Journal of Great Lakes Research 41 (2015) 760–769

Contents lists available at ScienceDirect

Journal of Great Lakes Research

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

Modeling conservation practices in APEX: from the field to the watershed

Wendy Francesconi [a,*], Douglas R. Smith [b], Dennis C. Flanagan [c], Chi-Hua Huang [c], Xiuying Wang [d]

[a] International Center for Tropical Agriculture (CIAT), Av. La Molina, 1581 La Molina, Lima, Peru
[b] Grassland, Soil and Water Research Laboratory, 808 E Blackland Rd, Temple, TX 76502, USA
[c] National Soil Erosion Research Laboratory, 275 S Russell Street, West Lafayette, IN 47907, USA
[d] Texas A&M University, Blackland Research and Extension Center, Temple, TX 76502, USA

ARTICLE INFO

Article history:
Received 1 June 2014
Accepted 21 April 2015
Available online 14 May 2015

Communicated by Joseph Makarewicz

Index words:
Lake Erie
Best management practices
Tile drainage

ABSTRACT

Evaluation of USDA conservation programs are required as part of the Conservation Effects Assessment Project (CEAP). The Agricultural Policy/Environmental eXtender (APEX) model was applied to the St. Joseph River watershed, one of CEAP's benchmark watersheds. Using a previously calibrated and validated APEX model, the simulation of various conservation practices (single and combined) was conducted at the field scale. Seven variables [runoff, sediment, total phosphorus (TP), dissolved reactive phosphorus (DRP), soluble nitrogen (SN), tile flow, and soluble nitrogen in tile (SN-Tile)], were compared between the simulated practices. The field-scale outputs were extrapolated to the areas encompassed by the different conservation practices at the watershed scale. The speculative estimations are presented as percentage reductions compared to the baseline scenario. When single conservation practices were implemented, reductions were 39% for sediment, 7% for TP, and 24% for SN-Tile. In contrast, losses of DRP and SN increased by 5% and 57%, respectively. When the conservation practices were combined, percentage reductions increased for all variables. The total reductions for combined two and three practices were 68% and 91% for sediments, 35% and 74% for TP, 1% and 48% for DRP, −43% and 28% for SN, and 50% and 85% for SN-Tile. Negative reductions were due to the slightly higher DRP and SN loads in no-till, mulch-till, and conservation crop rotation practices, and their greater extent of incorporation at the watershed scale. Overall, the cumulative and combined effects of field conservation practices can help address the watershed's excess nutrient and sediment concerns and improve water quality.

Introduction

With the goal of improving water quality by reducing sediments, nutrients and pesticides transported from agricultural fields, agricultural programs promote conservation practices [also referred to as Best Management Practices (BMPs)]. Conservation agricultural programs are designed by the United States Department of Agriculture, Natural Resources Conservation Service (USDA-NRCS), and implemented through local Soil and Water Conservation Districts (SWCDs). Driven by public concerns of nonpoint source environmental and water quality degradation, several conservation programs have been developed as a consequence of additional funding stipulated in the 2002 Farm Bill. To evaluate the environmental impact of such programs at the watershed scale, the Conservation Effects Assessment Project (CEAP) was established (Richardson et al., 2008). Within CEAP's Watershed Assessment Studies, the St. Joseph River watershed in northeastern Indiana has been targeted by the Agricultural Research Service (ARS) to provide information on the environmental effects of conservation practices. So far, the evaluation of a few conservation practices at the field scale has been completed for this watershed (Francesconi et al., 2014; Smith et al., 2008, 2015a,2015b; Pappas et al., 2008). However, more research is required on the impact of single and combined conservation practices at the field and the watershed scale.

Monitoring and modeling the potential benefits of conservation practices at the watershed scale is challenging (Tomer and Locke, 2011). While monitoring provides empirical data, it is also time consuming and costly which limits the number of practices to be evaluated. On the other hand, modeling can simulate multiple conservation practices. However, modeling of large watersheds makes the evaluation of distinct conservation practices difficult, as landscape components are merged into single units (e.g., hydrologic response units in the Soil and Water Assessment Tool — SWAT) (O'Donnell, 2010). Furthermore, detailed management information of agricultural practices at the watershed scale is difficult to collect, and several years of monitoring data are usually required for the modeling analyses to be robust. So far, various studies have been conducted to provide some accountability for the incorporation of conservation practices at CEAP's targeted watersheds. The review by Richardson et al. (2008) summarizes some of these findings. Among them, monitoring results have shown the significant benefits of Conservation Reserve Programs (CRP), fertilizer management techniques, reduced tillage, and wetlands for mitigating sediment and nutrient

* Corresponding author. Tel.: +51 1 349 2273x112.
E-mail address: W.Francesconi@cgiar.org (W. Francesconi).

http://dx.doi.org/10.1016/j.jglr.2015.05.001

losses. In addition, modeling is proving to be a useful tool for the evaluation of scenario simulations to identify successful practices. In conjunction, the extrapolation of monitoring and modeling results has been demonstrated to be a valuable research approach for evaluating the effectiveness of conservation practices at the watershed level.

The primary hydrological models used for the evaluation of CEAP's conservation practices have been SWAT and the Annualized Agricultural Non-Point Source (AnnAGNPS) Pollution Model (Richardson et al., 2008; Tomer and Locke, 2011). The application of these physically-based models has been favored as they can include soil, land-use, and topographic variability in the watershed (Rossi et al., 2008; Yuan et al., 2001). In the St. Joseph River watershed, SWAT has been shown to perform better than AnnAGNPS when predicting stream flow and pesticide losses (Heathman et al., 2008). Yet, the authors concluded that it is difficult to include detailed environmental and management information when modeling at the watershed scale. Modeling of large watersheds results in an increase in the model's input uncertainty and consequently in the loss of predictive power. In contrast, the use of field-scale prediction models can help evaluate the distinct contributions of selected BMPs to water quality.

