Reply to Referee comment 2

Dear Editors and Reviewers:

We would like to thank the editor and all reviewers for their valuable suggestions and comments on the manuscript. These comments have not only improved the quality of the current manuscript, but also are beneficial to our future research in general. All point-by-point responses are presented as follows and we will carefully revise the manuscript based on these comments. For clarity, all comments are given in the original version, while responses are marked in blue.

Anonymous Referee #2

The manuscript by Li et al "Impacts of land use/cover change and reforestation on summer rainfall for the Yangtze River Basin" used the WRF model to investigate how land cover changes and reforestation affect summer rainfall. The research topic is important given the massive ecological projects in China and its climate impact is worth studying. The manuscript is generally well-written, but I also have major comments for the authors.

Thanks for the positive evaluations and comments, all comments and suggestions have been addressed and will be incorporated into the revised manuscript.

1. For WRF model simulation, how land cover changes were implemented in the model needs more detailed explanations as different land surface models have different representations of land cover. It is still unclear what surface conditions/variables had been modified for the Noah-MP model to correctly reflect the intended land cover changes. I also have questions about the rationality of the randomly chosen crops for the two restoration scenarios.

The land use changes were included in the WRF model by modifying the geographical static data used in the model which further changed the simulation of subprocesses such as the vegetation phenology, canopy stomatal resistance, runoff and groundwater in the land surface model Noah-MP (Li et al. 2018). Many parameters were used in Noah-MP to describe the characteristics of different land use types, such as albedo, HVT (Top of canopy), LAI (Monthly leaf area index), and VCMX25 (Maximum rate of carboxylation at 25 °C). When the land use changed, these parameters changed accordingly which finally led to the changes in substance and energy exchanges between atmosphere and land surface. The geographical static data we used in the WPS is *landuse_30s_with_lakes* which was download from the WRF website. The land use data of 1990 and 2010 scenarios were derived from the Landsat thematic mapper (TM) digital images. And then, in the YRB, we replaced the land use data from the *landuse_30s_with_lakes* with the land use data from the Landsat thematic mapper (TM) digital images.

Finally, we randomly changed 20% and 50% of the croplands to be forests using the 2010 scenario as a baseline to produce 20% and 50% reforestation scenarios. Both land cover data (downloaded from the WRF website and derived from the digital images) have a resolution of 1km. As the resolutions of outer and inner WRF domain were set as 75km and 15km, respectively, the post-processed land cover data was resampled from 1km to 75km and 15km by the WPS (the WRF Preprocessing System). The percentages of land cover under four scenarios after resampled to 15km are presented in Table A1 below. The dominant land use categories in model grids were used for the Noah-MP model to correctly reflect the intended land cover changes. We admit that the randomly chosen crops for the two restoration scenarios is a limitation in our study, as we have explained in the discussion section, the restoration processes usually happen in specific areas that are related to local policy. However, it is a challenge to gather all related policies from multiple local governments over such a big basin. It can be also noticed that the crops are mainly located in specific areas such as Sichuan Basin and the middle- and down-stream of the YRB. Although we chose the crop grids randomly, the restoration grids concentrated in these specific areas which was similar with the real processes.

Table A1. The percentages of land use and cover under four scenarios after resampling.

Scenarios	Cropland	Forest	Grassland	Water and wetland	Urban	Unused land
1990 scenario	28.67	44.37	24.63	0.58	0.06	1.69
2010 scenario	28.12	45.02	24.60	0.69	0.45	1.12
20% scenario	22.97	51.55	24.83	0.69	0.54	1.12
50% scenario	14.76	58.49	25.32	0.69	0.58	1.12

Reference:

Li, J., Chen, F., Zhang, G., Barlage, M., Gan, Y., Xin, Y., and Wang, C.: Impacts of Land Cover and Soil Texture Uncertainty on Land Model Simulations Over the Central Tibetan Plateau, Journal of Advances in Modeling Earth Systems, 10, 2121-2146, https://doi.org/10.1029/2018ms001377, 2018.

2. When comparing simulation results between different experiments, the authors need to conduct statistical significance tests to determine whether the signal is robust while excluding any noise and random changes which may lead to misinterpretation.

We agree with this comment. We have conducted statistical significance tests to determine whether the signal is robust when comparing simulation results between different experiments. We display the revised Fig.5 and Fig. 6 as follows; other results of significance test will be incorporated into the revised manuscript.

