents an effort by the agricultural industry to actively embrace a scientific-based approach to nutrient management and sustainable crop production. Such an effort diminishes the need for and the likelihood of public regulations that might otherwise be implemented to decrease nutrient loading to surface waters.

Objectives:

The overall objective of the proposed project is to assess the environmental and socio-economic benefits of the 4R Nutrient Stewardship concept and the 4R Certification Program in the WLEB. We plan to use a multidisciplinary approach that will allow us to monitor, model, and measure the impacts of the 4R Nutrient Stewardship concept and Certification Program at the field, watershed, and lake scales. Specific project objectives include:

1. To monitor the impacts of 4R Nutrient Stewardship practices and the 4R Certification Program on crop productivity, nutrient losses, and biotic integrity from select fields, streams, and watersheds in the WLEB.
2. To model the environmental benefits in Lake Erie (turbidity and HABs) following various levels of implementation of 4R Nutrient Stewardship practices and the 4R Certification Program in three WLEB agricultural watersheds.
3. To determine the behavioral impact of 4R educational efforts and the 4R Certification Program on the knowledge, beliefs, and management practices of crop growers and nutrient service providers in the WLEB.
4. To conduct a triple bottom line evaluation of the economic, social, and environmental performance of the 4R Nutrient Stewardship Program in the WLEB.
5. To integrate information from all the above to develop indicators for continued public reporting of progress and guide the 4R Nutrient Stewardship Certification Program.

Approach and Methods:

Objective 1: Monitoring of 4R Impacts

The purpose of the monitoring component of this project is to evaluate the environmental benefits of the 4R Nutrient Stewardship concept and the 4R Certification Program at both the field- and watershed-scale in the WLEB. To accomplish this, we propose to quantify nutrient export from paired fields and watersheds with one field (or watershed) having 4R practices and the other field (or watershed) representing current management practices. For both edge-of-field (EOF) and watershed sites, we will use a before-after control-impact (BACI) design to determine changes in nutrient concentrations and loads in surface runoff, tile drainage, and watershed discharge following implementation of management practices recommended by the 4R Certification. The strength of the BACI design lies in the assumption that changes over time in the 4R test site (treatment), unrelated to the 4R practice, are controlled for by changes over time in the control site. Thus, a significant time (before-after) × treatment (control-impact) interaction indicates that the 4R practice truly had an effect on nutrient loss. Where possible, we propose to use existing sampling locations where baseline sampling has been ongoing for multiple years. The approach for this component of the project will include three tasks:

1. Quantify nutrient export in stream discharge from paired watersheds to document the environmental benefits of the 4R Certification Program at the watershed-scale.
2. Quantify nutrient export in surface runoff and tile drainage from paired EOF sites to assess water quality benefits of specific 4R practices.
3. Examine stream metabolism (gross primary production and ecosystem respiration) as a response to changes in nutrient levels.

Task 1: Quantifying the effects of the 4R Certification Program on nutrient loss from agricultural watersheds in the WLEB

We have identified 3 treatment and 3 control watersheds associated with the Heidelberg Tributary Loading Program (www.heidelberg.edu/academiclife/distinctive/ncwqr/data/data), and one treatment watershed associated with ongoing research from the National Soil Erosion Research Laboratory (Table 1). These programs have been monitoring water quality at these seven sites for 3 to 38 years. Treatment watersheds were determined based on the location of nutrient service providers participating in the 4R certification pilot audit in July of 2013, whereas control watersheds have no known plans for 4R implementation. We hypothesize that the implementation of 4R certification by nutrient service providers will reduce N and P concentrations and loads at the watershed scale. At each of these sites, water samples are collected 1-3 times a day using automatic samplers. The samples are retrieved from each location once a week and immediately analyzed for N (ammonium, nitrate, nitrite, total N), P (dissolved P, total P), suspended sediment, silica, specific conductance, and anions (chloride, fluoride, sulfate) according to U.S. EPA methods. Each site is co-located with a USGS gaging station from which we can use discharge measurements to calculate nutrient loads and flow-weighted mean concentrations.

