

## ***Interactive comment on “Regional effects of vegetation restoration on water yield across the Loess Plateau, China” by X. M. Feng et al.***

**X. M. Feng et al.**

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Comments from reviewer #2:

General Comment:

The authors present a paper on the effect of vegetation restoration in the framework of the Grain for Green (GFG) project in the time period 1999-2007 using a statistical model to calculate evapotranspiration and water yield. The model is developed, calibrated and evaluated for the entire Chinese Loess Plateau. They compare their model estimated to MODIS satellite and watershed ET determined from gauge stations. Using the model validated in 10 catchments with a total of 67 years of data the authors

C2894

are confident enough to apply the model to estimate the hydrological effect of the GFG induced land cover change. The general trend is a decrease in water yield across the Plateau. I think the subject of the paper is of great interest for the readership of HESS and I support a publication, however there some minor issues, which require clarification.

Response: We appreciate the reviewer's concerns on this paper. We have clarified all the issues according to the reviewer's suggestions.

Specific Comments 1:

The way the authors try to disentangle the effect of climate change from the effect of land cover change by running the model with the climate of the year 1999 (p12 | 1-10). I think the authors need to be quite careful here. My first question would be how representative is the year 1999 in terms of the general climate and the years 2000-2007. It might be 1999 is rather dry or wet and/or temperature is different from the long term mean. In this case the study would only identify the effect of the diversion from normality the year 1999 would present. I would suggest discussing this in detail. This holds also true for the spatial and temporal distribution of temperature and most importantly precipitation, as the latter one seems to be the key driver (p14, | 14).

Response: We have clarified the insignificant climate change in the method section (section 2.4). "Related work showed that plant growth (indicated by NDVI) of the Loess Plateau has been increasing despite insignificant climate change during 1999-2007, and the implementation of GFG project was the driving factor (Xin et al., 2008; Zhang et al., 2011)."

Specific Comments 2:

The representativeness issue is also true for the catchment used to calibrate and validate the model. The dataset is split into subsets of 36 for calibration and 10 others for validation. It would be good if the authors could present could justify the choice of the

C2895

particular catchments.

Response: We have revised the description in section 3.1. "Water-Balance-ET dataset was split into subsets for calibration and validation (Table 1). Watersheds in both subsets were randomly distributed to cover different precipitation regimes. More watersheds were used for model calibration to ensure the statistical regression analysis."

Specific Comments 3:

I am also a bit puzzled about the role of the Eddy data. Judging from the abstract and the paper they seemed to be the basis for the model development. But there are no tables or graphs to show how the data compared with the model. It looks like they were not used to validate as the model was only compared to watershed ET and MODIS. Some clarification would be useful.

Response: Eddy flux database contains 134 records (i.e. 134 site-months). Detailed descriptions of the data can be found in Sun et al. (2001), which was briefly described in the paper. These data was used to determine terms that can significantly explain monthly ET variability ( $p < 0.0001$ ), by which to form a primary linear relationship between monthly ET and the terms. Local watershed derived ET data and MODIS ET were used to compare with modeled ET during calibration and validation at watershed and regional scales. We have rewritten method section (section 2.2) to make it clearer.

"When pooling all data of 134 point-scale measurements from the ten ET flux sites, we found that 61%, 3.5% and 17% of monthly ET variability was explained by the terms  $PET \cdot PPT$ ,  $PPT \cdot LAI$  and  $PET \cdot LAI$ , respectively. All variables in the above equation were highly significant ( $p < 0.0001$ ). The monthly ET for semi-arid and arid region thus has the following form:  $ET = k_1 + k_2 \cdot PET \cdot PPT + k_3 \cdot PPT \cdot LAI + k_4 \cdot PET \cdot LAI$  (8) This model shows that precipitation and PET are two major drivers for ET in the study regions. To further constrain the values of the parameters  $k_1$ ,  $k_2$ ,  $k_3$  and  $k_4$  for the Loess Plateau region, we need the local data to calibrate the model. The calibration was conducted through parameter research to acquire the best fit between local measured

C2896

and estimated ET values with the SAS 9.2 software. The performance of the model was evaluated qualitatively using scatter plots and difference maps, Coefficients of Determination ( $R^2$ ), and the slopes of the linear regression models."

Specific Comments 4:

For the comparison with the MODIS ET it would be important to discuss the climatic data used for MODIS in more detail. At page 12 115-20 the authors say MODIS ET is only 75% of precipitation. The question is which precipitation, the one from the interpolated stations used for their model or the one associated to the climate data (reanalysis) used for MODIS AET.

