Hydrol. Earth Syst. Sci. Discuss.,
doi:10.5194/hess-2017-133-AC1, 2017

Hydrology and Earth System Sciences
Discussions
Open Access

Interactive comment on "Human amplified changes in precipitation-runoff patterns in large river basins of the Midwestern United States" *by* Sara A. Kelly et al.

Sara A. Kelly et al.

sara.kelly@aggiemail.usu.edu

Received and published: 28 April 2017

First we would like to thank referee Ben Livneh for reviewing our manuscript and providing constructive feedback. Original comments by the referee are denoted by "Referee Comment" and our responses are denoted by "Author Response".

Referee Comment: Overview The authors address the interesting problem of disentangling anthropogenic versus climate impacts on hydrology in agricultural catchments in the mid-western US. They propose that storage has decreased dramatically in drained (tile) watersheds and discuss other aspects of the water budget, as well as conduct a break-point analysis to understand drivers of LCLUC changes. Overall, this is a wonderful analysis and the most interesting paper I've read in a while, so I'd like to

Printer-friendly version

Discussion paper

commend the authors on a clearly articulated and thoughtful manuscript. A few points need to be clarified. However, I find the manuscript to be suitable for publication after minor revisions.

Author Response: Thank you! We are thrilled to hear that you find our analysis interesting and well-articulated.

Referee Comment: Major points INTRO, P2 second paragraph: do the widely reported systematic increases in peak, mean, total, and base flows from the literature attribute these to decreases in ET, or solely from increases in precipitation? This point needs to be clarified and discussed further.

Author Response: Increases in streamflows reported on page 2, lines 8-12, have been attributed to the combined effects of increasing precipitation and decreased ET from land use changes, including agricultural tile drainage and replacement of perennial vegetation and/or hay and small grains to corn and soybean rotations.

For example, Frans et al. 2013 examined the relative contributions of increasing precipitation and land use land cover change to observed streamflows in the Upper Mississippi River Basin (UMRB), upstream of Grafton, IL. They show that ET is expected to increase with twentieth century agricultural expansion, except in the places they modeled agricultural tile drainage. When tile drainage is present, ET decreases, while total runoff increases. This is entirely consistent with what we propose in our manuscript. Necessarily, storage must decrease between the pre and post period in the agricultural river basins to explain modern day water budgets and streamflow patterns. Tile drainage can accomplish this decrease in storage by draining soil moisture that would have otherwise gone as ET or contribute to regional groundwater. Therefore, twentieth century tile drainage expansion is expected to decrease ET and increase total runoff.

Schottler et al. 2014 corroborated this finding, and developed an empirical relationship between water yield and amount of precipitation (P) that goes as potential evapotranspiration (PET), PET/P. Their findings suggest that the PET/P ratio has decreased during the twentieth century due to combined effects of climate and crop conversions, and has contributed to the observed increases in annual water yields.

We discuss changes in annual runoff ratios, precipitation, and evapotranspiration in section 4.2.1 (specifically p. 17, lines 7-14), and will discuss ET findings of other streamflow change studies further in the introduction of the revised manuscript, as recommended by the reviewer.

Referee Comment: P3L20: studies report reductions in early season ETâĔŸAĔĞTpresumably these are because replacing mature grasslands with fledgling crops reduces ET early in the season. However, what occurs later in the season, when the crops matureâĔŸAĔĞTwill the ET be greater than grasslands?

Author Response: Although studies generally agree that conversion of mature prairie or grasslands with annual row crops reduce ET early in the growing season, there are mixed findings about how this land cover conversion affects ET later in the growing season, as well as annually (p. 2, lines 16-19). Crop growth and water use (ET) are highly dependent on local antecedent conditions such as precipitation, wind, humidity, solar radiation, and crop growth stage. For example, Zeri et al. (2013) found that maize had the highest values of ET annually in 2009 but the lowest values of ET in the drought year 2011, when compared to water use by miscanthus, switchgrass, and native prairie in central Illinois. In general, total annual water use between annual row crops and native prairie are not drastically different in Iowa (Wolf and Market 2007). However the distribution of water use throughout the season may be differ depending on antecedent climate conditions, as well as crop planting, emergence, and harvesting date. Because row crops have a relatively short growing season – planted generally in late April through early June, maximum growth and water use generally occurring in July-August , and harvested in September-October – evapotranspiration rates can be greater than native prairie during the peak growing season (July/August) and less than native prairie during early spring and late fall (Wolf and Market 2007). We will clarify this point in our revised manuscript.

Referee Comment: What is the spatial resolution of the census drainage data? For which 5 years are drainage data available at the county-level?

Author Response: The census drainage data are reported at the county level for 1940, 1950, 1960, 1978, and 2012 (page 6, lines 14-16). These are, unfortunately, the best available data for this spatial extent.

Referee Comment: The use of the Livneh et al. hydrometeorology data allows for calculation of the water balance at scales that are appropriate for the analysis. Although the authors acknowledge that the derived hydrologic outputs, e.g. ET, were generated using a modeling framework that considered static vegetation cover, they should report (if possible), which vegetation cover was used in VIC, e.g. was it natural vegetation or crop land cover? This would bolster the authors acknowledgement of the limitation.

Author Response: In a previously submitted version of the paper (doi:10.5194/hess-2016-571, p. 28, lines 7-13) we discussed the limitations associated with using the Hansen et al. (2000) static global vegetation classification in the VIC model. Several referees suggested significant shortening of the manuscript. Upon our own review, we eliminated details (∼2600 words) that were not essential to the manuscript. However, we agree that this would be a useful piece of information to convey for readers interested in this level of detail, so we will include this information in the Supplement of the revised manuscript.