Our preliminary analysis pairing monthly sums of daily discharge and loads of total P, dissolved P, and nitrate-N for the 2011-2012 water years between treatment and control watersheds indicate strong and statistically significant correlations among many of our proposed watersheds (Table 2). We have identified 4 pairs that serve as excellent tests of our hypotheses (see TP load in Fig. 1) - Rock Creek as a control for the Portage, Blanchard, and Sandusky rivers, and the

Table 1. Watershed characteristics

Watershed	Trtmnt/ Control	Area (mi^2)	Years in Operation	% Ag.
Portage	Trtmnt	421	3	84.4
Blanchard	Trtmnt	336	6	78.8
Sandusky	Trtmnt	1251	38	77.6
Cedar	Trtmnt	74.8	9	76.2
Rock	Control	34.5	31	71.9
Honey	Control	81.1	37	81.1
Tiffin	Control	412	6	60.5

Tiffin River as a control for Cedar Creek. Since we are hypothesizing that nutrient l ads will de rease with 4R implementation at least for some seasons, we would expect a decr ase in the slope of the relationships between these pair d watershe s after implementation.

Table 2. Correlation coefficients for treatment (columns) vs. control (rows) watersheds. Note: Italicized indicates correlation was marginally significant (p=0.06)

Discharge	Rock	Honey	Tiffin
Portage	0.91	0.87	0.87
Blanchard	0.95	0.95	0.86
Sandusky	0.94	0.97	0.86
Cedar	0.76	0.77	0.97
DRP	Rock	Honey	Tiffin
Portage	0.90	0.89	0.85
Blanchard	0.85	0.77	0.87
Sandusky	0.90	0.95	0.80
Cedar	0.62	*0.52*	0.83
TP	Rock	Honey	Tiffin
Portage	0.90	0.86	0.88
Blanchard	0.91	0.87	0.89
Sandusky	0.90	0.95	0.83
Cedar	0.86	0.81	0.93
NO_3-N	Rock	Honey	Tiffin
Portage	0.87	0.93	0.89
Blanchard	0.85	0.94	0.91
Sandusky	0.86	0.97	0.89

Task 2: Quantifying the impact of 4R practices on EOF nutrient loss in the WLEB

In three of the treatment watersheds (Portage, Sandusky, and Cedar), four fields (two pair) will be used to quantify the influence of specific 4R practices (e.g., broadcast vs. banded P application) on nutrient losses in surface runoff and subsurface tile drainage. Currently, one pair of fields within each watershed is instrumented and collecting baseline data on nutrient losses from the prevailing land anagement. An additional pair of fields in each watershed will be identified and instrumented at the start of the project.

Following baseline data collection from each of the fields, one field from each pair will represent a treatment scenario (i.e., 4R recommended practice), while the other field will serve as the control or prevailing practice. The fields selected will be representative of the larger watersheds in terms of physical characteristics (e.g., soils and topography) and agricultural practices. Additionally, we will select a set of paired fields that have had the same land management history.

The field sites will be equipp d for both hydrology a d water quality measurements. Each EOF site will be equipped with an appropriately sized H-flume, Isco 6712 automated sampler, and Isco 4230 bubbler to monitor surface ru off and water quality. Stage will be recorded on a 10-minute interval and water sa ples will b collected on a flow pr portional basis in order to determine nutrient losses throughout runoff events. Additionally, hydrology and water quality data from tile drainage will be c llected in a similar manner to surface runoff. ater samples will be analyzed col rimetrically using flow injection analysis for dissolved and total N and P concentrations (Kor leff, 1983; Parsons et al., 1984).

