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Discussions

Interactive comment on "Urbanization dramatically altered the water balances of a paddy field dominated basin in Southern China" *by* L. Hao et al.

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Response to Anonymous Referee #3 Received and published: 20 March 2015

This study "Urbanization dramatically altered the water balances of a paddy field dominated basin in Southern China" discussed an important hydrological consequences of urbanization over the typical agricultural landscape of the southern China over which paddy field dominates. The conclusion that urbanization will increase the total streamflow and decrease ET is within our common sense, while this article provided more evidence and data to support this idea and highlighted the larger magnitude in the increase of runoff coefficient due to the urbanization over paddy fields than other vegetation cover. My major concern is the robustness of statistical analysis over this short time period (i.e. 2000-2013) over which natural fluctuations due to climate variations may overcast the human influences. Although the authors provided several different statistical methods to support their conclusions, I still have doubt on their conclusions because of some missing data and assumptions (see detail comments that followed).

Response: The authors appreciate the reviewer's careful review, insightful comments, and suggestions to make the study more robust and convincing. Therefore, we have added an attribution analysis to quantify the effects of climate variability and land use change on streamflow separately. The new findings were consistent with the previous conclusion that the main reason (85%) for the observed increase in streamflow was due to land cover change and 15% the increase was due to increase in precipitation. The rise of air temperature and thus evaporative potential (PET) masked somewhat the decrease in ET as a result of decrease in water use by vegetated surfaces dominated by rice paddies. The new analysis provided us more confidence to our early conclusions.

As suggested by the Reviewer that it seems to be a common sense that urbanization increases impervious surface areas, thus stormflow and total streamflow increase as well. However, to our knowledge, there are no studies in the literature that have comprehensively examined water balances in paddy field-dominated watersheds using relatively long term hydrometeorological data. Very few studies have devoted to paddy field watershed hydrology, but mostly using engineering hydrological models with a sole interest of stormflow or flooding events (e.g., Du et al., 2012). We believe that to have a full understanding the impacts of urbanization on watershed hydrology, a process-based study, starting from ET and associated controlling factors, is needed.

To make it publishable, this manuscript need major edits in the language. Figure 1: Capitalize "Overland flow" and put it in one line; Separate each item with ";" or line break in each text box; increase the width of lines. Make a brief description of this figure in the text.

Response: We have fixed the grammar problems and have a native English speaker to review the manuscript. We have added a description of the Figures.

Page 1945, Line 27: add "to" between "was" and "understand";

Response: done. Rephrase the title of Figure 2 as "The location and land use change of the Qinhuai River Basin during 1988-2012". Replace "The insert map..." with "The land use map was classified from Landsat ETM+ images of the year 2012". Response: done.

P1946, L23: The rate should be clarified. according to Fig. 3, the rate should be 0.26 Celsius degree / decade since 1961. The "1990s" represents a 10-yr period. Is it exactly what the authors want to report that the temperature increased 0.44 Celsius degree in this decade?

Response: we have rewritten the sentence as: “Mean air temperature (1961-2013) across the study basin has increased drastically at rate of 0.44 oC/decade from 1990 to 2013 (Figure 3), suggesting an increasing trend in evaporative potential during the past two decades.

Figure 4: replace "P" with "PPT"; spell out the "SD".

Response: done. we used P throughout the paper in the revision. Figure 5: Rephrase the title, such as "Changes in MODIS ET and LAI during the peak growing season (July - August) during 2000-2013. What’s the unit of ET?

Response: The unit of ET is mm/ two months.

P1946, L25: Add "per unit basin area" after "streamflow". P1948, L10: Delete "are". P1950, L5-6: It’s better to replace these two "change" with "linear trend". Response: Good suggestion. Done.

Figure 6: Need to explain why using different time scales on LAI (annual mean?) and

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PET (in the peak growing season) when calculating their correlations with departure of ET (annual).

Response: In Fig 6, all variables for the peak growing season were used. We have clarified this the Figure title.

Figure 7 & P1950,L13-15 & L24-27: This figure and analysis are misleading since the data for the first time period is not complete, i.e. missing 2004 & 2005.

From the diagram of runoff coefficient during May-October in each year, I am arguing that there might be no significant change during 2006-2011 and the big increase in the last two years may due to climate variations. I am concerning the robustness of statistical method for this short time period.

Response: Unfortunately, we do not have daily streamflow data for the period 2004-2005. Thus, our analysis was limited to show the flow duration change for selected periods.

