The Impact of Climate Variability and Land Management Practices on Water Quality in Iowa at the Watershed Scale

Kelsie M. Ferin[1], Andy VanLoocke[1] & Adam Ward[2]

[1]Department of Agronomy, Iowa State University, Ames, IA
[2]Department of Geological Sciences, Indiana University, Bloomington, IN

IOWA STATE UNIVERSITY
Department of Agronomy

Introduction

The US Corn Belt is known to be one of the most productive areas for food and energy crops due to nutrient-rich, water-holding soils, and intense management strategies [6; 9]. However, the productivity of this land is being threatened by climate change impacts [1; 10; 11; 14]. Climate and hydrological variability impacts crop performance in ways critical to crop performance (e.g. yield and profitability) but also cropping system resilience. Changes in hydrological forcing may exacerbate the already large nutrient exports from the Corn Belt (e.g., [4; 15]).

The North Raccoon River basin (**Figure 1**) is arguably the current epicenter of conflicts over agriculture's role in water quality, specifically agriculture's contribution to high nutrient loads reaching local water supplies and the Gulf of Mexico [2; 8]. The Iowa Nutrient Reduction Strategy (INRS) has presented a number of management options for improving water quality, including planting cover crops and perennial bioenergy crops with the goal of reducing nitrate loads by 41% [7]. Transitioning non-profitable annual/conventionally managed land with high nitrate leaching to cover crops or perennial bioenergy crops may help nitrogen-related environmental impacts while providing increased soil health and reduced runoff and soil erosion [3; 7].

Hypotheses

1. Under current practices, increasing climate variability will decrease cropping system resilience (as indicated by yield and profit) and water quality.
2. Implementing INRS practices will improve water quality and will have a greater impact on water quality improvement under future climate conditions relative to under current conditions.