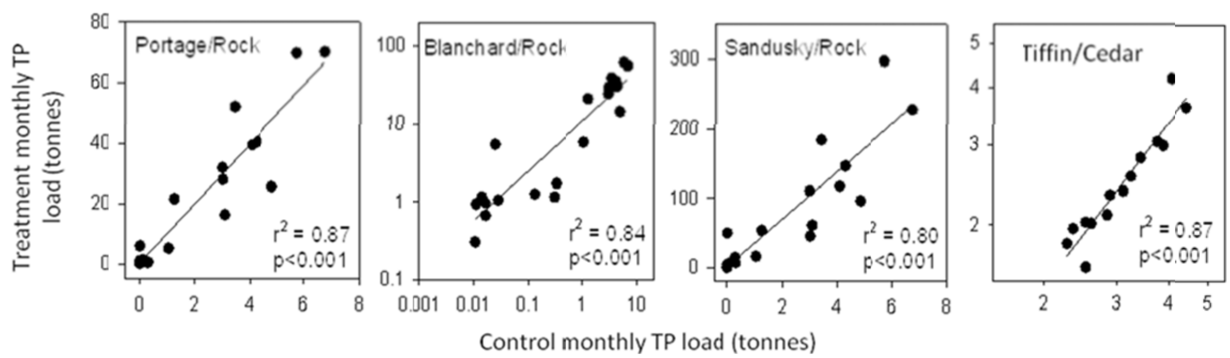

Figure 1. The relationships between monthly total P loads for treatment and control watersheds.

Task 3: Examining the response of stream metabolism to changes in nutrient levels

At the EOF sites described above, we will measure stream metabolism to examine gross primary production (GPP) and ecosystem respiration (ER) (i.e., production and consumption of oxygen). We hypothesize that an overall reduction in nutrient concentrations associated with 4R management will reduce algal growth and heterotrophic (e.g., bacteria, fungi) production leading to an overall decrease in both GPP and ER. In addition, decreased GPP and ER would result in smaller fluctuations in daily dissolved oxygen. Both of these expected results would indicate an overall improvement in stream biotic integrity.

Stream metabolism will be measured using the two-station open-channel diel oxygen method (Odum, 1956). Dissolved oxygen sensors and photosynthetically active radiation (PAR) sensors will be permanently installed above and below select EOF sites for the duration of the project. Metabolism will be calculated by integrating the difference in dissolved oxygen concentrations over each 24 h period after accounting for atmospheric exchange. Atmospheric exchange will be either measured using injections of sulfur hexafluoride (SF6) or modelled using the daytime regression method (Kosinski, 1984).

Objective 2: Modeling of Environmental Benefits

The purpose of the modeling component of this project is to evaluate the environmental benefits in the WLEB of nutrient application practices related to the 4R Certification Program at various levels of implementation. To accomplish this we propose to link Soil and Water Assessment Tool (SWAT) watershed models for the Maumee, Portage, and Sandusky watersheds to a linked hydrodynamic-sediment transport-eutrophication model for the WLEB, called Western Lake Erie Ecosystem Model (WLEEM). In this way, 4R management practices such as those being monitored in this project (i.e., objective 1) can be scaled up and quantitatively connected to environmental benefits in the stream network of the watersheds in the WLEB as well as to the reduction of turbidity, sedimentation, and HABs in Lake Erie. The approach for this component of the project will include four tasks:

1. Develop fine-scale SWAT models for the three watersheds of concern for evaluation of the 4R Certification Program in the WLEB.
2. Modify the SWAT models to accurately reflect the effect of 4R implementation on nutrient loading from agricultural fields to the watershed stream network.
3. Prepare WLEEM for application to years being used for the 4R evaluation analysis.
4. Run evaluation scenarios using the linked SWAT-EFDC-A2EM modeling framework to quantify the benefits derived from various levels of 4R implementation scaled up from the pilot sub-watersheds to the three full watersheds being evaluated.

Task 1: Develop watershed models

The research team already has SWAT models for the Maumee (LimnoTech, through funding from the GLPF and the USACE-Buffalo District) and for the Sandusky (Heidelberg, through funding from GLPF and USDA-NRCS) watersheds. SWAT was developed by the USDA-ARS “to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over a long period of time” (Neitsch et al., 2005). In a spatially distributed model, the processes (e.g. landscape, hydrologic, and plant growth) are implemented in the smallest spatial area as possible to increase accuracy and minimize uncertainty. In SWAT, the entire watershed is

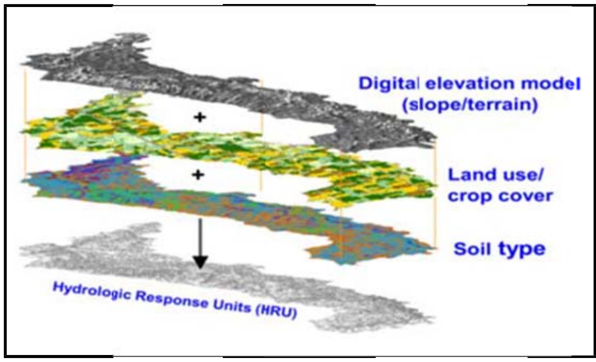

Figure 2. Calculation of the hydrologic response unit (HRU).