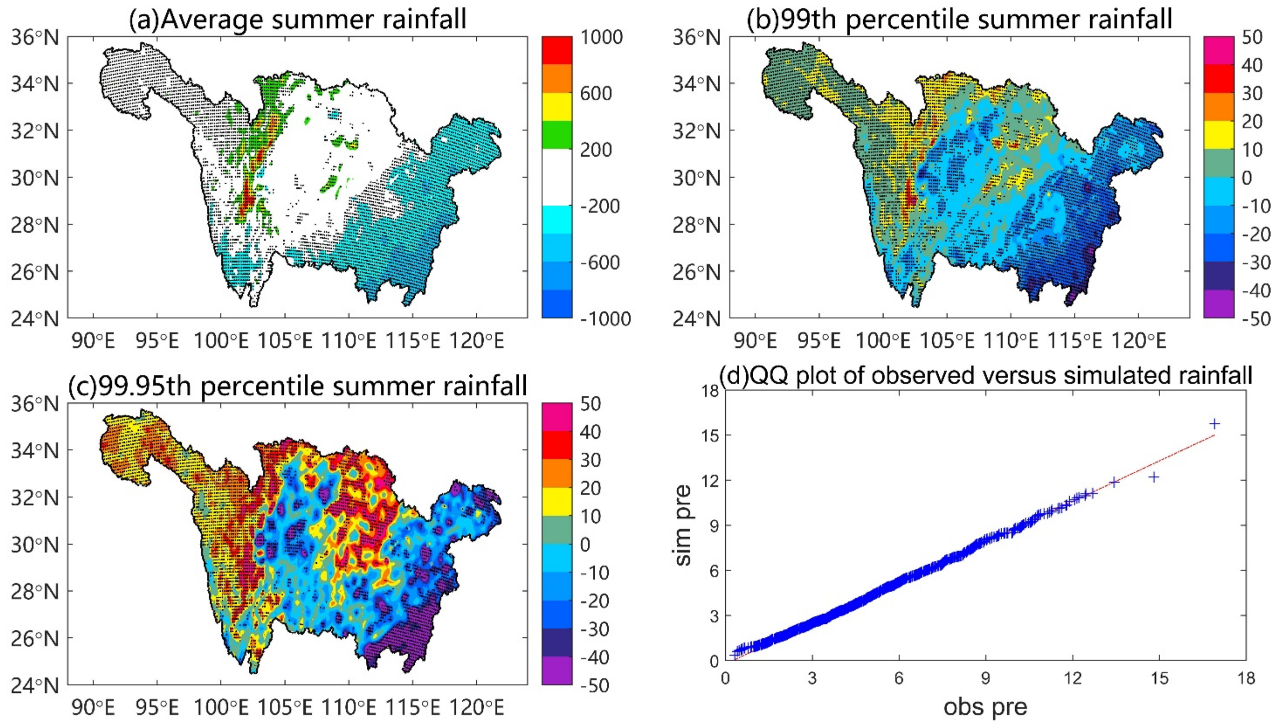

Figure 5. The bias of (a) average summer rainfall (mm), (b) 99th percentile summer rainfall (mm/day) and (c) 50th percentile summer rainfall (mm/day) between the observed data and 2010 scenario, and (d) the qq-plot of observed rainfall versus simulated rainfall. The stippling regions show statistically significance of bias identified by t-test at a 5% significance level.

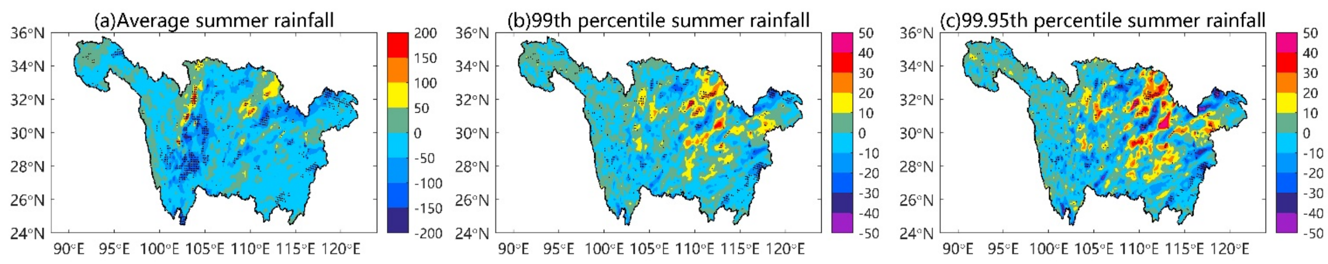

Figure 6. The changes in (a) average summer rainfall (mm), (b) 99th percentile summer rainfall (mm/day) and (c) 50th percentile summer rainfall (mm/day) between the 1990 scenario and 2010 scenario. The stippling regions show statistically significance of changes identified by t-test at a 5% significance level.