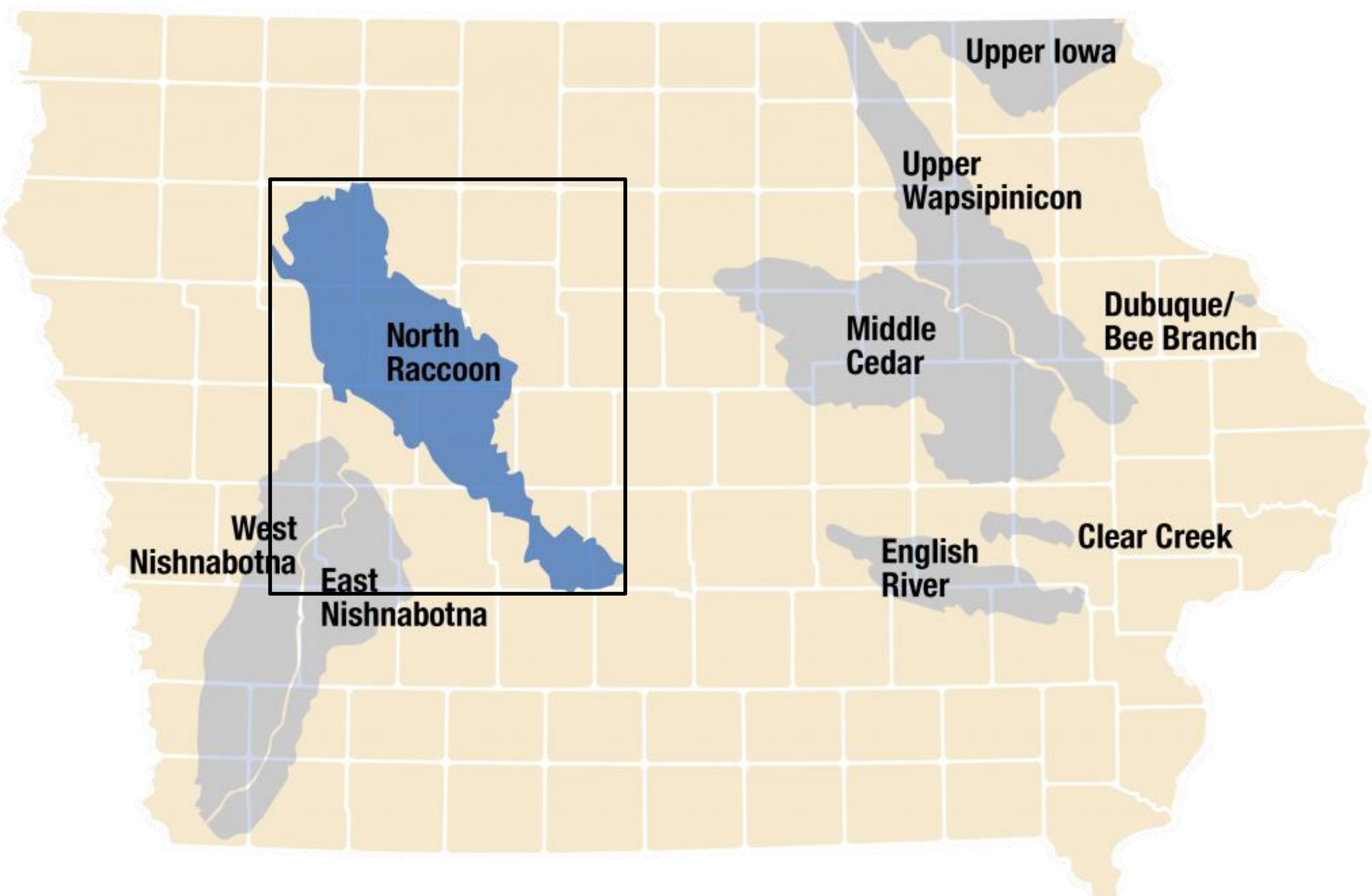

Figure 1: North Raccoon River Watershed domain is represented by the black box [12].

This research was supported by the Iowa Nutrient Research Center.

Objectives

<u>Objective 1</u>: Baseline - Simulate and evaluate modeled streamflow and water quality for a baseline scenario for the North Raccoon River.

<u>Objective 2</u>: Climate – Quantify the impact of future climate variability on crop yields, ET, drainage, nitrate leaching, and consequent changes in streamflow and water quality for the North Raccoon River.

<u>Objective 3</u>: Land management – Quantify the streamflow and water quality impacts of key management strategies listed in the INRS under current and future climate.

Methodology

A coupled version of Agro-IBIS (Integrated Biosphere Simulator – Agricultural Version) and THMB (Terrestrial Hydrology Model with Biogeochemistry) are used to simulate streamflow and water quality for specific crop and management specifications (**Figure 2**). The new version of Agro-IBIS being used incorporates Iowa-specific soil, land use, and climate data sets to run on a 500-m grid resolution similar to the scale of agricultural fields in Iowa.