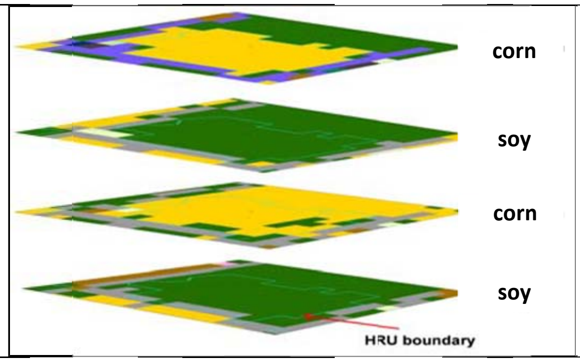

Figure 3. Four hypothetical crop layers as basis of the crop rotation of an HRU.

divided into subwatersheds and each subwatershed is further divided into unique combinations of land use and soil properties (called hydrologic response units; HRUs) (Fig. 2). A GIS interface is used to input and designate land use, soil, weather, groundwater, water use, management, pond and stream water quality data, and the simulation period (Di Luzio et al., 2001). GIS input files include a digital elevation model (DEM), land use/land cover and soil properties layers, and a daily weather database.

Current farming practices will be incorporated into the SWAT models for the three watersheds in order to establish a baseline condition for evaluation of 4R implementation. The latest 4-year cropland GIS layer data (currently 2009 to 2012) from USDA-NRCS Geospatial Data Gateway will be used to designate the crop rotation of each HRU in the SWAT setup (Fig. 3). In each HRU, agricultural practices (e.g., tillage methods, fertilizer rates and application, time of crop planting, etc.) will be based from the crop rotation for realistic SWAT setup. We will calibrate the SWAT model with the daily flow, sediment, P loads, and N loads using the method developed by Confesor and Whittaker (2007). The calibration method was based on a multi-objective evolutionary algorithm, the nondominated sorted genetic algorithm (NSGA-II, Deb et al., 2002). Previous works in the Sandusky watershed showed that each population of optimal solutions (i.e., combinations of calibrated parameters) resulted in a model simulation output that is unique from each other. These different model realizations can be used to account for parameter and mode output uncertainties.

Task 2: Modify SWAT models for simulating 4R practices

As part of this task, we will implement and model 4R practices within SWAT for several different scenarios. We plan to use the EOF and watershed monitoring to parameterize SWAT simulation of 4R practices by calibration of SWAT for the watersheds being monitored in this study (see objective 1). The EOF data will be used to support necessary SWAT algorithm and parameterization for the 4R practices being simulated in the models. We will then develop scenarios for various levels of implementation that can be scaled up to the watershed scale (i.e., Portage, Sandusky, Maumee) with our calibrated SWAT models. Specific scenarios may include:

- Rate of fertilizer application based on tri-state recommendations for corn, soybean, and wheat and at 0.5, 1, and 1.5x the recommended application rates.
- Fertilizer application method over different watershed acreage: broadcast vs. injected/banding at 100 vs. 0; 25 vs.75; 50 vs. 50; 75 vs. 25; 0 vs. 100 % coverage.
- Fertilizer application timing: fall vs. spring fertilizer application timings as well as the amount of time between application and a rainfall event.

- Fertilizer source will be chosen depending on application method, crop, and rates.

Task 3: Compile input for WLEEM

The Western Lake Erie Ecosystem Model (WLEEM) was developed over the last four years by LimnoTech (funding: NSF and USACE-Buffalo District) specifically to address the types of questions posed by this project. WLEEM is a time-dependent, 3-D model that computes temporal and spatial profiles of water, sediment, nutrients, and plankton and benthos dynamics as a function of loadings from all major and minor watersheds, the Detroit River, and hydro-meteorological forcing functions. The model consists of two linked public domain models, Environmental Fluid Dynamics Code (EFDC) (TetraTech, 2007) and a modified version of RCA (HydroQual, 2004). Limnotech has also coupled EFDC with a wind-wave model (SWAN) (Delft University of Technology, 2006) to facilitate simulation of wind-driven sediment resuspension as a source of internal sediment and P loading in the western basin. The LimnoTech-customized RCA includes the capability to model up to five phytoplankton functional groups; the effects of Dreissenids on nutrient cycling, particle fate and transport, algal production, and water clarity; and a benthic algal functional group based on the Auer GL Cladophora Model (GLCM) (Auer et al., 2010; Bierman et al., 2005; DePinto et al., 2009; LimnoTech, 2010; LimnoTech, 2013). This improved RCA framework is called the Advanced Aquatic Ecosystem Model (A2EM).