3. I hope the authors could provide more mechanistic explanations of the results. For example, why did the 20% reforestation result in more precipitation changes than the 50% reforestation scenario?

Thanks for the comment. We will provide more mechanistic explanations of the results in the revised manuscript. As for the 20% reforestation resulted in more precipitation changes than the 50% reforestation scenario, after analysing the changes in the water vapor mixing ratio at 2m and upward moisture flux at the surface (Fig. A2 and A3), we found that the number of grids showing increased upward moisture flux in the 50% scenario slightly exceeded that in the 20% scenario. In contrast, the 2m water vapor mixing ratio increased over almost all basin in the 20% scenario while showed large decreases in the midstream of the basin in the 50% scenarios. From the surface level to the 2m level, the moisture kept increased in the 20% scenarios while decreased in the 50% scenarios. This suggested that the distribution of moisture may be changed by the horizontal transportation process. Moreover, Yu et al. (2020) found that the vegetation greening reduced rainfall in some region in the southern China which may be caused by the East Asian monsoon. As the East Asian monsoon significantly influenced the summer precipitation patterns in China (Ding et al., 2007). All these information and explanations will be incorporated into the revised manuscript.

Ding, Y., Ren, G., Zhao, Z., Xu, Y., Luo, Y., Li, Q., and Zhang, J.: Detection, causes and projection of climate change over China: An overview of recent progress, Advances in Atmospheric Sciences, 24, 954-971, https://doi.org/10.1007/s00376-007-0954-4, 2007.

Yu, L., Liu, Y., Liu, T., and Yan, F.: Impact of recent vegetation greening on temperature and precipitation over China, Agricultural and Forest Meteorology, 295, https://doi.org/10.1016/j.agrformet.2020.108197, 2020.

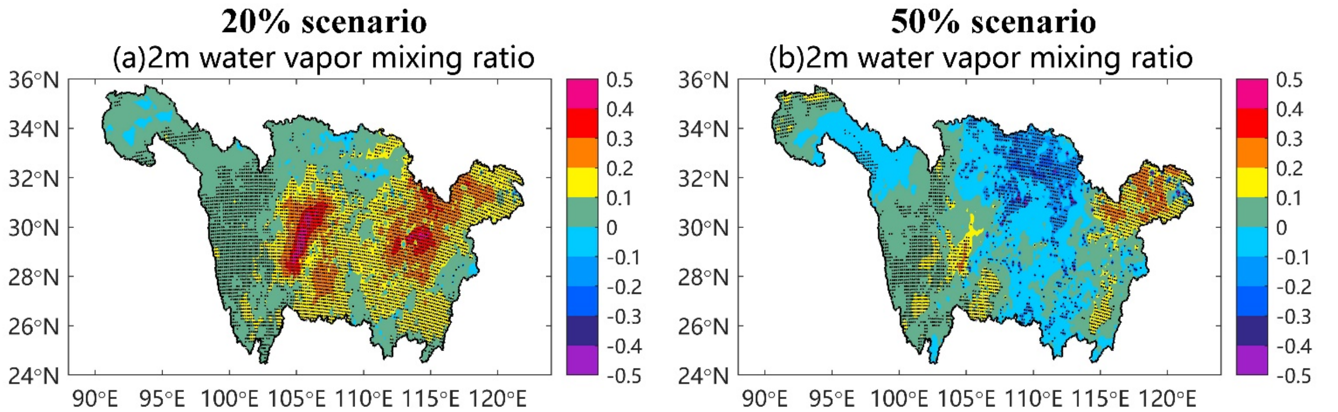

Figure A2. The changes in (a-b) 2m water vapor mixing ratio (g/kg) between the 20% scenario and 2010 scenario, and between the 50% scenario and 2010 scenario. The stippling regions show statistically significance of changes identified by t-test at a 5% significance level.

