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Modeled climate change impacts on subirrigated maize relative yield in northwest Ohio☆,☆☆

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ABSTRACT

Subirrigation is employed to supply water to crop root zones via subsurface drainage systems, which are typically installed for the purpose of excess soil water removal. Crop yield increases due to subirrigation have been demonstrated in numerous studies, but there is limited information regarding yield under future climate conditions when growing season conditions are expected to be drier in the U.S. Corn Belt. DRAINMOD was calibrated and validated for three locations with different soil series in northwest Ohio and used to investigate maize relative yield differences between subirrigation and free subsurface drainage for historic (1984–2013) and future (2041–2070) climate conditions. For historic conditions, the mean maize relative yield increased by 27% with subirrigation on the Nappanee loam soil, but had minimal effect on the Paulding clay and Hoytville silty clay soils. Maize relative yield under free subsurface drainage is predicted to decrease in the future, causing the relative yield difference between free subsurface drainage and subirrigation practices to nearly double from 9% to 16% between the historic and future periods. Consequently, the subirrigation practice can potentially mitigate adverse future climate change impacts on maize yield in northwest Ohio.

1. Introduction

Although the U.S. Corn Belt generally receives sufficient annual precipitation to satisfy the total annual crop evapotranspiration demands, disparities exist between crop water demands and effective water availability during the drier months of the growing season. Irrigation is often used on agricultural lands to supplement precipitation and maintain appropriate soil water during periods of high crop water demands. In the U.S. Corn Belt, supplemental water supply to maize (*Zea mays*) through irrigation may help mitigate the impacts of drought on yield, therefore helping to sustain or increase agricultural productivity (Baker et al., 2012). Irrigation can be implemented using several available methods, including sprinkler, drip and subirrigation. Subirrigation has considerable potential in the U.S. Corn Belt because it relies on subsurface drainage systems to supply water directly to the crop root zone (Brown et al., 1997), therefore minimizing irrigation water losses as well as irrigation system installation and operation costs. The application of water below the ground surface during subirrigation helps raise and maintain the water table at an appropriate depth in the crop root zone (Cooper et al., 1992). The subsurface drainage system serves a dual purpose of a channel network to provide root zone drainage during wet periods or irrigation during periods of

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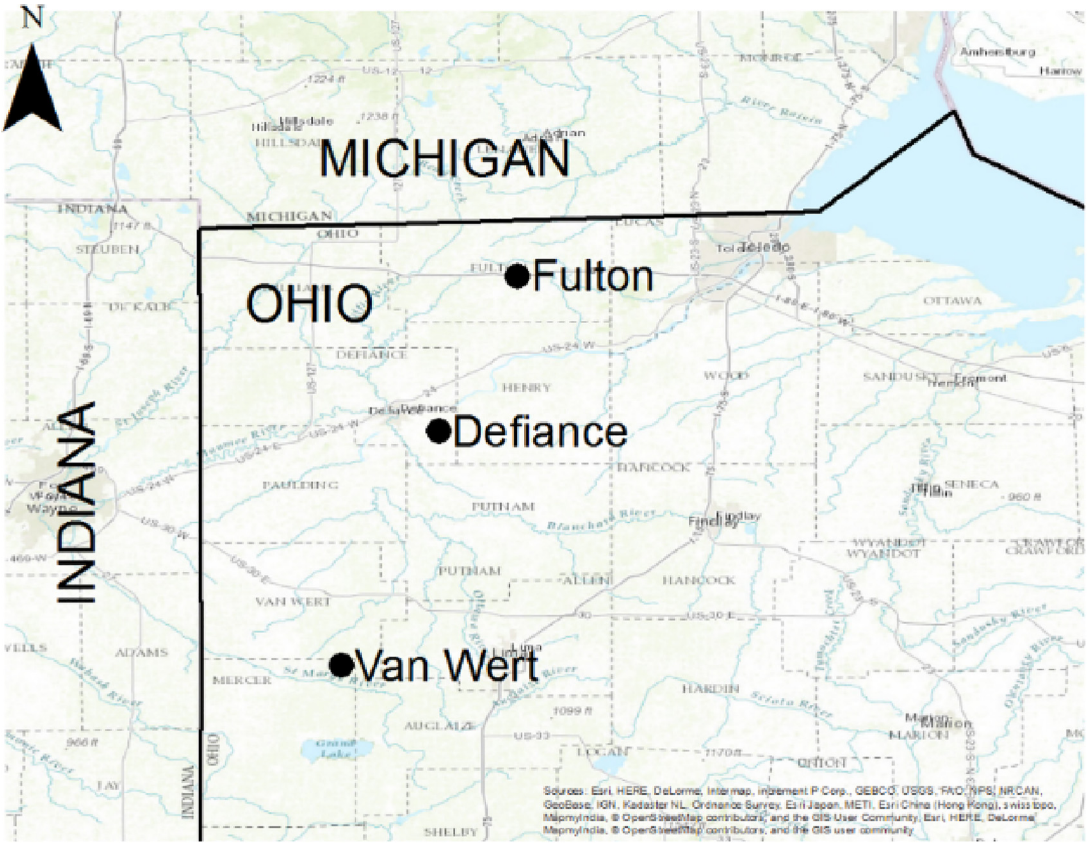