The WLEEM is driven by input loads of water, sediments, nutrients, and organic carbon (both detrital and viable chlorophyll a) from the Detroit River and all tributaries to the Western Basin, including the Huron, Stony, Raisin, Ottawa, Maumee, Cedar, and Portage Rivers. The WLEEM will be applied to simulate suspended solids, nutrient, and lower food web dynamics for the years being tested during this project. Atmospheric observations during the simulation period (air temperature, wind speed and direction, cloud cover, etc.) will be downloaded from NOAA. River discharge observations for the major tributaries (Detroit, Maumee, Raisin, and Huron) will be downloaded from the USGS at the most downstream gaging station. Discharges will be scaled to reflect any additional watershed area not captured by the gage before its outlet to Lake Erie. Discharge from direct drainage or ungaged watersheds will be estimated from relationships to neighboring gages based on watershed area. To fully simulate the transport and export of nutrients and water out of the western basin to the east the model will be forced at this boundary by hydrodynamic output from the NOAA developed Great Lakes Coastal Forecasting System (GLCFS) model for Lake Erie. Boundary conditions will be extracted from archived model simulations of hourly average results from 2014. Nutrient loads for tributaries monitored by Heidelberg University (Maumee and Raisin) will be estimated directly from the monitoring data. Nutrient loads from other Western Basin tributaries (Huron, Stony, Ottawa, Cedar, and Portage Rivers) will be estimated from the SPARROW modeling work described above. Nutrient loads for the Detroit River will be estimated based upon previous studies (Dolan and McGunagle, 2005; Dolan and Chapra, 2012) as well as routine monitoring data collected by the State of Michigan at the mouth of the Detroit River.

Task 4: Model Framework Application for 4R Evaluation

This task will involve developing and simulating scenarios for various levels of 4R implementation in comparison with current baseline condition. The scenarios will involve applying the linked watershed-WLEEM modeling framework to evaluate the 4R Certification Program in terms of reducing stream network nutrient levels, sediment and HABs in the WLEB.

Data collected from the survey portion of the project (discussed in the next section) will be utilized to ensure realistic baselines for past and current nutrient application practices.

Objective 3: Determining the Behavioral Impact of 4R Education and Certification Efforts

The objective of the behavioral component of this project is to assess the impact of ongoing 4R efforts as well as understand the decision making process used by growers and nutrient service providers as a springboard for revealing what, if any, methods may be employed to increase 4R adoption going forward. Ultimately, understanding and improving management practices among growers and nutrient service providers is the key to improving water quality and protecting associated ecosystem services. Although many recommended 4R practices are believed to be effective at reducing nutrient loss, their adoption is generally voluntary and growers may choose not to practice them.

A pilot survey conducted in early 2012 among row crop growers living within the Maumee watershed revealed several key findings that are relevant to evaluating past and planning future education and outreach efforts (Wilson et al., 2013). Namely, ~75% of growers in the Maumee watershed believe that agricultural practices contribute to water quality issues and that the available BMPs are effective. In addition, a similar majority is concerned about nutrient loss and believes that nutrient loss is likely to have a negative impact on both water quality and profit potential. However, ~77% also believe that what they are doing on their own farm is currently adequate. Related field level data indicates that ~70% of farmers are using conservation or no-till practices on fields where runoff is a concern, and 87% have an established rotation. However, ~25% do engage in fall or winter fertilizer application and ~46% broadcast apply their fertilizer. Such results do indicate a need to improve practice among the minority. Fortunately, ~75% of growers see taking at least one new action on their farm to reduce nutrient loss as beneficial and valuable, even though they do not all agree about the necessity or fairness. Opportunity exists to further analyze this and future data on the basis of proportion of land area under each of the various management practices, in addition to percentages of growers. To follow-up on this initial survey research, the approach for this component of the project will be comprised of three tasks:

1. Use ongoing survey research in the Maumee watershed and conduct new surveys of grower decision-making as it relates to 4R nutrient stewardship in the Sandusky and Portage watersheds.
2. Conduct a survey of nutrient service providers across the WLEB to assess their knowledge, attitudes, beliefs and behaviors related to 4R nutrient stewardship and certification.
3. Identify commonality and differences in the decision making process between growers and nutrient service providers in order to evaluate ongoing efforts as well as make recommendations to improve adoption going forward.

