Journal of Environmental Management 228 (2018) 197–204

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Research article

Evaluation of the effectiveness of conservation practices under implementation site uncertainty

Mohammad Abouali[a], A. Pouyan Nejadhashemi[a,*], Fariborz Daneshvar[a], Matthew R. Herman[a], Umesh Adhikari[a], Timothy J. Calappi[b], James P. Selegean[b]

[a] Department of Biosystems and Agricultural Engineering, Michigan State University, 524 S. Shaw Lane, Room 216, East Lansing, MI, 48824, USA
[b] U.S. Army Corps of Engineers, 477 Michigan Ave., Detroit, MI, 48226, USA

ARTICLE INFO

Keywords:
Targeting method
SWAT
Best management practices
Random implementation
Spatial distribution

ABSTRACT

Agricultural nonpoint source pollution is the leading source of water quality degradation in United States, which has led to the development of programs that aim to mitigate this pollution. One common approach to mitigating nonpoint source pollution is the use of best management practices (BMPs). However, it can be challenging to evaluate the effectiveness of implemented BMPs due to polices that limit data sharing. In this study, the uncertainty introduced by data sharing limitations is quantified through the use of a watershed model. Results indicated that BMP implementation improved the overall water quality in the region (up to ~15% pollution reduction) and that increasing the area of BMP implementation resulted in higher pollution reduction. However, the model outputs also indicated that uncertainty caused by data sharing limitations resulted in variabilities ranging from −160% to 140%. This shows the importance of data sharing among agencies to better guide current and future conservation programs.

1. Introduction

Almost half of the river and streams in the United States are impaired due to several reasons including agricultural activities and hydrological alterations associated with dam and channel development (USEPA, 2009). Among them, agricultural nonpoint source pollution has become the leading cause of water quality degradation of the rivers and streams (Einheuser et al., 2013; USEPA, 2016a), which includes nutrients, primarily nitrogen and phosphorus, sediments, pathogens, salts and agricultural chemicals (USEPA, 2016b). Large amount of nitrogen and phosphorus transported from the agricultural watersheds results in eutrophication and cyanobacteria blooms in freshwater and coastal marine ecosystems, severely restricting the water use (Sharpley et al., 1999; Smith, 2003). Agriculture has also been a major contributor of the water quality impairment such as expansion of dead zones and harmful algal blooms in many water bodies including Chesapeake Bay (USEPA, 2010), Northern Gulf of Mexico (Dale et al., 2010) and Lake Erie Basin (Michalak et al., 2013). Furthermore, global warming is expected to enhance the persistence of the algal bloom through alteration in contributing processes that include rainfall, runoff, and nutrient and sediment delivery (Paerl et al., 2016). Hence, controlling pollutants loading, especially nutrients from the agricultural watersheds, is crucial for maintaining and improving the quality of water bodies (Giri et al., 2015).

In the United States many programs exist to control the nonpoint source pollution and improve the quality of water bodies (Smith et al., 2009). For example, ‘conservation provisions’ is the name of one of these programs that is managed by the U.S. Department of Agriculture (USDA) through the Farm Bills program (Sowa et al., 2016). This program provides incentive to producers through the cost share to implement conservation practices. The annual average cost of this program is around five billion dollars (CRS, 2014). Since the beginning, the program has enrolled about 25.6 million acres of land annually and reduced soil erosion by 8 billion tons (Stubbs, 2014). By 2010, over 810,000 ha of wetland and buffers have been enrolled into the program (Stubbs, 2014). U.S. Environmental Protection Agency (USEPA) also provides support to control nonpoint source pollution through funding opportunities such as ‘319 Grant Program’. Enacted by the Clean Water Act, the fund can be used in wide range of activities including implementation of watershed projects and monitoring the success of specific nonpoint source pollution implementation projects (USEPA, 2016b). A resent EPA report showed that between 1990 and 2016, the grant provided over four billion dollars to states, territories and tribes to implement their nonpoint source programs (USEPA, 2017a).

* Corresponding author.
E-mail address: pouyan@msu.edu (A.P. Nejadhashemi).

https://doi.org/10.1016/j.jenvman.2018.09.035
Received 24 February 2018; Received in revised form 10 August 2018; Accepted 10 September 2018
0301-4797/ © 2018 Elsevier Ltd. All rights reserved.

Meanwhile, about 10% of the 319 Grant Program is directly spent in implementation of best management practices (BMPs) (USEPA, 2011).

In addition to the type and number of implemented practices, BMPs' effectiveness is also site-specific, which means that an effective BMP implementation strategy at one location may not be applicable to other locations (Tuppad and Srinivasan, 2008; Giri et al., 2012). Using watershed models, many studies have evaluated the effectiveness of the BMP implementation strategies at the watershed level (Woznicki et al., 2011; Chiang et al., 2012; Giri et al., 2014; Hall et al., 2017). However, beside a few exceptions that introduce risk/optimization methods to minimize water quality degradation (e.g., Herman et al., 2015; Herman et al., 2016; Sabbaghian et al., 2016) majority of them are only providing a site specific implementation plan; and almost all of them, do not document the effectiveness of BMP implementation plans beyond the period of studies even though climate variabilities impact the performance of BMPs (Woznicki and Nejadhashemi, 2012). In addition, it is important to note that even evaluating the effectiveness of BMP at the field-level poses a substantial challenge as the process is time consuming, and resource intensive (Sommerlot et al., 2013a). Thus, studies documenting the relationship between field-level BMP implementation and the water quality improvement at the watershed outlet are rare (Makarewicz, 2009; Sommerlot et al., 2013b). And finally, the major challenge in evaluating the effectiveness of BMP implementation projects is that the implementation data is protected by the federal government. For example, Section 1619 of the Farm Bill restricted the distribution of information from whom who participated in the Farm Bill program (USDA, 2015). Owing to such protection and confidentiality policies, federal agencies such as USEPA and USDA aggregates the BMP implementation data to a geographic scale such as county levels or watershed levels (Donald et al., 2014). So, it is not easy to track the actual water quality outcome of the BMP implementation. This study aims to highlights the importance of data sharing by federal agencies while measuring the level of uncertainty introduce by restricting information related to conservation practices. The analysis is performed for the Saginaw River Basin in Michigan and the goal is to measure the effectiveness of the sediment and nutrient management practices implemented through the Great Lake Restoration Initiative (GLRI).