Response: The explanation of MODIS ET product can be found in the second paragraph of section 2.3 of the revised paper. "MODIS-ET was developed using the Penman-Monteith logic and MODIS imagery, and global meteorological data. The MODIS-ET algorithm employs reanalyzed surface meteorological data (0.05° resolution) from the NASA Global Modeling and Assimilation Office with MODIS land cover, albedo, LAI and the Fraction of Absorbed Photosynthetically Active Radiation (FPAR) inputs for regional and global ET mapping and monitoring with 1 km resolution." We have also made some correction in section 3.1. "While MODIS ET was much lower, less than 75% of precipitation from local interpolated stations in the wet and average precipitation years, and 85% in the dry years."

Specific Comments 5:

I also certainly miss a uncertainty estimation for the parameter of the regression model and the resulting uncertainty in the results. Right now it is not clear to me if any of the results are significant. There are no error/uncertainty bars at any of the graphs.

Response: We appreciate the reviewer's constructive comments. Uncertainty of estimation for the parameter of the regression model can be found in section 2.2. "When pooling all data of 134 point-scale measurements from the ten ET flux sites, we

C2897

found that 61%, 3.5% and 17% of monthly ET variability was explained by the terms PET\*PPT, PPT\*LAI and PET\*LAI, respectively. All variables in the above equation were highly significant ( $p < 0.0001$ ).” We have added the statistically significant analysis on water yield change and created the map showing the difference in water yield trend between scheme 1 and scheme 2. We have added descriptions of testing the significance of the difference in water yield trend between scheme 1 and scheme 2 in the method section (section 2.4). We have also revised the result section (section 3.2) and figure 5, 6.

Descriptions on the method (section 2.4): “We used the MATLAB Program to detect the trend of modeled annual water yield for each pixel by conducting linear regressions relating water resource with time (year). Regression coefficient was used to predict rate of annual water yield variations before and after GFG project. A positive or negative value predicts an increase or decrease rate of annual water yield. If the regression coefficient passes through the significance test ( $P < 0.01$  or  $P < 0.05$ ), it shows an “extremely significant” or “significant” ascending or descending trend. Paired sample T-test (two-tailed) was carried out with Matlab for each pixel to detect significant differences of annual the water yield from 1999-2007 between scheme 1 and scheme 2. The level of significance was taken as  $p < 0.05$ .”

Revision on the results (section 3.2): “3.2 Spatial Variability of Annual Water Yield 3.2.1 Effects of Land Cover Change Only The results of trend analysis suggested that vegetation restoration only during the study period caused annual water yield to decrease as much as 1.6 mm per year on average across the Loess Plateau (Fig. 5a). Divided the trend in water yield over the period 1999-2007 by the baseline conditions in 1999, change in water yield can also be expressed in a relative term (Fig. 5b). About 26% of the study region located in the southeast portion (i. e., southern Shaanxi and Shanxi Provinces) had a significant decrease trend ( $P < 0.05$ , T-test) in water yield with a range of 1–48 mm per year, among which a small portion (6%) experienced a decrease trend greater than 10 mm per year. About 19% of the study region located in the north portion

C2898

(i.e., northern Shaanxi and Inner Mongolia Province ) experienced less but also significant decrease ( $P < 0.05$ , T-test) (Fig. 5a, Fig 5c, Fig. 6a). Because of the low baseline in these dry areas, the decrease less than 1 mm per year caused a relative value greater than 100% in water yield (Fig. 5b, Fig. 6b). 3.2.2 Effects of Land Cover Change + Climate Variability The combined water yield responses to land cover change and climate variability during 1999-2007 decreased by 1.0 mm per year on the Loess Plateau as a whole. The significant difference in water yield trend between the combined scenario and land cover only occurred in northern Shaanxi, Shanxi and Inner Mongolia Province (Fig. 5g). Because of the climate effect, the previous significant decrease in water yield in these areas became to an insignificant increase with a range of 1-10 mm per year (Fig. 5d). As expected, small changes in water yield amount resulted in a large relative change in the dry portion (northern Shaanxi, northwestern Shanxi and Inner Mongolia Province) due to their low background (Fig. 5e, Fig. 6c). Because of the climate effect, about 37% of the study area saw a decrease in water yield within a range of 1–54 mm per year. Only 4% of the study region (southern Shaanxi Province and southwestern Shanxi Province) has undergone a significant decrease ( $P < 0.05$ , T-test) in water yield of more than 5 mm per year (Fig. 5f, Fig. 6a).”

Specific Comments 6:

Page 14/116-17 it is unclear if it should read increase rather than decrease as stated.

Response: We have corrected the words. “We argue that the young forests or shrubs established by the project in the initial stage of early 2000s might not have caused increase in ET and thus decrease in water yield.”

Specific Comments 7:

Page 16 13 is seems the SWAT model was used in the study area. This is in contrast to the statement in the introduction, that there are no models applicable for the area. I would appreciate some word why they did not use SWAT.

C2899

Response: We have added some words in the introduction part regarding SWAT model.