Task 1: Use ongoing research and conduct new surveys of grower decision making

Ongoing research by Drs. Wilson, Roe, and others is evaluating grower decision-making in order to 1) better understand the prevalence of key BMPs in the Maumee watershed; 2) identify why growers choose to adopt certain BMPs; and 3) identify what motivates individual grower willingness to adopt additional practices on their farm. The goal of this ongoing research is to reveal what, if any, methods may be employed to increase BMP implementation, thereby ultimately improving water quality. In addition to the pilot survey discussed above, a survey of grower behavior, including current and planned adoption of many 4R recommendations, the economic burden of implementing key 4R recommendations, as well as beliefs about their effectiveness, is planned for February 2014. We plan to leverage and extend the data collected from the ongoing study on BMP adoption to inform our understanding of 4R adoption and effectiveness over the past 2 years in the selected subwatersheds of the Maumee. Specifically, we will have general measures of 4R awareness and engagement in outreach among growers, measures of the perceived effectiveness of requiring 4R certification for nutrient service providers, as well as the extent to which growers are hiring or willing to hire a nutrient service provider. We will also be able to assess the degree to which several 4R practices are currently being used on the farm or are likely to be adopted in the future, and assess changes in grower beliefs and practices from 2012 to 2014 (e.g., awareness of algae issues, perceived responsibility for the problem, perceived risk associated with nutrient loss, and perceived ability to further limit nutrient loss on one's own farm), while controlling for overall awareness and engagement in 4R outreach and education. At the field level, we can also assess any net increase in 4R practices across the watershed. Although these changes over time cannot be solely attributed to 4R certification or ongoing outreach, they will provide some evidence of the potential positive impact of such programming. We also plan to compare knowledge, beliefs and practices cross-sectionally among our control and treatment watersheds in order to further assess whether any differences are the result of the Certification program or other ongoing outreach.

We will conduct an additional survey of growers in the Sandusky and Portage watersheds that are also targeted in the monitoring and modeling of Objectives 1 and 2. We will use the existing survey instrument from our Maumee watershed research to allow for comparability between the locations (see the prior description and Wilson et al. 2012 for an overview of survey measures). We will purchase a random sample of grower mailing addresses across the target watersheds (n = 2000) from Farm Market ID. We will purposefully oversample for our target subwatersheds, essentially conducting a census of all growers in our target areas. This sample will then be used to administer a mailback survey using a modified version of Dillman's Tailored Design Method (Dillman, 2000). The survey data from both this new effort and the existing Maumee research will be analyzed both descriptively to assess baseline conditions, as well as correlationally (through multiple regression analysis and structural equation modeling) to develop predictive models of grower behavior. We will conduct paired comparisons of the knowledge, beliefs and practices across the control and treatment watersheds, as well as across time where applicable. A final set of surveys across all of the study locations is planned in year 4. This panel study will involve contacting the same respondents to the surveys at time point 1 (described above) to assess any changes in knowledge, beliefs and practices over time by replicating the survey at time point 2.

Task 2: Conduct a survey of nutrient service providers.

The role of nutrient service providers in shaping water quality in the WLEB is poorly understood. Most of the ongoing research focuses on grower decision-making and management. However, these professionals provide guidance to local growers and often influence management decisions regarding the timing and application of nutrients. We propose to conduct a similar survey of the population of nutrient service providers in the WLEB to compare how their knowledge, attitudes, beliefs, and behaviors compare to local growers when it comes to the 4R Nutrient Stewardship concept and current outreach and education efforts. We will conduct a mixed mail/online survey of the entire population of nutrient service providers (n = ~250) replicating select measures from our grower surveys, and adding additional measures to assess constructs of interest that are particularly relevant to service providers. Measures will include awareness of local water quality issues, perceived risk associated with local water quality and nutrient loss, beliefs about the effectiveness of the 4R Nutrient Stewardship concept as well as current and intended adoption. Survey administration will occur over a 6 week period and follow Dillman's Tailored Design method (Dillman, 2000). Similar to the above, both descriptive statistics and correlational analyses will be used to describe the knowledge, attitudes, beliefs and behaviors of this population.