Fig. 1. Study site locations in northwest Ohio (Allred et al., 2003).
This figures shows the geographic location of the experimental sites simulated in this paper.

drought. More than 30% of agricultural lands in the U.S. Corn Belt have subsurface drainage systems, some of which can be retrofitted for subirrigation (Zucker and Brown, 1998). Drainage system retrofitting usually involves reducing drain spacing by installing new drain lines between old ones, to more effectively distribute water horizontally within the soil profile during subirrigation and to more quickly drain water from the soil in response to large rainfall events.

Subirrigation capable fields are not only operated in subirrigation mode, but also controlled drainage and free subsurface drainage modes as the need arises. In free subsurface drainage systems, the soil profile is allowed to drain freely to the depth of the drains. During controlled drainage, the drainage depth is regulated at a controlled structure, most often installed at the subsurface drainage system outlet, but without the addition of supplemental water. On subirrigation capable fields, water can be supplied continuously to the root zone during the growing season or can be interrupted by short periods of free or controlled subsurface drainage. In this paper, the term "subirrigation" refers to the period during which water is supplied to the crop, whereas "subirrigation practice" refers to the water management practice that includes subirrigation, free and/or controlled subsurface drainage.

Studies of the effectiveness of subirrigation practice on maize yield have generally found that the yield increased significantly and stabilized at a high level under subirrigation practice. Cooper et al. (1999) found that maize production on Ravenna silt loam and Hoytville silty clay loam soils in Ohio was 2900 kg/ha to 3750 kg/ha higher under subirrigation practice mainly during dry years. In 1998, Drury et al. (2009) found that maize yield was significantly lower under subirrigation practice on Brookston clay loam soil at Woodslee (Ontario), and suggested the large August precipitation as well as the tile spacing and depth as plausible causes for the lower yield. On Omulga silt loam soil in southern Ohio, Fisher et al. (1999) found that maize yield was 19% greater under subirrigation practice than under free subsurface drainage. Maize yield was found to be 64% larger under subirrigation practice in a sandy loam soil in southwestern Ontario (Ng et al., 2002), and 2.8% to 13.8% greater in eastern Ontario (Mejia et al., 2000). Other studies also based on field experiments used wetland-reservoir complexes, where runoff and subsurface drainage water was captured and recycled back into the subsurface drainage system. At Holiday Beach (Ontario), Tan et al. (2007) found that maize yield under subirrigation practice was 91% larger than under free subsurface drainage during dry years, and 7%–22% larger during wet years. In northwest Ohio, Allred et al. (2014) used a water capture and recycle system designated Wetland Reservoir Subirrigation System (WRSIS) on three different soil types and found that maize yield increased by 19.1% with the implementation of subirrigation practice.

Field measurements need to be extended by modeling studies to predict the impact of subirrigation under future climate conditions. Maize yield performance under subirrigation practice has also been investigated through DRAINMOD simulations. DRAINMOD is a field hydrology water balance computer model that simulates free subsurface drainage, controlled drainage, and subirrigation, either as single water table management practices or in combination with one another (Skaggs et al., 2012). Murugaboopathi et al. (1995) conducted a study based on a 37-year period (1950–1986) simulation with uncalibrated DRAINMOD using the Rains and Portsmouth sandy loam soils found in North Carolina, and found that subirrigation practice had a 21% maize relative yield advantage over free subsurface drainage.

The study in northwest Ohio by Allred et al. (2014) measured crop yield impacts at three sites with different soils for twelve years. Baule et al. (2017) utilized results from Allred et al. and regional climate model output to evaluate the impact of growing season precipitation on yields at the three sites and how yields will respond under projected climate conditions. As the U.S. Corn Belt is expected to experience annual shifts in temperature, solar radiation, and precipitation regimes

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