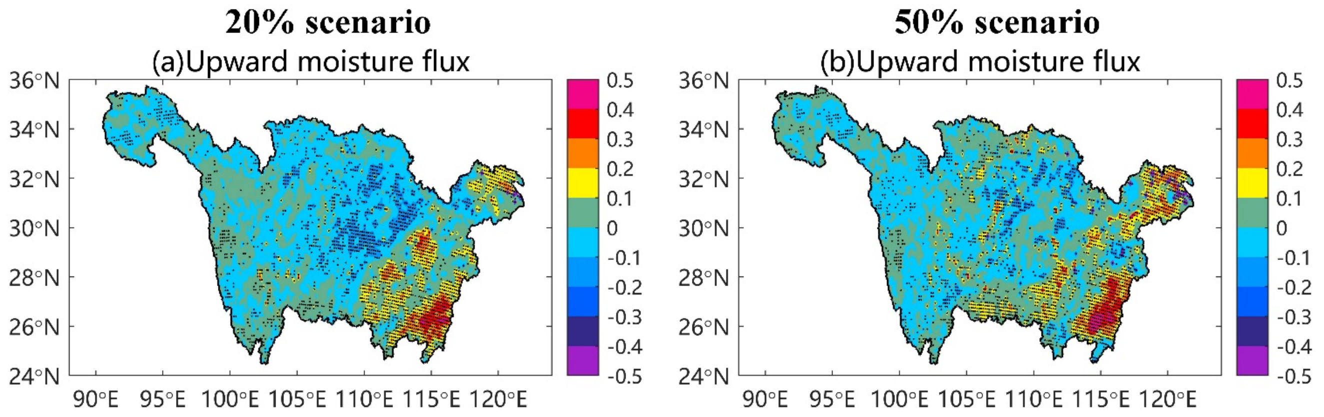

Figure A3. The changes in (a-b) upward moisture flux at the surface (kg/m^2) between the 20% scenario and 2010 scenario, and between the 50% scenario and 2010 scenario. The stippling regions show statistically significance of changes identified by t-test at a 5% significance level.

Specific comments:

L9: There is another terminology “Grain for Green” frequently used in the literature for “Returning Farmland to Forest Program”. Which one is better acknowledged?

Thanks for the comment. Both the terminologies are correct, and the “Grain for Green” may be more widely used. We will change all the “Returning Farmland to Forest Program” to “Grain for Green” in the revised manuscript.

L130-140: What kinds of WRF experiments have been conducted to compare different schemes/parameterizations, what domain and simulation length was used for the comparison experiments?

According to previous studies in China (e.g., Hu et al., 2015; Zhang et al., 2019; Feng et al., 2012; Xue et al., 2017), we chose three microphysical schemes (i.e., Purdue Lin Scheme (Lin), WRF Single-moment 5-class Scheme (WSM5), and Eta Scheme (Ferrier)) and two cumulus parameterization (i.e., Kain-Fritsch Scheme (KFN) and Grell–Devenyi Ensemble Scheme (GD)) for tests. Five parameterization scheme combinations (i.e., Lin-KFN, WSM5-KFN, Ferrier-KFN, Lin-GD and WSM5-GD) were used to simulate the rainfall and temperature for the Yangtze River basin during 2005 summer, as there were several rainstorm events in 2005 summer for this basin. The most suitable parameterization schemes were chosen by comparing the performance of these five combinations. The domain setting was same as the whole experiment which can be seen in Fig. 2. The simulation length was 3 months from June to August. We will add these information and explanations in the method and results of the revised manuscript.

References:

Feng, J.-M., Wang, Y.-L., Ma, Z.-G., and Liu, Y.-H.: Simulating the Regional Impacts of Urbanization and Anthropogenic Heat Release on Climate across China, Journal of Climate, 25, 7187-7203, https://doi.org/10.1175/JCLI-D-11-00333.1, 2012.

Hu, Y., Zhang, X.-Z., Mao, R., Gong, D.-Y., Liu, H.-b., and Yang, J.: Modeled responses of summer climate to realistic land use/cover changes from the 1980s to the 2000s over eastern China, Journal of Geophysical Research: Atmospheres, 120, 167-179, https://doi.org/10.1002/2014jd022288, 2015.

Xue, H., Jin, Q., Yi, B., Mullendore, G. L., Zheng, X., and Jin, H.: Modulation of Soil Initial State on WRF Model Performance Over China, Journal of Geophysical Research: Atmospheres, 122, 11,278-211,300, https://doi.org/10.1002/2017JD027023, 2017.