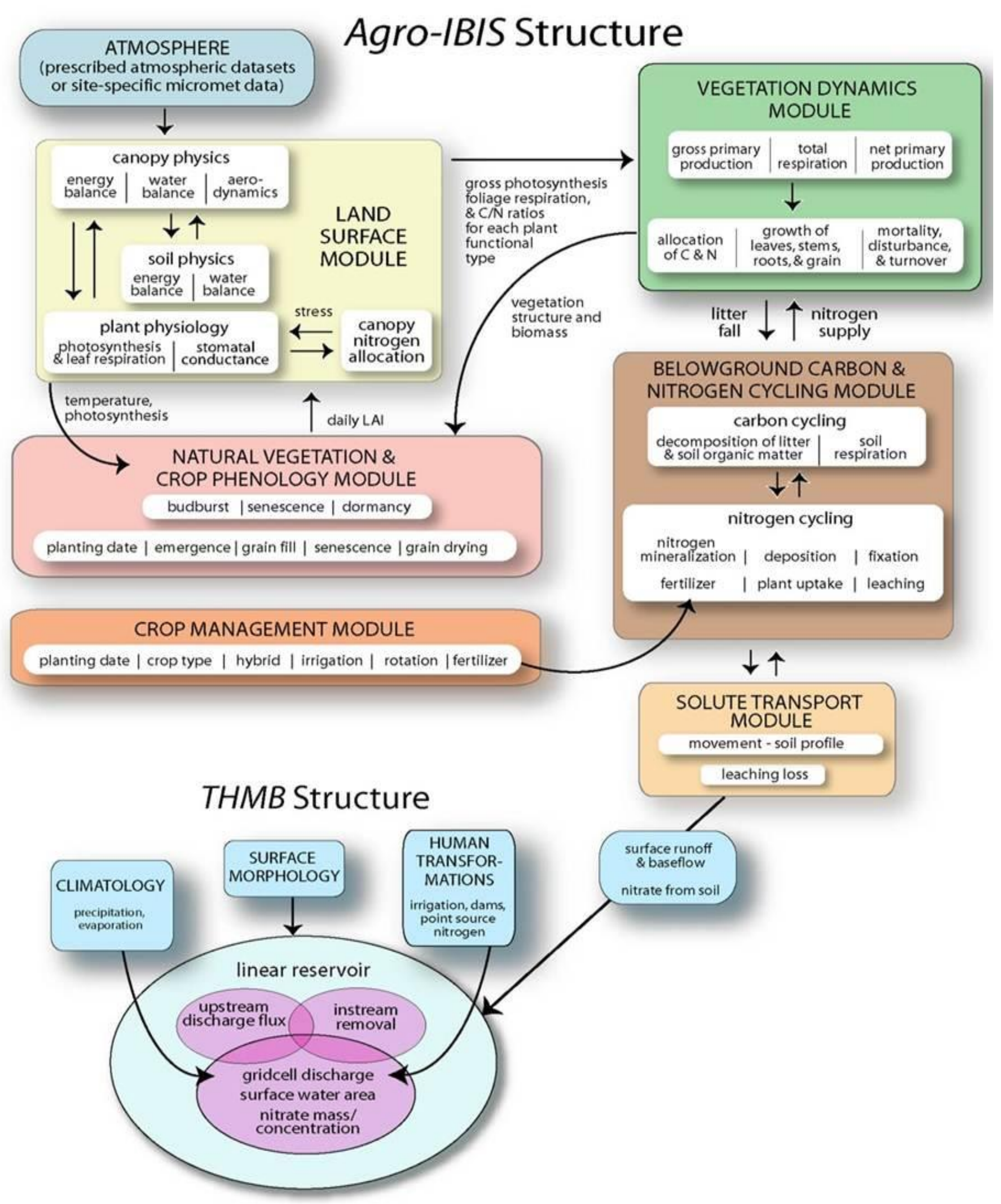

Figure 2: Schematic representing depiction of the coupled Integrated Biosphere Simulator – agricultural version (Agro-IBIS) and Terrestrial Hydrology Model with Biogeochemistry (THMB) process representation and workflow structure.

Preliminary Results - Baseline Scenario

Simulations were run for 1998-2007 for the North Raccoon River Basin using the fine grid Iowa data and a corn-soybean rotation. The results shown in **Figure 3** and **Figure 4** depict the streamflow and leached nitrate output from Agro-IBIS and THMB model, which are compared to observed date from the USGS [13] and DNR [5] for streamflow and nitrate leaching rates, respectively.