Referee Comment: Would the use of static land cover of Livneh et al. (2013) mean that the authors results are a conservative estimate of LCLUC impacts, or would this mean that the authors findings would overestimate impacts?

Author Response: As stated above, we originally discussed potential limitations of using the Livneh et al. (2013) evapotranspiration data in a previously submitted version of the paper and will consider including such discussions in the Supplement of the revised manuscript, specifically in discussion of Figures S4 and S5. In general, static vegetation that does not include tile drainage should mean the Livneh et al. (2013)

ET estimates are overestimated in croplands, especially during modern times. This is exactly what we found when we compared the ET estimates to nearby Ameriflux stations in cropland cover (Figure S5). This potential bias is what allows us, independent of the climate drivers of ET change, to test whether drainage affects water balances. We anticipate that incorporating dynamic vegetation and tile drainage expansion in the VIC model would have reduced ET estimates and allowed for water budget closure in our analysis (i.e. storage term = zero). That said, Frans et al. (2013) tested the effects of dynamic vs. static cropland cover and found no statistically significant results of this effect on modeled annual runoff. Given that ET estimates between cropland and prairie are relatively similar, especially at annual scales, we do not think that dynamic land cover alone would have fully explained our water budget storage deficits, unless tile drainage was explicitly included.

Referee Comment: It would be useful to see a figure that shows historical land-cover change, precipitation change, and streamflow through time, if it is straightforward to show these together, as this would be very informative.

Author Response: While we appreciate this suggestion and have considered creating such a figure, the paper already contains ten figures, and we believe that incorporating the three suggested metrics into a single figure may become too cluttered for interpretation. We gladly welcome further suggestions from the referee as to how we might create such a figure, but our opinion is that the information is most effectively shown as three separate plots.

Referee Comment: Would it be possible to test the interpretation hypothesis (2) in the discussion, that precipitation intensity may be influencing runoff efficiency? This could be something for future work, but would be an interesting experiment.

Author Response: We agree that this would be a wonderful line of inquiry for future work, however this type of analysis should be written as a separate paper.

Referee Comment: Minor points I don’t think “Midwestern” is a technical term, rather the Northeaster Great Plains is probably more apt and the authors should consider revising the references and title accordingly.

Author Response: While Midwestern may not be a formal ecoregion or physiographic province, the term is commonly used in academic literature to describe the large part of the US that is covered in our analysis. We believe it more effectively conveys the location to our audience than would the term Northeaster Great Plains.

Referee Comment: How did the authors reach the number of 286 for the t-test and KS-tests? This needs to be clarified as it is presently unclear.

Author Response: Good catch. Thank you for the careful eye! We regret the error made on page 9, line 25, which should read “312 t-tests and 312 KS-tests...for a total of 652 statistical tests”. On page 9, lines 16-17, we state that we ran all statistical tests using three defined breakpoints for each basin: three breakpoints X four study basins X 13 (or 12 monthly values + 1 annual value) = 156 t-tests and 156 KS-tests for each precipitation (P) and streamflow (Q) record, which is how we arrived at 312 t-tests and 312-KS-tests. Finally, 312+312+28 = 652 statistical tests total. This point will be clarified in the revised manuscript.

Referee Comment: All figuresâËŸAËĞ Tit is unacceptable to include acronyms in the figure and then not define them in the caption. The figures should be readable as standalones. Hence, the authors need to define all acronyms in each figure in the respective captions.

Author Response: We would like to thank the referee for the suggested comment and will define acronyms in individual figure captions.

Referee Comment: Figure 5, explain briefly how the flow was normalized in the caption.

Author Response: We would like to thank the referee for the suggested comment and will define “Normalized Flow” in the figure caption.

References

Frans, C., Istanbulluoglu, E., Mishra, V., Munoz-Arriola, F. and Lettenmaier, D. P.: Are climatic or land cover changes the dominant cause of runoff trends in the Upper Mississippi River Basin?, Geophys. Res. Lett., 40(6), 1104–1110, doi:10.1002/grl.50262, 2013.

Hansen, M. C., DeFries, R. S., Townshend, J. R. and Sohlberg, R.: Global land cover classification at 1 km spatial resolution using a classification tree approach, Int. J. Remote Sens., 21(6-7), 1331–1364 [online] Available from: http://data.globalforestwatch.org/datasets/7876b225f8034a0ebba79fad4afb80ad, 2000.

Livneh, B., Rosenberg, E. A., Lin, C., Nijssen, B., Mishra, V., Andreadis, K. M., Maurer, E. P. and Lettenmaier, D. P.: A Long-Term Hydrologically Based Dataset of Land Surface Fluxes and States for the Conterminous United States: Update and Extensions, J. Clim., 26, 9384–9392, 2013.

Schottler, S. P., Ulrich, J., Belmont, P., Moore, R., Lauer, J. W., Engstrom, D. R. and Almendinger, J. E.: Twentieth century agricultural drainage creates more erosive rivers, Hydrol. Process., 28(4), 1951–1961, doi:10.1002/hyp.9738, 2014.

Wolf, R.A., and Market, P.S.: On the impact of corn and soybeans to the local moisture budget in Iowa, National Weather Digest, 31(1), 3-7, 2007.

Zeri, M., Hussain, M. Z., Anderson-Teixeira, K. J., Delucia, E. and Bernacchi, C. J.: Water use efficiency of perennial and annual bioenergy crops in central Illinois, J. Geophys. Res. Biogeosciences, 118(2), 581–589, doi:10.1002/jgrg.20052, 2013.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., doi:10.5194/hess-2017-133, 2017.