Task 3: Identify commonality and differences between the two populations.

In addition to the within-group assessments and models that will be developed to explain and understand grower and nutrient service provider knowledge, attitudes, and behaviors across the selected watersheds and across time, we will also conduct a comparative assessment of the two groups. Such a comparison will identify relative differences and similarities in understanding and practice, and will be critical to informing education and outreach tools to broaden the adoption of the 4R Nutrient Stewardship concept moving forward. These assessments will also address issues of distribution of farm sizes and interpretation of data from the standpoint of proportions of the cropland impacted by each management practice.

Objective 4: Triple bottom line evaluation

Triple bottom line (TBL) evaluation is a framework that simultaneously assesses economic, social, and environmental performance. Elkington (1994) conceptualized TBL evaluation as a way to operationalize concepts of sustainable development such that businesses could document corporate social responsibility efforts, though the concept has been adapted to communicate performance of programs and initiatives such as 4R Nutrient Stewardship concept (Slaper and Hall, 2012). While the economic bottom line is measured in dollars, placing a dollar value on social and environmental performance faces technical challenges and philosophical resistance, leaving a single integrated measure of the TBL elusive. The approach for this component of the project will have one task:

1. Estimate how widespread implementation of the 4R concept and Certification Program would alter the economic, social, and environmental performance of the agricultural system in the WLEB.

Task 1: Conduct triple bottom line evaluation

Environmental measures for the TBL assessment will be taken from those measurements discussed in previous sections of the proposal. Economic measures will include 1) the annual economic burden on growers who implement 4R practices, 2) the perceived costs to nutrient service providers of implementing 4R plans, and 3) the annual benefit to residents near Lake Erie from improvements in the reduction in the number and severity of HABs on Lake Erie reasonably attributable to successful 4R implementation. Social measures will include 1) growers' perceived efficacy of 4R management practices in reducing nutrient runoff and increasing yield, 2) basin residents' perceived concern with and risk from HABs attributable to farm runoff and 3) basin residents' frequency of visits to Lake Erie. Sources for the social and economic measures to be used in the TBL assessment include surveys of Maumee watershed growers from 2012 (Wilson et al., 2013) and 2014 (pending OSU IRB approval); surveys of

Ohio (OSU IRB #2013B0303, slated for early 2014 collection) and Maumee watershed (Nisbet, 2013) residents; and the farm input nutrient service provider survey described in this proposal.

Unlike the environmental measures of water quality proposed earlier, which are designed specifically to isolate the impact of 4R practices on water quality, isolating the impact of 4R practices on economic and social measures faces greater challenges. We propose applying statistical techniques to the data sources detailed above to estimate the likely change in each measure as a function of 4R practices. For example, Howard and Roe (2013) leverage a choice experiment implemented via the Wilson et al. (2013) survey to estimate a grower's economic burden from adding a filter strip to a field. A similar choice experiment focusing on 4R practices will be implemented in an upcoming grower survey (OSU IRB approval pending) slated for February 2014. The choice experiment offers growers a hypothetical choice between maintaining current cultivation practices or accepting payment for implementing one or more 4R practices. Statistical techniques allow us to estimate the probability that growers implement the additional practices as function of the monetary compensation offered and the nature of the practice, which allows for the formation of an implicit economic burden associated with implementing different types of 4R practices. We will develop similar statistical approaches with the data sources available to estimate the change in the other economic and social TBL measures associated with 4R implementation.