The Agricultural Policy/Environmental eXtender (APEX) model has been proposed as a tool for evaluating conservation practices in CEAP watersheds (Gassman et al., 2010). APEX was developed to predict water flow, sediment, and nutrient transport in agricultural fields and small watershed (Williams and Izaurralde, 2006). In addition to simulating structural conservation practices, the model is capable of incorporating detailed environmental and management information at the field scale. Hence, it is currently promoted as being more flexible and having a broader range for evaluating agricultural practice scenarios (Gassman et al., 2010). Yet, so far APEX has only been applied to test the effectiveness of a handful of conservation practices in the USA (Francesconi et al., 2014; Tuppad et al., 2010; Wang et al., 2008, 2009), and some of these are specific to particular regions in the country. The study by Tuppad et al. (2010), for example, provides a review of the effect of conservation practices tailored to agricultural watersheds in Texas. The implementation of APEX modeling for the evaluation of BMPs in other agricultural regions in the US can help identify practices that can address pressing environmental issues in those regions.

In the Midwest where the primary agriculture is corn (*Zea mays*) and soybeans (*Glycine max*), farmers can choose from a variety of conservation practices available through government-supported cost-share programs. In fact, some of these programs work synergistically, and participant farmers often bundle two or three conservation practices within a single agricultural field. Given the persistent eutrophication problems in surface water bodies in the Midwest, the effectiveness of these single and combined practices adopted to improve water quality needs to be tested. One way to evaluate the effects of single and multiple conservation practices is through APEX modeling. This would allow for a quantitative evaluation of conservation practices and serve as a tool for ranking their effectiveness when dealing with specific conservation goals.

The overall purpose of this study was to evaluate different government-promoted cost-share conservation practices and their combined effect on water quality in the St. Joseph River watershed. More specifically, the objectives were: 1) to model conservation practices particular to the Midwest region and compare their relative effectiveness at reducing nutrient transport from agricultural fields, and 2) to extrapolate the APEX modeled edge-of-field outputs by their incorporation areas at the watershed scale to provide a preliminary estimation of their sediment and nutrient reduction potential.

Methods

Study site

The St. Joseph River watershed is an 8 digit Hydrologic Unit Code (HUC 04100003) catchment located at the intersection of the states of Michigan, Indiana, and Ohio (Fig. 1). The St. Joseph River is the main source of drinking water for the city of Fort Wayne and surrounding areas in Indiana. The watershed is composed of nine 11-digit HUC sub-watersheds. Among them, the upper Cedar Creek (HUC 04100003080) has been monitored by the National Soil Erosion Research Laboratory for water quality for more than 10 years. Cedar Creek is the largest tributary of the St. Joseph River, which joins the St. Mary's River in Fort Wayne to form the Maumee River, which in turn drains into Lake Erie. The sub-watershed for Cedar Creek is located in the northeast region of the state of Indiana (41° 28′ 33.28″ N, 84°59′ 18.38″ W), and its area is approximately 708 km^2 with elevation ranging between 275 to 320 m above sea level. The average annual precipitation in Cedar Creek is approximately 900 mm and the greatest rainfall events occur in May and July (Heathman et al., 2008). The topography can be described as being predominantly flat, with some depressions and hills throughout the landscape. The predominant soil orders are alfisols, inceptisols, and

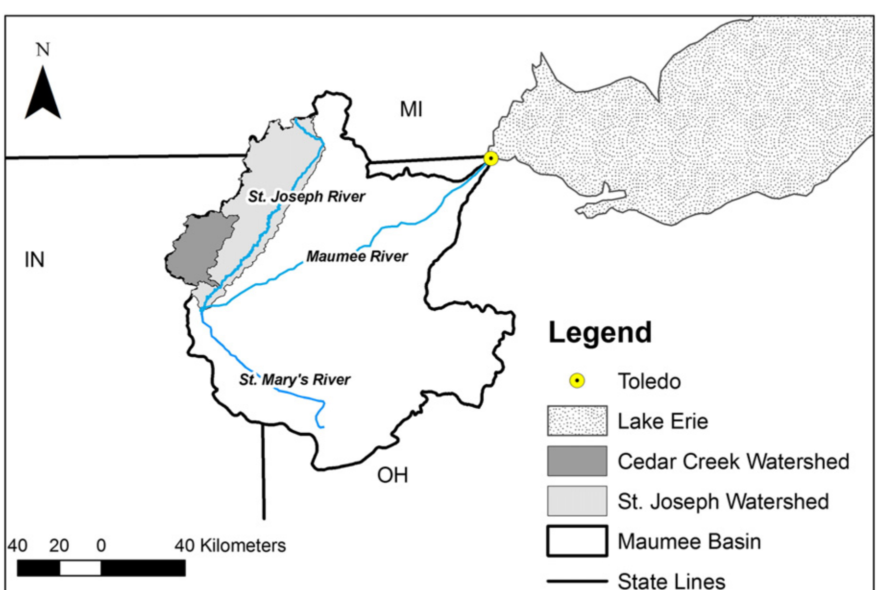

Fig. 1. Location of St. Joseph River watershed and Cedar Creek watershed.