Zhang, H., Wu, C., Chen, W., and Huang, G.: Effect of urban expansion on summer rainfall in the Pearl River Delta, South China, Journal of Hydrology, 568, 747-757, https://doi.org/10.1016/j.jhydrol.2018.11.036, 2019b.

L145-149: It is better to also report the quantities of land cover changes between 1990 and 2010.

Thanks for the comment. We have added a table with the quantities of land cover under four scenarios. The quantities of land cover changes between 1990 and 2010 can be easily found from this table.

Table 1. The percentages of land use and cover under four scenarios.

Scenarios	Cropland	Forest	Grassland	Water and wetland	Urban	Unused land
1990 scenario	29.15	42.82	23.50	1.65	0.19	2.69
2010 scenario	28.48	43.60	23.13	1.79	0.86	2.14
20% scenario	22.80	49.28	23.13	1.79	0.86	2.14
50% scenario	14.58	57.50	23.13	1.79	0.86	2.14

L148: How did the random changes from cropland to forest being incorporated in the model surface land condition at 15 km resolution? I am not sure whether this choice is necessary. What land variables had been modified to represent the land cover change in WRF model and what are their changes? What types of forest were used in the reforestation experiment? How many grid boxes experienced land cover change?

The land use changes were included in the WRF model by modifying the geographical static data used in the model which further changed the simulation of subprocesses such as the vegetation phenology, canopy stomatal resistance, runoff and groundwater in the land surface model Noah-MP (Li et al. 2018). Many parameters were used in Noah-MP to describe the characteristics of different land use types, such as albedo, HVT (Top of canopy), LAI (Monthly leaf area index), and VCMX25 (Maximum rate of carboxylation at 25 °C). When the land use changed, these parameters changed accordingly which finally led to the changes in substance and energy exchanges between atmosphere and land surface. The geographical static data we used in the WPS is *landuse_30s_with_lakes* which was download from the WRF website. The land use data of 1990 and 2010 scenarios were derived from the Landsat thematic mapper (TM) digital images. And then, in the YRB, we replaced the land use data from the *landuse_30s_with_lakes* with the land use data from the Landsat thematic mapper (TM) digital images. Finally, we randomly changed 20% and 50% of the croplands to be forests using the 2010 scenario as a baseline to produce 20% and 50% reforestation scenarios. Both the land use data (downloaded from the WRF website and derived from the digital images) have a resolution of 1km. As the resolution of inner domain of the WRF model was set as 15km, the post-processed land cover data were resampled from 1km to 15km by the WPS (the WRF Preprocessing System). Then, the dominant land use categories in model grids were used for the Noah-MP model to correctly reflect the intended land cover changes. There were two main types of croplands, i.e., dry cropland and pasture (USGS code 2), and irrigated cropland and pasture (USGS code 3), and three main types of forest, i.e., shrubland (USGS code 8), savanna (USGS code 10) and deciduous broadleaf forest (USGS code 11). For the 20% and 50% scenarios, there were 408 and 1060 cropland grids experienced land cover changes, while the total grids of cropland in the 2010 scenarios was 2231.

Reference:

Li, J., Chen, F., Zhang, G., Barlage, M., Gan, Y., Xin, Y., and Wang, C.: Impacts of Land Cover and Soil Texture Uncertainty on Land Model Simulations Over the Central Tibetan Plateau, Journal of Advances in Modeling Earth Systems, 10, 2121-2146, https://doi.org/10.1029/2018ms001377, 2018.

L170: What about statistical significance levels of these precipitation changes? This needs to be reported for this and other figures as well.

Thanks for the comment. We have conducted statistical significance tests with t-test at 5% significance level for all spatial difference plots to determine whether the signals are robust when comparing simulation results between different experiments. We display the revised Fig. 6 as follow; other significance test results will be incorporated into the revised manuscript.