2. Materials and methods

2.1. Study area

The study area was the Saginaw River Basin, which is located in the central portion of Michigan's lower peninsula (Fig. 1). Saginaw River Basin drains an area of 16,120 km^2 into the Lake Huron. This makes it the largest 6-digit hydrologic unit code (HUC) watershed in Michigan (HUC 040802). This HUC 6 watershed is comprised of six smaller HUC 8 watersheds, namely the Tittabawassee (HUC 04080201), Pine (HUC 04080202), Shiawassee (HUC 04080203), Flint (HUC 04080204), Cass (HUC 04080205), and Saginaw (HUC 04080206) watersheds, of which the largest is the Flint Watershed and the smallest is the Saginaw Watershed. Rivers and streams within this region are predominately classified as warm water streams, which means that rainfall and surface runoff are the dominate sources of water for the region. Furthermore, the region is dominated by agricultural land that covers 36.2% of the total area, followed by forest (24.8%), water (14.3%), pasture (12.4%) and finally urban (12.3%). The combination of warm water streams and a highly altered landscape have resulted in the degradation of many of the regions aquatic ecosystems. In fact, the Saginaw River Basin has been identified as an Area of Concern by the EPA (USEPA, 2017b). The major causes for this classification are increased sediment and nutrient loadings, sediment contamination, degraded fisheries, and loss of recreational value.

2.2. Overall modeling process

A schematic view of the modeling process is presented in Fig. 2. The process started by identifying the total number/area of BMPs that were given in aggregated form at HUC 8 level. In the next step, the areas in which different BMPs can be implemented were identified. Knowing the total eligible area and type of BMPs, a series of BMP implementation scenarios were generated that meet the criteria. These scenarios were later incorporated into a watershed model called Soil and Water Assessment Tool (SWAT) to evaluate the impacts of different management scenarios on sediment, nitrogen, and phosphorus reductions at the watershed scale.

2.2.1. Identify the types and locations of best management practices

As described earlier, due to existence of data privacy in agricultural industry (Ferris, 2017), the type of BMPs and sites in which they are implemented are not available except in the aggregated form. Through collaboration with USDA Natural Resources Conservation Service (NRCS), this information was provided in an aggregated form at HUC 8 level for this project. The GLRI Action Plan I occurred during the period of October 2009 to September 2014 in which 706 BMP projects were implemented in the Saginaw River Basin. Tables S1–S5 summarize details of these BMP projects, including contract type, program, National Conservation Practice Standards (NCPS) code, size/number of implemented BMPs, and unit for each of the HUC 8 watersheds. In addition, it is important for the policy makers to know how additional investment under the GLRI Action Plan II (October 2014–September 2019) can improve water quality in the study area. Finally, how these investments improve the water quality condition in the region comparing to pre-BMP implementation scenarios.

Since the location of BMP sites are not available under the both GLRI Action Plans I and II, the possible implantation sites (agricultural lands and pasture lands) in each watershed were first identified. Next the type of BMPs that can be implemented on these sites were selected (Tables S6 and S7). This information will be later used to generate various BMP arrangements that meet the total number/area of BMP implementations in each watershed.

2.2.2. Generate various best management practice arrangements

After determining the BMPs and the subbasins that these BMPs could be implemented, it is time to assign a location to each BMP. Depending on the type of the BMP, either (1) a certain number of subbasin needs to be selected regardless of their size, for example, select three subbasins among the many possible eligible subbasins, or (2) the sum of the area of the selected subbasins needs to add up to a certain amount (total implementation area for various BMPs).

For the first case that certain number of subbasins need to be selected regardless of the subbasin size, a random permutation of subbasins is generated using *randperm(n,k)* function of MATLAB (version R2017b), where n is the number of eligible subbasins and k is the number of the subbasins that must be selected.

For the second case, that a total implementation area for various BMPs were know, the pseudo-random targeting implementation strategy was used (Abouali et al., 2017). Under this strategy, a genetic algorithm harnesses a binary coding of the subbasins into a bit-stream and a Gaussian objective function. Depending on the bit pattern of the bit-stream, i.e. on or off, the subbasins are either selected or not selected for implementation a BMP. The Gaussian objective function based on this bit-stream would calculate the objective value, which would be at its minimum if the sum of the area of the selected subbasins is exactly the one that was specified. As the area deviates from the specified total area, the objective value increases. By running the Genetic algorithm, i.e. *ga()* function of MATLAB (version R2017b), a population of solutions are provided, which are sorted and the bests solutions are selected for further analysis. However, the selected arrangements are going through additional evaluations before they are

Download English Version:

https://daneshyari.com/en/article/10149046

Download Persian Version:

https://daneshyari.com/article/10149046

Daneshyari.com