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Modeling the effects of climate change on water, sediment, and nutrient yields from the Maumee River watershed

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ABSTRACT

Study region: Harmful algal blooms (HABs) in the Western Basin (WB) of Lake Erie have been linked to nonpoint pollution from agricultural watersheds. The Maumee River watershed is the largest in the Great Lakes region and delivers the biggest sediment and nutrient load to Lake Erie.

Study focus: Climate change could alter the magnitude and timing of sediment and nutrient delivery to Lake Erie's WB. Data from four Coupled Model Intercomparison Project Phase 5 (CMIP5) models were inputted into a calibrated Soil and Water Assessment Tool (SWAT) model of the Maumee River watershed to determine the effects of climate change on watershed yields. Tillage practices were also altered within the model to test the effectiveness of conservation practices under climate change scenarios.

New hydrological insights for the region: Moderate climate change scenarios reduced annual flow (up to −24%) and sediment (up to −26%) yields, while a more extreme scenario showed smaller flow reductions (up to −10%) and an increase in sediment (up to +11%). No-till practices had a negligible effect on flow but produced 16% lower average sediment loads than scenarios using current watershed conditions. At high implementation rates, no-till practices could offset any future increases in annual sediment loads, but they may have varied seasonal success. Regardless of future climate change intensity, increased remediation efforts will likely be necessary to significantly reduce HABs in Lake Erie's WB.

1. Introduction

1.1. Study area and background

The Maumee River is over 210 km (130 mi) long and drains an area over 17,100 km^2 (6600 mi^2) in Ohio, Michigan, and Indiana, making it the largest watershed in the Great Lakes region (USEPA, 2013) (Fig. 1). The Maumee River is one of the five rivers (St. Clair, Huron, Raisin, and Sandusky) that discharge into the Western Basin of Lake Erie. Of all the Great Lakes, Lake Erie is the shallowest (average depth of 19 m), southernmost, and most productive (Botts and Krushelnicki, 1987). Of the three main basins that make up Lake Erie (Western, Central, Eastern) the Western is the shallowest with an average depth of less than 8 meters. Lake Erie and the surrounding watershed provide the fresh water supply for over 11 million people and is home to a $20 million annual fishery, making it an important economic and natural resource (Botts and Krushelnicki,

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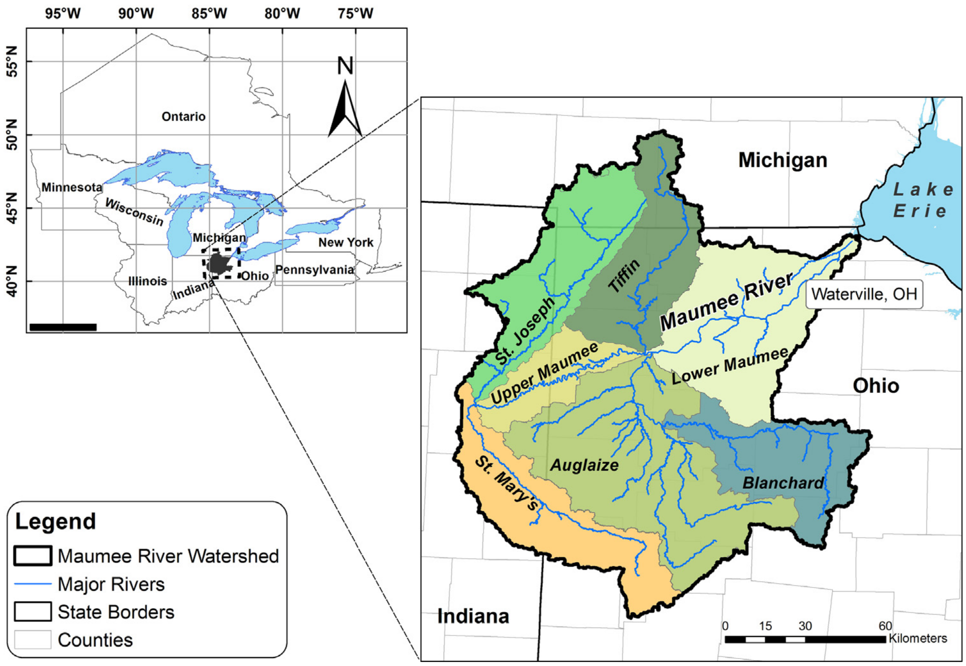

Fig. 1. Location of the Maumee River watershed. The watershed is the largest in the Great Lakes region, consisting of seven HUC 8 subbasins that drain into the WB of Lake Erie. Flow and sediment measurements were taken at Waterville, Ohio (denoted with a star), allowing characterization of over 96% of the watershed.

1987; Kinnunen, 2003). However, high population areas and extensive agricultural land in the contributing drainage basin coupled with shallow depth make the Western Basin susceptible to anthropogenic influence (Richards et al., 2009, 2010).

1.2. Problem description

Lake Erie has a history of environmental problems due to excess sediment and nutrient loading. One of the primary problems is eutrophication from phosphorous loading from point and non-point sources. Phosphorus is considered the limiting nutrient in aquatic ecosystems such as Lake Erie, and primary production is well-correlated with phosphate input (Logan, 1987). Large phosphorus inputs to Lake Erie lead to extensive algal blooms. These blooms reduce water quality, increase water treatment costs, introduce foul taste and odors, and lead to hypoxic conditions. In recent years, harmful algal blooms (HABs) containing the cyanobacteria *Microcystis* have increased in frequency and number in the Western Basin. *Microcystis* produces a toxin called microcystin which can be harmful to human health in high concentrations (Dyble et al., 2008). High bloom activity increases water treatment costs, and beach advisories limit swimming and other recreational activities, reducing tourism revenues (Watson et al., 2008).

Excess sediment runoff also has an economic impact on shipping in the Western Basin. The Port of Toledo is a major shipping hub on the Great Lakes and requires annual dredging of the channel to allow passage of large ships. More than 870,000 m^3 of sediment must be removed from Maumee Bay and the lower part of the Maumee River at a cost of over $2 million annually (Myers and Metzker, 2000). The dredged material must be disposed of in confined disposal facilities due to high concentrations of PCBs and heavy metals (mercury, lead, etc.) as a result of industrial practices over the past half century (Myers and Metzker, 2000).

The Detroit River contributes 95% of the total incoming water to Lake Erie from the upper Great Lakes, but the Maumee River contributes 44% of the total river sediment input to Lake Erie (Kemp et al., 1977; Botts and Krushelnicki, 1987). About 72% of the Maumee watershed is agricultural land (Table 1) consisting of intensive row crop cultivation and highly erodible, poorly-drained soils. As a result of agricultural land use covering ~50% of the total Lake Erie basin, Lake Erie receives more sediment than any other of the Great Lakes by almost threefold (Baker, 1993). Since the 1960s, average fertilizer application has steadily increased in the state of Ohio (NASS, 2010). Most crops may only utilize one-third to one-half of fertilizer applied while the remainder of fertilizer has the potential to runoff during storm events as particulate phosphorus bound to sediment particles or as dissolved phosphorus (Tilman et al., 2001).

Prior to 1970, reduction of sediment, nutrient inputs and remediation efforts were practically non-existent (Mortimer, 1987). In 1972, the United States and Canada signed the Great Lakes Water Quality Agreement (GLWQA), which implemented strategies for reducing phosphorus loading to the Great Lakes (IJC, 1978). Subsequently, better management practices—including banning phosphates in soaps/detergents and improvements to wastewater treatment—significantly reduced phosphorous loading from point sources during the 1970s and 1980s (Richards et al., 2008). This initial approach