“To our knowledge, no attempts have been made to quantify the land cover change and climate variability on regional water yield for the Loess Plateau as a whole, largely due to lacking of reliable and practical hydrological models. The commonly-used process based hydrological model such as SWAT (Li et al., 2009) was not feasible because hydrological responses to vegetation restoration vary across the Loess Plateau, a region that has a strong north-south gradient in precipitation and terrain.

Specific Comments 8:

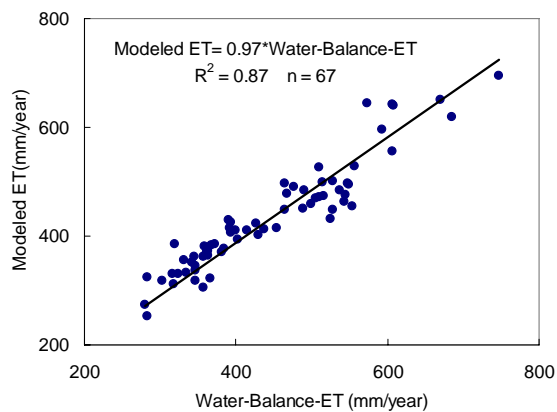
I would also recommend to look into Falloon and Betts (2009) and Wattenbach et al. (2007)

Response: We have read the papers and cited them in the manuscript.

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 9, 4161, 2012.

C2900



**Fig. 1.** Revised figure 3

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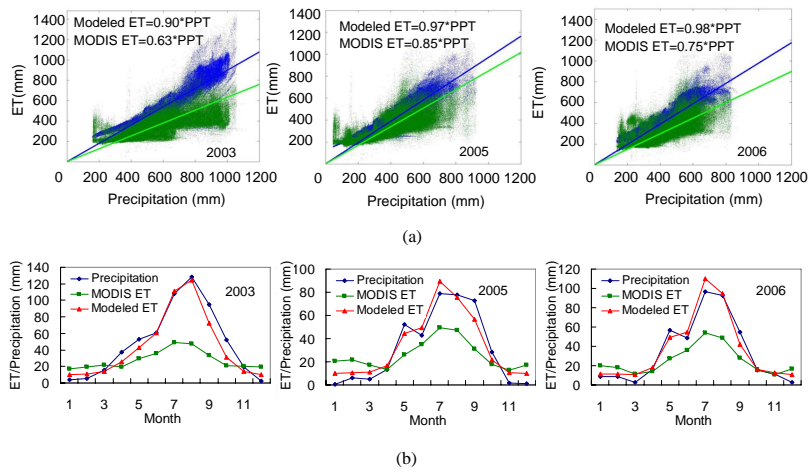


Fig. 2. Revised figure 4

C2902

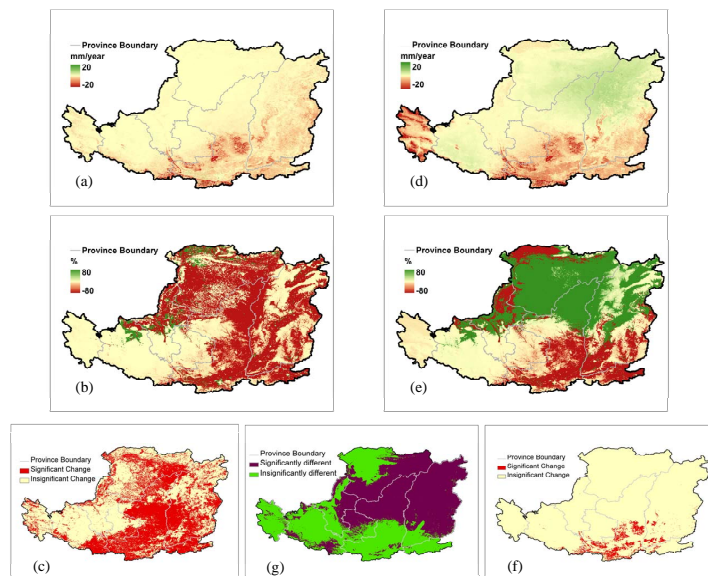


Fig. 3. Revised figure 5

C2903

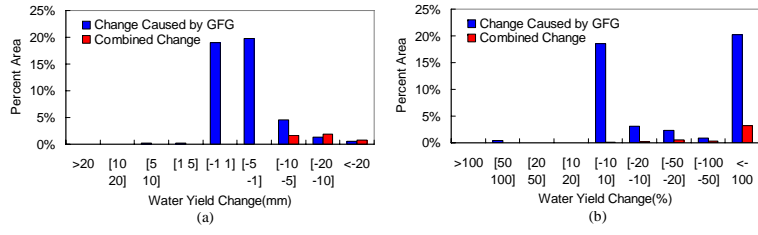


Fig. 4. Revised figure 6

C2904