The reviewer had a good point on the uncertainty of our statement on the streamflow increase during the 'flood season' as a result of short data series. However, at the annual scale, we have demonstrated that the streamflow rise was a result of land use change not climatic variation. Since most of the annual streamflow was from the 'flood season', so we argue that it is likely that the change in runoff coefficients reflect the hydrological regime change in the study basin.

P1951,L10-12: As authors mentioned in P1950,L22-24 that groundwater levels were on the rise in recent decade, estimating ET with "PPT - Q" might be questionable; while it may also indicates that ET might decrease in a higher rate than the current estimations.

Response: Good point that supports our hypothesis. We have added this argument – an increase in the water storage term may suggest the ET estimated by the P-Q method might represent lower end of ET reduction, i.e. the true ET could even lower.

P1951,L15-17: Fig. 10 shows the trends of annual streamflow during the period of 1986 - 2013, but here the authors are talking about the trends over the period of 2000 - 2013. Do these two time periods have the same trends in the magnitude?

Response: We added the time period for Figure 12 (1986-2013). Using different data, we tried to show streamflow at multiple temporal scales (annual flow and summer flooding wet season) all increased. Yes, all the data show the same direction of change.

P1951,L22-24: The strong correlation between MODIS ET and LAI is most likely from the equations on which MOD16 product based (Mu et al., 2007). I question the usage of this information to support author's point at here. But without doubt, the authors can make this claim that MODIS ET also have the same result as detected with other methods (in this article).

Response: In this study we did not use LAI data from Mu et al. (2007). Instead, we used a LAI products released by Beijing Normal University (Yuan et al., 2011). This product represents an improved data over the previous data used in Mu et al., (2007). So the MODIS ET data stream was somewhat independent from LAI data.

As the reviewer suggested, the trend of MODIS ET was similar to tread of ET estimated by the P-Q method, so we have confidence that the ET reduction was negatively related to trend of LAI.

P1952,L1-2: Here the authors claim that "regional annual ET is generally controled by PET, P, and ..." which is inconsistent with their previous claim (P1951,L20), i.e. "LAI is a major controlling factor for ET". Do these control factors' role change in various spatial and temporal scales? The authors should clarify in the text. P1952,L2-3: I believe there is a typo. Should replace "an increase in P and PET" with "a decrease in P and PET".

Response: The Reviewer is correct. There was a typo that caused the confusion. The sentence has been corrected as “A decrease in ET is normally caused by a decrease in P and/or PET (Sun et al.., 2005; Sun et al., 2011a, 2011b).

LAI is a major factor at the shorter time scale (i.e., monthly) than longterm such as annual ET since LAI does not change from year to year in general for most land covers (unless extreme drought or disturbances). We have clarified this point to stress the temporal scale effects ET controlling factors.

P1954,L22-23: The claim of "The changes in water balances were mainly through the reduction in growing season ET and not by increasing impervious surfaces alone" is confusing. One conclusion from this study should be that the decrease of ET is mainly caused by the shrinkage of rice paddy fields and expansion of impervious surface area. Are there other reasons that could decrease ET? Are the authors mentioning decreasing LAI (is it not dominantly from urbanization)?

Response: We have rewritten the sentence as "A significant increase in streamflow and a decrease in ET in the study basin were detected, and the changes were considered to be associated with urbanization characterized as shrinkage of rice paddy fields and an increase in impervious surface area. Urbanization that resulted in a reduction in LAI during the peak growing season overwhelmed the hydrological effects of climate warming and precipitation variability during the study period."

P1952,L6-7 & P 1950,L24-25: Why does this shift in runoff coefficient happen around 2003?

Response: We believe that the main reason was urbanization – converting paddy fields to urban uses. We provided new remote sensing (Landsat 7 TM+ data) to show paddy field change land use change (Figure 2 insert). The urban built-up areas increased from 9% (222km2) to 12% (301 km2) from 2000 to 2004, but jumped to 23% (612 km2) in 2012, and the area of rice paddy fields decreased from 45% (1188 km2) of the total land area in 2000 to 43% (1112 km2), and jump to 36% (932 km2) in 2012. Prier to 2000, we used published data by Du et al. (2012) and Du and Chen (2014).

References: Mu, Q., F.A. Heinsch, M. Zhao, and S. W. Running, (2007), Development of a global evapotranspiration algorithm based on MODIS and global meteorology data, Remote Sensing of Environment, 111, 519-536, doi: 10.1016/j.rse.2007.04.015

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