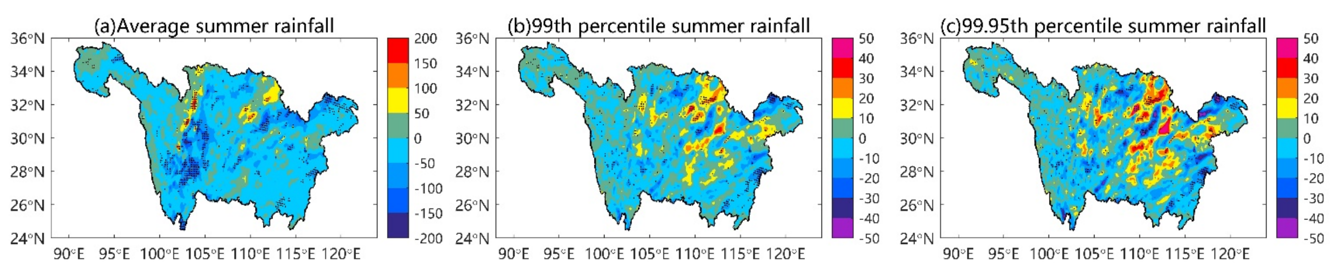

Figure 6. The changes in (a) average summer rainfall (mm), (b) 99th percentile summer rainfall (mm/day) and (c) 50th percentile summer rainfall (mm/day) between the 1990 scenario and 2010 scenario. The stippling regions show statistically significance of changes identified by t-test at a 5% significance level.

L224: Why did 20% and 50% reforestation grids at the model resolution are different?

For the 20% reforestation scenario, only 20% cropland grids of the 2010 scenario were changed to forest grids. While for the 50% reforestation scenario, the proportion of cropland grids changed to forest grids was 50%. Moreover, the two reforestation scenarios were independently produced using random sampling. Thus, the 20% and 50% reforestation grids are different. This will be clarified in the revised manuscript.

L241: For this section, the overall decreases in both LHF and SHF after reforestation were unexpected to me. Not sure if these changes are robust enough. Typical, ET would increase after reforestation, as described in the introduction, so how to explain this result?

Thanks for the comment. From the results of significance test in the revised Fig. 12, we found that the increases of LHF were more significant than decreases after reforestation. Moreover, we added a quantitative investigation on the changes in LHF and SHF over the whole basin and found that the multiyear average summer daily LHF increased by 2.08×10^3 and 4.82×10^3 W/m^2 for the 20% and 50% scenarios, respectively, while the multiyear average summer daily SHF decreased by 4.30×10^3 and increased by 4.25×10^3 W/m^2 for the 20% and 50% scenarios, respectively. Therefore, the ET did increases after reforestation. We will add these results in the revised manuscript.

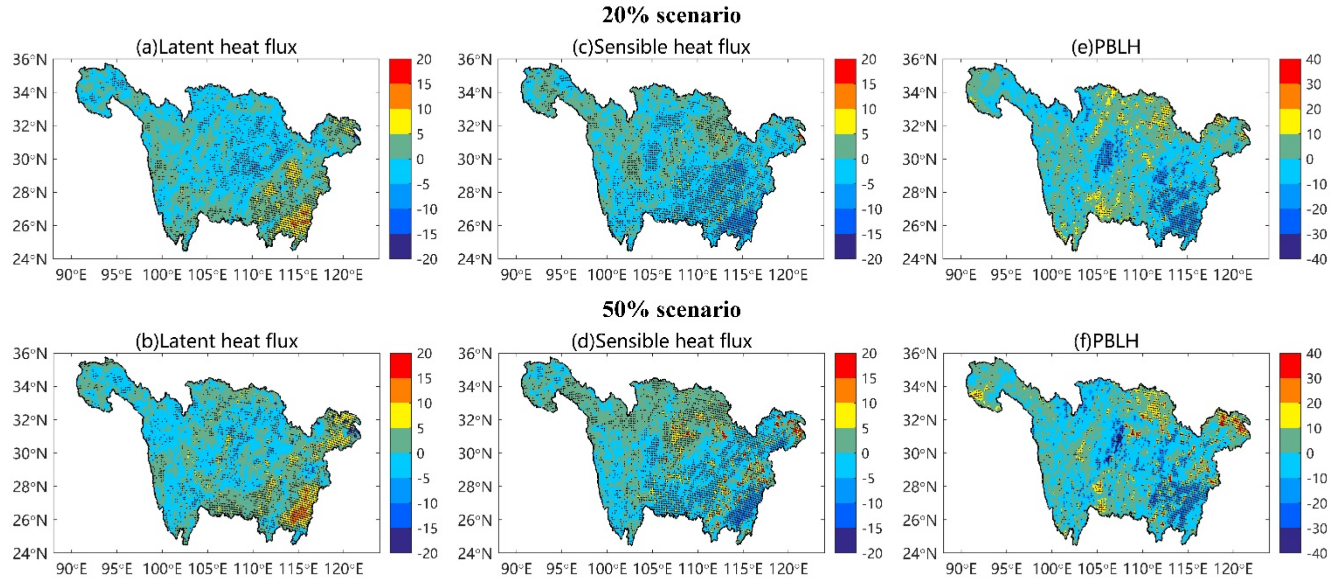

Figure 12. The changes in (a-b) latent heat flux (LHF, W/m2), (c-d) sensible heat flux (SHF, W/m2) and (e-f) PBL height (PBLH, m) between the 20% scenario and 2010 scenario, and between the 50% scenario and 2010 scenario. The stippling regions show statistically significance of changes identified by t-test at a 5% significance level.