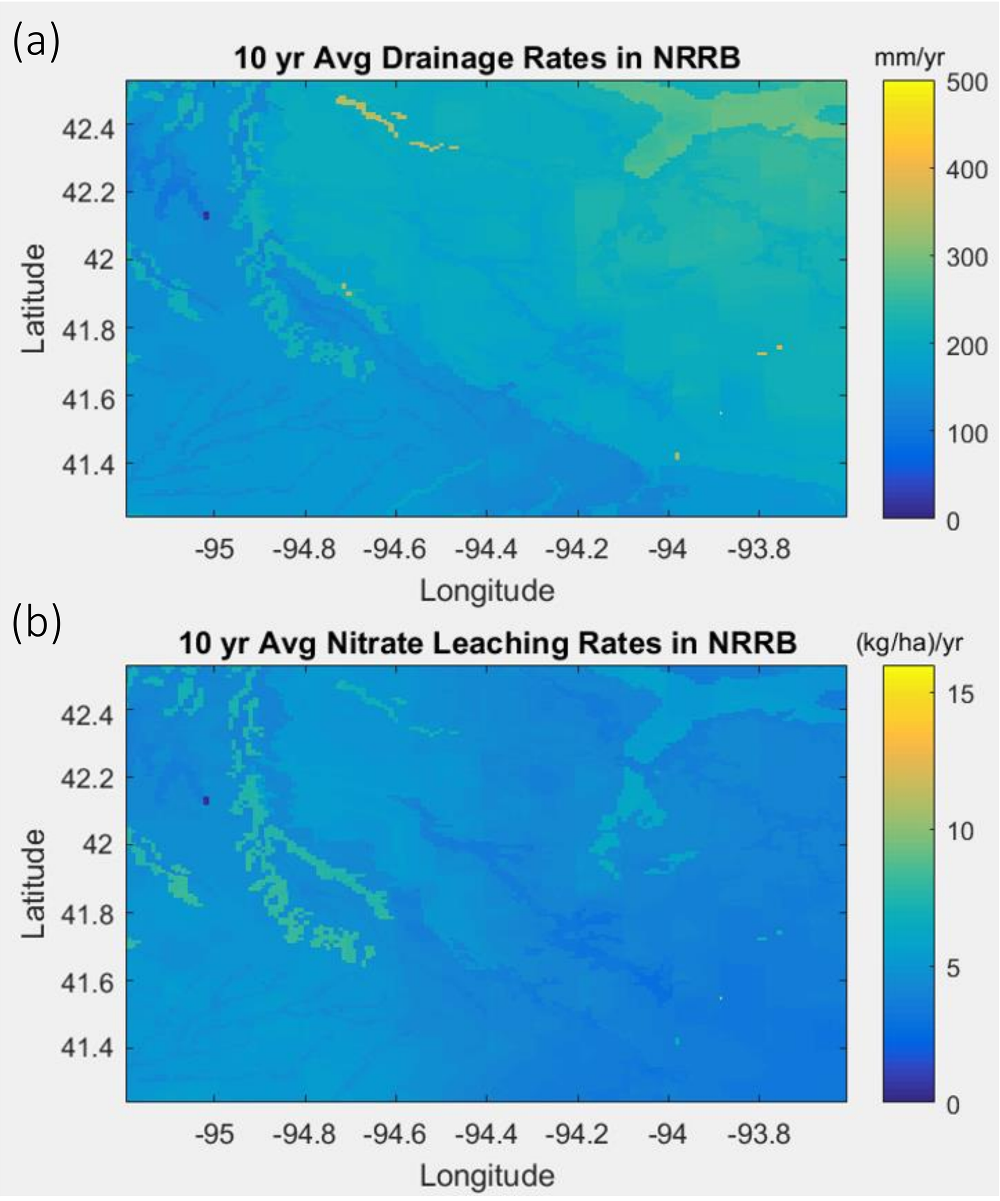

Figure 3: Simulated mean drainage (a) and nitrate leaching (b) for a grid which cover the NRRB watershed.