<u>Objective 5: Integration, Education, and Outreach</u>

The results from the proposed project will be disseminated to stakeholders through a variety of outlets. Stakeholders include the nutrient service providers, growers, and conservation, environmental, and governmental partners within the WLEB. We will post project information and updates on the 4R Nutrient Stewardship Certification Program website, print information in newsletters and brochures to inform audiences about the research and findings, publish research findings in peer-reviewed journals, hold or participate in field days and conferences to showcasing EOF, in-stream, and modeling efforts related to 4R conservation practices, and hold meetings on specific topics for individual stakeholder groups. Ultimately, changes, based on this research will be integrated into the WLEB 4R Certification Program with the support from members of the 4R Advisory Committee and the Nutrient Stewardship Council. These two entities will be updated annually at a minimum as they are the key stakeholders for this research.

Project Management:

We have assembled a diverse, interdisciplinary team comprised of both public and private institutions with demonstrated ability to cooperate in all aspects of project management and implementation. This proposed project is a collaborative effort between USDA-ARS, Heidelberg University, Ohio State University, LimnoTech, International Plant Nutrition Institute (IPNI), and The Nature Conservancy. The assembled team is familiar with one another and represents organizations with common concerns about environmental stewardship and nutrient management in agricultural production settings. Dr. Kevin King (USDA-ARS) will serve as project lead with oversight for organization, budgeting, execution, reporting, and communication. Dr. King will also co-lead with Dr. Mark Williams (USDA-ARS) the EOF field research in Ohio. Dr. Doug Smith (USDA-ARS) will lead EOF and watershed research in Cedar Creek watershed in Indiana. Dr. Laura Johnson (Heidelberg University) will lead the watershed scale data collection and analysis from the control and treatment watersheds in Ohio and also have responsibility for leading the biotic integrity portion of the proposed project. Dr. Remegio Confesor (Heidelberg

University) and Dr. Joe DePinto (LimnoTech) will jointly lead and have responsibility for the model development and simulation component. Dr. Robyn Wilson, Dr. Brian Roe, and Mr. Greg LaBarge (Ohio State University) will co-lead the socio-economic portion of the proposed project. Ultimately, changes, based on this research will be integrated into the WLEB 4R Certification Program. Dr. Tom Bruulsema (IPNI) will review research related to nutrient service providers and assist in interpreting how the data impacts the 4R Certification Program. Ms. Carrie Vollmer-Sanders (The Nature Conservancy) will have responsibility for integrating the information and identifying and developing educational and outreach materials for the continued assessment of the 4R Certification Program.

Deliverables:

- Surface and tile drain hydrology and water quality results from EOF monitoring (4R and prevailing practices)
- Biotic integrity of select streams within the WLEB
- Environmental benefits of 4R implementation at the watershed scale
- Calibrated and confirmed watershed and Lake Models representative of the WLEB
- Extent of practices necessary to affect a difference in nutrient delivery to Lake Erie and its response
- Knowledge, attitudes, beliefs, and behaviors of growers and nutrient service providers toward 4R nutrient stewardship and certification
- Triple-bottom line evaluation of 4R nutrient stewardship and certification in the WLEB
- Outreach and education materials related to 4R nutrient stewardship certification (web site, publications, brochures, presentations, and field days) that integrates the socio-economic, monitoring, and simulation components of the proposal

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TimeLine/Milestones:

A 5-year project is proposed starting July 1, 2014 with completion on June 30, 2019.

Actions and Milestones	2014		2015				2016				2017				2018				2019	
Quarter	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**
Objective 1: Monitoring of 4R practices (watershed, EOF, in-stream)																				
Confirm control & treatment watersheds																				
Watershed water quality (WQ) analysis																				
Identify & equip EOF sites																				
EOF baseline WQ analysis																				
EOF treatment WQ analysis																				
Install biotic measurement devices																				
Collect biotic measurements																				
Collect EOF management data																				
Objective 2: Modeling of environmental benefits (watershed, basin/lake)																				
Data acquisition																				
Model setup																				
Calibrate models																				
Confirm models																				
Run linked watershed-lake scenarios																				
Results analysis & reporting																				
Objective 3: Determining behavioral impact																				
Analyze existing data																				
Collect new producer data																				
Collect new provider data																				
Analyze data & estimate models																				
Objective 4: Triple Bottom Line assessment																				
Review of TBL literature																				
TBL Evaluation																				
Objective 5: Integration, education, and outreach																				
Meetings/Field days/Presentations																				
Website updates																				
Publications																				
4R Standard revisions																				
Project Management																				
Quarterly team mtgs.																				
Annual reports																				
Project final report																				