L259: What about the changes in near-surface air temperature? For example, 2m air temperature.

Thanks for the comment. We actually analysed the changes in 2m air temperature which were not showed in the manuscript. And the results were almost the same as the changes in surface skin temperature. We display the changes in 2m air temperature in Figure A1 below. Considering that the length of the paper is too long, we will show it in the appendix.

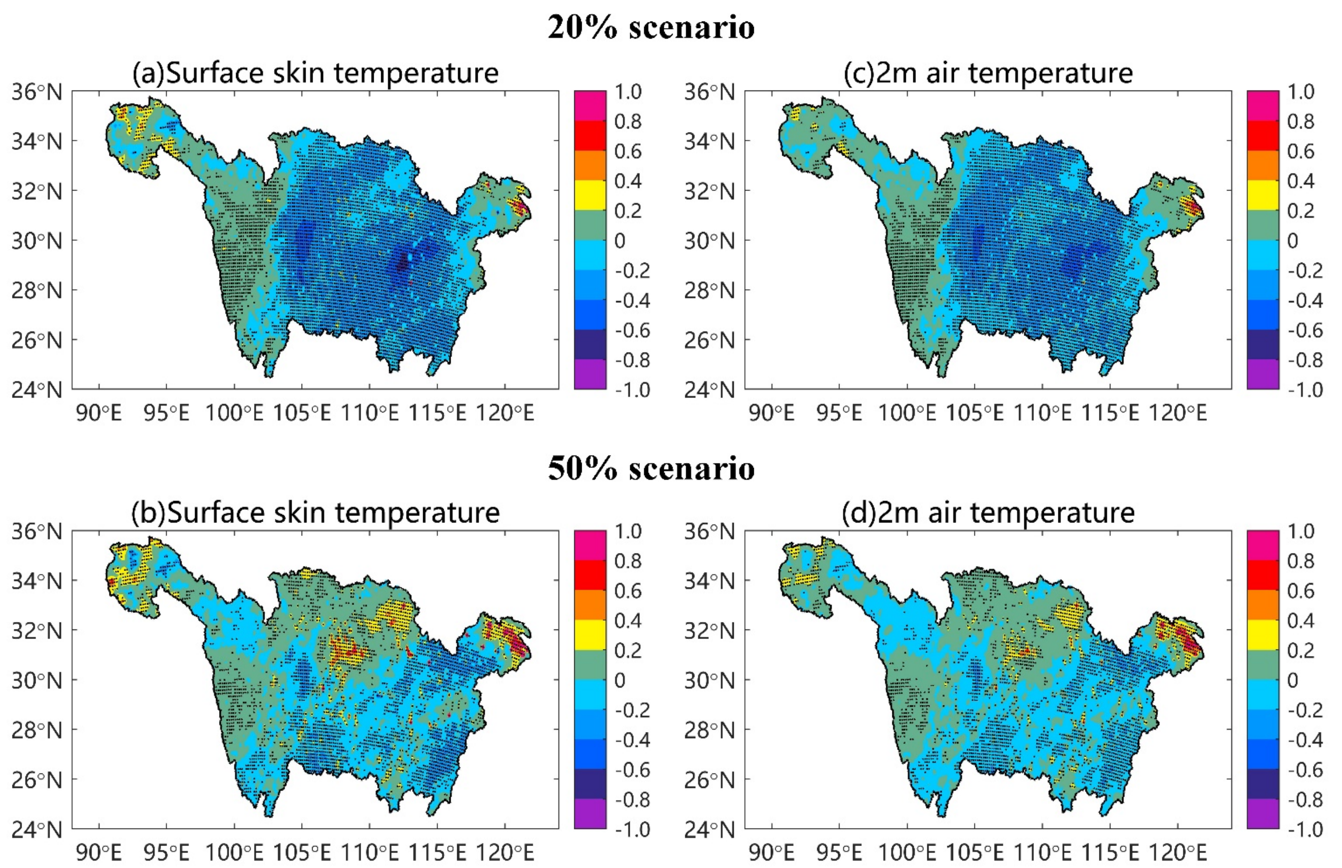

Figure A1. The changes in (a-b) surface skin temperature (℃) and (c-d) 2m air temperature (℃) between the 20% scenario and 2010 scenario, and between the 50% scenario and 2010 scenario. The stippling regions show statistically significance of changes identified by t-test at a 5% significance level.