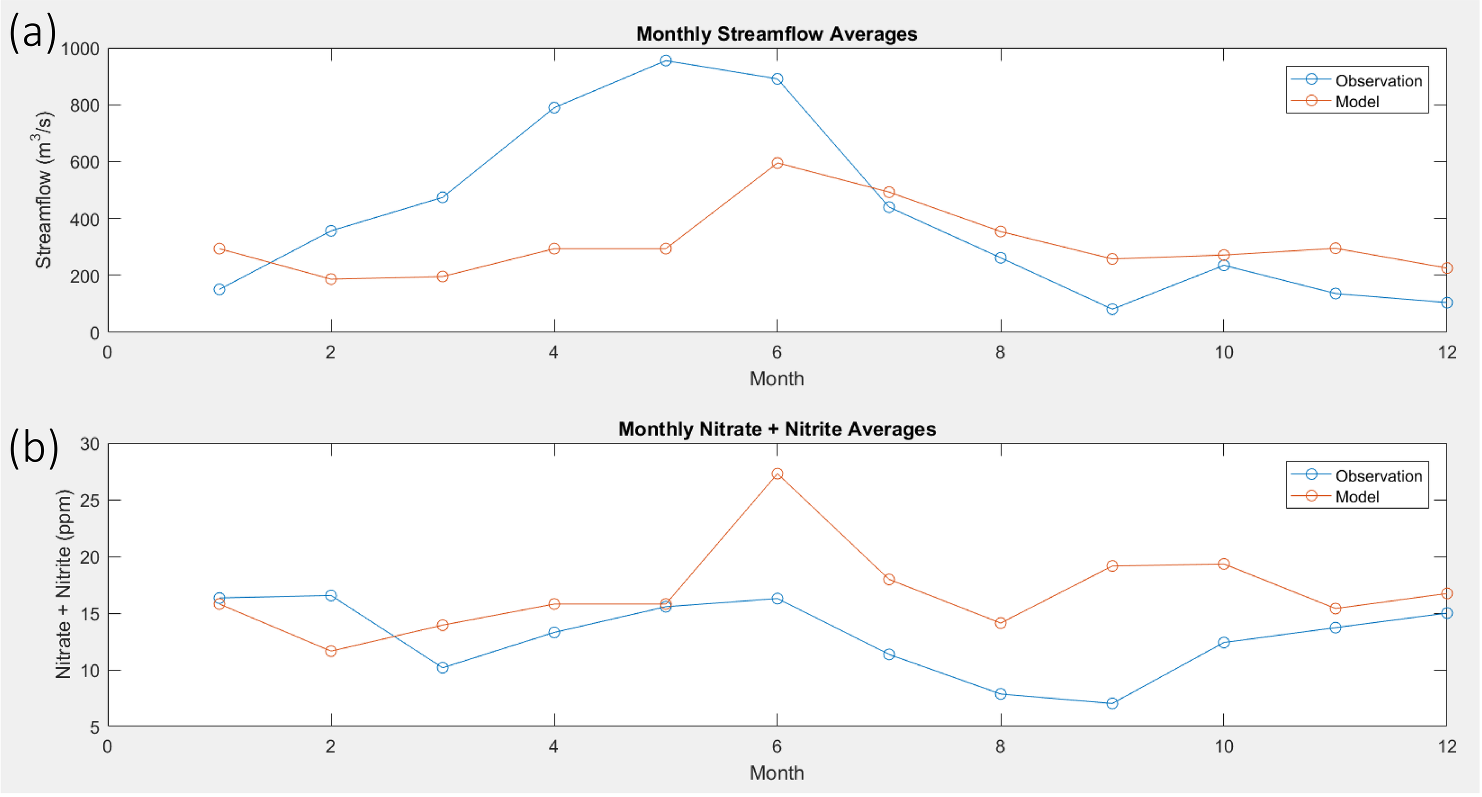

Figure 4: Observed [5; 13] and simulated monthly mean streamflow (a) and nitrate leaching (b) for the NRRB domain.

References

[1] Dai S. *et al.,* 2015:A spatiotemporal analysis of Midwest US temperature and precipitation trends during the growing season from 1980 to 2013. *International Journal of Climatology*, **525**, 517-525.
[2] David *et al.,* 2010: Sources of nitrate yields in the Mississippi River Basin. *J. Environ. Qual.,* doi:10.2134/jeq/2010.0115.
[3] Davis S.C. *et al.,* 2011: Impact of second-generation biofuel agriculture on greenhouse-gas emissions in the corn-growing regions of the US. *Frontiers in Ecology and the Environment*, **10**, 69-74.
[4] Davis S.C. *et al.,* 2014: Antecedent Moisture Controls on Stream Nitrate Flux in an Agricultural Watershed. *Journal of Environmental Quality*. DOI: 10.2134/jeq2013.11.0438.
[5] Department of Natural Resources (DNR): Iowa STORET/WQX Water Quality Database. Accessed 27 Feb 2017. [Available at https://programs.iowadnr.gov/iastoret/]
[6] Gaunter *et al.*, 2014: Global and time-resolved monitoring of crop photosynthesis with chlorophyll fluorescence. *Proceedings of the National Academy of Sciences*, **111**, E1327-E1333.
[7] Iowa Nutrient Reduction Strategy (INRS), 2013: A Science and technology---based framework to assess and reduce nutrients to Iowa Waters and the Gulf of Mexico", Prepared by: Iowa Department of Agriculture and Land Stewardship, Iowa Department of Natural Resources, Iowa State University College of Agriculture and Life Sciences. Available at http://www.nutrientstrategy.iastate.edu/documents
[8] Jones *et al.*, 2016: Crop rotation and Raccoon River nitrate. *Journal of Soil and Water Conservation*, **71**, 206-219.
[9] Ray *et al.,* 2013: Yield trends are insufficient to double global crop production by 2050. *PloS ONE*, **8.6**, e66428.
[10] Ryberg K. *et al.,* 2014: Impact of climate variability on runoff in the North-Central United States. *J. Hydrol. Eng.*, **10**, 148-158.
[11] Steffens K.J & Franz K.J., 2012: Late 20th-century trends in Iowa watersheds: an investigation of observed and modelled hydrologic storages and fluxes in heavily managed landscapes. *International Journal of Climatology*, **32**, 1373-1391.
[12] University of Iowa, 2016: Iowa Watershed Approach. Accessed 10 Dec 2017. [Available at http://www.iihr.uiowa.edu/iwa/watersheds/north-raccoon/]
[13] U.S. Geology Survey (USGS), 2017: Instantaneous Data Archive. Accessed 27 Feb 2017. [Available at https://ida.water.usgs.gov/ida/]
[14] Wuebbles D.J. & Hayhoe K., 2004: Climate change projections for the United States Midwest. *Mitigation and Adaption Strategies for Global Change*, **9**, 335-363.
[15] Yang *et al.,* 2015: Increased nitrogen export from eastern North America to the Atlantic Ocean due to climatic and anthropogenic changes during 1901–2008. *J. Geophys. Res. Biogeosci.*, **120**, 1046–1068.