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Hydrology and Earth System Sciences
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 #2

Received and published: 8 March 2015 General:

This study discussed the impact of urbanization on water balance in the Qinhuai River basin, a region undergoing rapid development. I believe it is an interesting topic. However, I do not feel the results presented in the paper could well support the main hypothesis, i.e. decreases in ET resulted from urbanization contribute greatly to the reduction in streamflow. In the manuscript, the data were presented in an inconsistent way, and

trends were compared for various different periods. There are also many general hypotheses in the discussions that have not been tested. I recommend at least major revision.

Response: The reviewer had concerns about our conclusion that the observed increased in streamflow was mainly caused by the decrease in ET. To address the reviewer's concerns we have made two major efforts in this revision: 1) conducted an attribution study using two models (Climate Elasticity, and Rainfall-Runoff models) and consistent results achieved – over 85% of the increase in flow was caused by land cover/land use change and 15% by the increase in Precip. Since the land cover change was characterized as converting to urban uses that directly resulted in a decrease in ET due to a decrease in leaf area index. The decrease in ET was detected both by MODIS ET data and water balance method (Precip-Streamflow), two independent data source giving more confidence that the decrease in ET was the main cause of increase in streamflow. In addition, we argue it is plausible that rise of baseflow was caused by the decrease in ET in the study basin. The increase in impervious surface was not likely the main cause of the observed increase in streamflow. It is well known the impervious area mainly elevates stormflow. We found that all flow percentiles increased during recent years 2) In the revision, we focused our analysis on annual streamflow for two periods, 1986-2002 (reference period), and the period 2003-2012 (rapid urbanization period as confirmed from remote sensing data. We updated Fig 2). Since MODIS data are available only for the period 2000-2012, we limited our analysis on examining trend of LAI, ET, and PET for this period. We intended to use all pieces of information to solve the puzzle and test our hypothesis.

See Section 2.4 and Section 3.5.

Specific comments: 1. The land cover data statistics, which was arranged from different data sources, is somehow inconsistent, and this uncertainty should be addressed in the manuscript. For example, Fig. 2 (Section 2.1) shows 17% increases (of the total basin area) in the impervious surface areas from 2003 to 2012, while the areas of rice

paddy only accounts for about half of the changes (∼8% of the total basin area from 2001 to 2012). However, both the statistics in Table 2 and conclusions indicated the increase in impervious areas was mainly due to conversion of the rice paddy fields in the 2000s. Please clarify this. Also, why not give the statistics for the same period in the text for better comparison?

Response: The impervious surface area (1988-1994) data were from Du et al. (2012) and Du and Chen (2014). In the revision, we have reanalyzed the Lansat 7 TM + imagines for 2000-2012 to derive urban bult up areas, and made sure the land use data are consistent. We have updated Table 2 to reflect our new analysis.

2. This study used multiple data sources (including land cover data, surface meteorology, streamflow, Remote sensing data etc), which were presented at various periods. This makes the paper hard to follow. Moreover, trends from different periods are generally incomparable (especially for a short period). Yet, this study compared the trends of different variables (including P, ET, runoff, LAI etc) at different periods, and used these results to support the main hypothesis, which renders this questionable (see comments #3). E.g. MODIS LAI and ET data were analyzed for the period from 2000 to 2013; river flow data were analyzed from 1986-2013 (Fig. 10) and various sub-periods from 2000 to 2013 (Fig. 7, 8 & 9).

Response: Streamflow data were acquired from hydrologic monitoring stations. Unfortunately, the data did not come with the same temporal resolution. Consequently, we could not analyze the hydrological variable for the same period, the longest one from 1986-2013 that was used to examine annual hydrological change. However, for baseflow and flow duration curve analysis we could only examine a shorter period, 2006-2013, and 2002-2013, respectively. We have updated the Double Mass analysis for up to the period from 1986-2013.

3. The major hypothesis of this study is that ET reduction caused by land cover change is a big contributor to the increase in stream flow from 1980s to present. However, there

is no independent ET data to test this hypothesis. The study used water balance (i.e. P-Q, Fig. 10) to estimate annual ET from 1986 to 2013, which may subject to great uncertainties due to likely substantial changes in the water storage. For example, the MODIS ET data (Fig. 5) somehow shows inconsistent inter-annual variability as the ET time series estimated using P-Q (Fig. 10).

Response: As in any method to estimate ET, there was uncertainty of the P-Q method, such storage change in ponds, soils, and groundwater. However, we argue that over the long term (25 years in this study) the trend of P-Q reflects the true trend of ET. We found a similar decreasing trend for MODIS ET, providing more confidence that P-Q is a reliable approach to detect the change in ET and provides a plausible explanation of the increase in streamflow. Attribution study using two empirical models further confirmed that precipitation was not the major contributor to the increase in streamflow (15%), but rather 85% of the increase in streamflow was due to landcover/landuse change indicating the ET was a major driver for the increase in streamflow.

4. What factors control the ET variability in Qinhuai River basin? This may need further clarification. - MODIS ET algorithm uses MODIS LAI data as an input (Mu et al. 2011), and therefore these two datasets are not totally independent. - Section 4.1, Line 2-3:

Response: The reviewer's concern could be valid. However, we used a different LAI dataset from Mu et al. (2011). The LAI data set was derived by Beijing Normal University (Yuan et al., 2011) using a modified temporal spatial filter (mTSF). So we argue that the positive correlations between MODIS ET and LAI were not an artifact. Again, the P-Q also showed a decreasing trend consistent with the decrease in basin wide mean LAI.

"A decrease in ET is normally caused by an increase in P and PET": this needs further consideration.

Response: This was a typo. It should be stated as 'A decrease in ET is normally caused by an decrease in P and PET"...

The relationship between ET and PET/P may vary in different climate zones. The MOD16 product also produces PET; this product may be more suitable for diagnosing the relationship between ET and PET, since both variables are likely affected by the uncertainty in surface meteorology inputs. Response: We argue that the FAO PET values based on local weather stations provide stronger evidence that the PET and ET had different trends since PET data were derived from independent variables used in calculating MODIS ET.

5. How much do the changes in precipitation frequency and distribution contribute to the changes in streamflow characteristics? Should this be included in the discussions related to Figs 7-10 as well?

Response: The Reviewer had an excellent point and suggestion. Therefore, we added an attribution study using two empirical models to examine precipitation effects on the streamflow. We found that precipitation contributed about 15% of the increase in streamflow during the rapid urbanization period (2003-2013) and the rest of the change in streamflow could be attributed to land cover/landuse change.

Minor comments: (technique corrections) 1. Section 3.2 Line 21-22: why add this sentence? This has nothing to do with the trend analysis presented here (i.e. from 2000 to 2013).

Response: The sentence was removed.

2. Please switch Tables 1 and 2. Response: Done. âĂČ

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 1941, 2015.