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COMMENT

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This article is a comment on *Gupta et al.* [2015], doi:10.1002/2015WR017323.

Key Points:
- Increasing precipitation and LU/LC change contributed to increasing streamflow
- Row crop expansion in Midwest increased base flow in rivers
- Soybean area is useful surrogate to track LULC changes

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Comment on "Climate and agricultural land use change impacts on streamflow in the upper midwestern United States" by Satish C. Gupta et al.

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Abstract Increasing precipitation and land use/land cover (LU/LC) change have contributed to increasing streamflow and base flow in many Midwestern rivers but the relative importance of causal factors is open to debate. The dominant LULC change in the agricultural Midwest is the emergence of soybean production that occurred in the mid- to late-20th Century that replaced many sod-based rotations and increased total row crop area devoted to annual maize and soybean crops. Increasing precipitation may be a more important factor for increasing total discharge whereas LULC changes contributed more to base flow changes.

1. Introduction

In the paper "Climate and agricultural land use change impacts on streamflow in the Upper Midwestern United States," the authors Gupta, Kessler, Brown and Zvomuya (hereafter Gupta et al.) mischaracterize my research on land use change and streamflow. Although I have specific comments, I focus here on three general concerns.

2. Influence of Precipitation on Streamflow Changes

Gupta et al. [2015] claim that our research [*Schilling*, 2003, 2005; *Schilling and Libra*, 2003; *Schilling et al.*, 2008, 2010; *Zhang and Schilling*, 2006a] has concluded "higher annual streamflows . . . in Iowa in recent years were **mainly due** [emphasis added] to land use/land cover (LULC) changes. . .." While this section of the paper was focused on the North Raccoon River, the implication made by citing my papers was that I believed that that LULC change was more important than precipitation in changing streamflow in Iowa [e.g., *Schilling and Libra*; 2003] and the Midwest [e.g., *Schilling et al.*, 2010]. This implication is false. In my papers on land use change and streamflow, I and my coauthors explicitly stated that "discharge . . . changed more than precipitation alone can explain" [*Schilling and Libra*, 2003]. In *Schilling et al.* [2010], we quantified the effects of land cover change on streamflow in the Mississippi River near Clinton, Iowa and reported that increasing soybean acreage (LULC change) changed the slope of the annual Q-P relation by 32%. This percentage change in water flux due to LULC change was consistent with a 30% increase reported by *Raymond et al.* [2008]. In other words, we are attempting to account for factors other than the ~70% that is due to precipitation.

In their best-fit lines (annual P vs. Q) describing the effects of precipitation on streamflow in the North Raccoon and Iowa rivers in Iowa, *Gupta et al.* [2015] reported coefficients of determination (r^2) of 0.51 and 0.48, respectively. From these statistical relations, it would appear that there are factors other than precipitation that affect streamflow in these two watersheds.

3. Effects of LULC Change on Base Flow

In a word search of the *Gupta et al.* [2015] paper, the word "base flow" was used a total of one time in the Introduction section. This is particularly surprising given that much of my work cited in the Gupta et al. paper is specifically addressing changes in the base flow fraction of streamflow, not total streamflow. This is an important distinction and the lack of exposition on this by *Gupta et al.* [2015] is a major mischaracterization of my research. In my initial work investigating streamflow changes in Iowa across the 20th Century, the major finding of this study (so much so that I made it the paper title) was that while total streamflow was changing slightly in some Iowa rivers, annual base flow, minimum flows and base flow fraction significantly increased in nearly all watersheds studied [*Schilling and Libra*, 2003]. In follow-up studies, we related the increasing base flow to increasing row crop intensity [*Schilling*, 2005] and expanded the analysis to report increasing base flow in the entire Mississippi River basin [*Zhang and Schilling*, 2006a].

The distinction between changes in base flow versus total streamflow is critically important when assessing the effects of LULC changes. Total streamflow consists of base flow and stormflow components, with base flow mainly due to groundwater inflow to the stream channel and stormflow due primarily to surface water runoff. While there is a clear link between increasing precipitation and increasing runoff (i.e., more rain produces more runoff), the relation with base flow is less straightforward since base flow is essentially equivalent to groundwater recharge [*Scanlon et al*., 2002]. With this in mind, my work has largely focused on changes that have affected groundwater recharge, including changes in evapotranspiration [e.g., *Zhang and Schilling*, 2006b], tile drainage [e.g., *Schilling and Helmers*, 2008] and other factors [*Schilling and Libra*, 2003].

Recent work with collaborators [*Xu et al*., 2013] indicated that changes in precipitation contributed more to increasing total streamflow than LULC change ($\sim$60% to 40%) in 55 Midwestern watersheds, whereas LULC change contributed more to base flow (74%) and the fraction of streamflow due to base flow (119%). Results from this study provide compelling evidence that while increasing precipitation is important to both total streamflow and base flow, LULC changes exert more control on base flow. Hence, given the prominence of base flow in my research, it is puzzling why *Gupta et al*. [2015] conflated base flow with total streamflow.

4. Effects of Increasing Soybean Area

Gupta et al. [2015] note that my research has emphasized the role of soybeans in LULC changes in Iowa and the Midwest. LULC changes in the agricultural Midwest are often quantified by the large increase in soybean production that occurred in the mid- to late-20th Century. This focus on increasing soybean production may, at first glance, appear to target the crop as the source of the streamflow changes. However, we have made it clear in numerous publications that "...increasing soybean production is largely a surrogate measure of increasing row crop production since maize and soybean are annual crops that are often in rotation." [*Schilling et al*., 2010]. Soybean management is a greater nitrate loading risk than corn [*Jones et al*., 2016] and these revelations should not be interpreted as indictments of soybean. Rather, they offer farmers and researchers new opportunities to improve environmental performance in the maize-soy rotation. It is worth noting that most efforts to reduce nutrient loss in the U.S. Cornbelt over the past 30 years have focused on maize and progress has been agonizingly slow.

In conclusion, the effect of LULC changes on hydrologic processes is an important topic and there is ample space for healthy disagreement on causal factors. Advancing environmental performance in the Mississippi River basin will require intense discussions and debate about evidence. Mischaracterization of research will only prolong the time required for sorely needed water quality improvements in the Gulf of Mexico and Mississippi River stream network.

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