Research paper

Implications of biofuel-induced changes in land use and crop management on sustainability of agriculture in the Texas High Plains

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1. Introduction

The Texas High Plains (THP) region, which encompasses 41 counties in the northwest Texas in the United States, is a treeless, windswept and semi-arid region within the Great Plains \cite{1}. Cotton (\textit{Gossypium hirsutum} L.) is one of the major crops grown in this region. The harvest area of cotton in the THP was about 37\% of the entire U.S. cotton harvest acreage in 2015 \cite{2}. In general, cotton is planted around mid-May and harvested at the end of October in the THP. Setting of cotton blooms in this region begins in late June and ends in mid-July \cite{3}. During the early stages of cotton growth, minimal ground cover conditions that are favorable for wind erosion exist. Between setting of blooms and harvest, cotton conditions that are favorable for wind erosion exist. Growing cover crops after harvesting cotton and/or changing land use from cotton to perennial bioenergy crops could not only address above challenges, but also assist in meeting the national biofuel target. The objective of this study is to assess the implications of changes in land use (replacing cotton with Alamo switchgrass (\textit{Panicum virgatum} L.) and \textit{Miscanthus giganteus}) and crop management (growing winter wheat (\textit{Triticum aestivum} L.) cover crop) on hydrology and wind erosion in the Double Mountain Fork Brazos Watershed using the Agricultural Policy/Environmental eXtender (APEX) model. Simulated average annual wind erosion, total nitrogen (TN) loss to surface water and nitrate-nitrogen (NO\textsubscript{3}-N) leaching to groundwater reduced by more than 37\%, 43\% and 73\%, respectively, when winter wheat was grown as a cover crop under the 457 mm (18-inch) annual groundwater pumping limit setup by the High Plains Water District. In addition, winter wheat produced about 0.20–0.26 kg m\textsuperscript{-2} of biomass for biofuel purposes. Land use change from irrigated cotton to switchgrass and rainfed cotton to \textit{Miscanthus} decreased the TN load, NO\textsubscript{3}-N leaching and soil loss by wind erosion by > 89\% relative to the baseline scenario. Under the groundwater pumping restrictions, multiple harvests of perennial grasses were found to be better in terms of biomass production (> 2 kg m\textsuperscript{-2}), and protection of groundwater and soil.

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\textbf{https://doi.org/10.1016/j.biombioe.2018.01.012}
Received 29 March 2017; Received in revised form 14 December 2017; Accepted 18 January 2018
Available online 22 February 2018
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allowable groundwater pumping at 457 mm (18 inches). Chaudhuri and Ale [7] also found that the percentage of groundwater quality observations from the shallow wells in the THP region that exceeded the United States Environmental Protection Agency’s Maximum Contaminant Level (MCL) for nitrate (NO$_3$) (44 g m$^{-3}$) increased from 3% in the 1960s (1960–1969) to 32% in the 2000s (2000–2010).

Recently, cellulosic bioenergy crops have been promoted to fulfill the mandated 2022 U.S. biofuel target of 79 million m$^3$ [8] and about 11.4% of existing croplands and pastures in the Southeastern U.S., including the THP, were estimated to be required for producing biofuel according to the U.S. Department of Agriculture (USDA) [9]. Groundwater concerns, wind erosion and the biofuel target may necessitate substantial changes in land use and management in the THP such as adoption of the best management practices (BMPs) for cotton production and land use change from cotton to environment-friendly bioenergy crops. While groundwater pumping restrictions imposed by the HPUWCD address groundwater depletion concerns, growing of cover crops in the winter could not only serve as one of the BMPs for reducing wind erosion and improving groundwater quality, but also provide biomass for biofuel production. In addition, replacing cotton in the THP region with perennial grasses such as Alamo switchgrass (Panica virgatum L.) and Miscanthus (Miscanthus × giganteus), which were identified as environment-friendly bioenergy crops in many studies [10–14] could also provide multiple benefits of protecting soil and groundwater quality, and meeting the national biofuel target. However, studies evaluating the long-term effects of growing cover crops and changes in land use from cotton to perennial grasses on hydrology and wind erosion are lacking in this region and this study focuses on this research gap.

The Agricultural Policy Environmental eXtender (APEX) model, a continuous, daily time step model with a built-in wind erosion module, was used in this study. The APEX model has demonstrated strength in simulating the impacts of BMPs and land use change on hydrology and wind erosion in many intensively farmed watersheds [15–23]. For example, using the APEX model, Wang et al. [24] found that the total sediment yield from the Shoal Creek Watershed in Texas was
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