L276-277: Any evidence to support this argument, given the latent heat flux decreased?

We have done the quantitively analysis of the changes of LHF over the whole basin, and have found that the latent heat flux increases after reforestation. We will revise this part of results and then rewrite this argument.

L296-297: How many urban grids had changed between 1990 and 2010? Whether urban expansion will affect the entire Yangtze river basin?

There were 32 urban grids out of the total of 7935 grids in Yangtze river basin, had been changed between 1990 and 2010. Moreover, as the urban expansion mainly concentrated in the midstream and downstream of Yangtze River basin, it was difficult to identify how much impact the urban expansion would have on the Yangtze river basin through only 32 grids, probably be negligible. We assume that urbanization mainly affects the local region.

L332: Is there actual data to support the increased water vapor mixing?

From the model data, it can be found that the water vapor mixing increased at the 2m, especially for the 20% scenario. For the 50% scenario, areas with the significant water vapor mixing ratio increased were more than areas with significant water vapor mixing ratio decreased. We will add spatial difference plots in the revise manuscript to show this result.

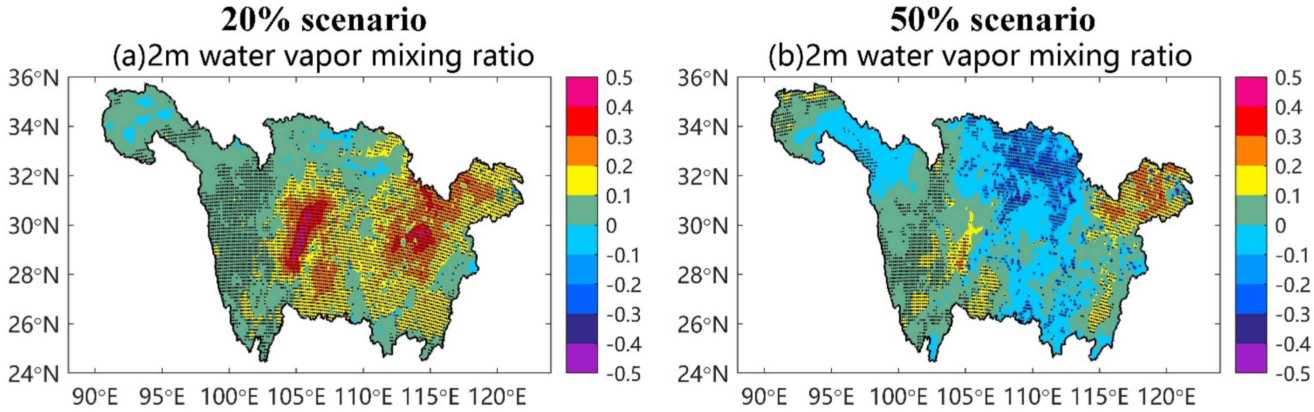

Figure A2. The changes in (a-b) 2m water vapor mixing ratio (g/kg) between the 20% scenario and 2010 scenario, and between the 50% scenario and 2010 scenario. The stippling regions show statistically significance of changes identified by t-test at a 5% significance level.

L335: Why is the precipitation response larger in 20% than in the 50% scenario? There is no related explanation or discussion.

After analysing the changes in the water vapor mixing ratio at 2m and upward moisture flux at the surface (Fig. A2 and A3), we found that the number of grids showing increased upward moisture flux in the 50% scenario slightly exceeded that in the 20% scenario. In contrast, the 2m water vapor mixing ratio increased over almost all basin in the 20% scenario while showed large decreases in the midstream of the basin in the 50% scenarios. From the surface level to the 2m level, the moisture kept increased in the 20% scenarios while decreased in the 50% scenarios. This suggested that the distribution of moisture may be changed by the horizontal transportation process. Moreover, Yu et al. (2020) found that the vegetation greening reduced rainfall in some region in the southern China which may be caused by the East Asian monsoon. As the East Asian monsoon significantly influenced the summer precipitation patterns in China (Ding et al., 2007). All these information and explanations will be incorporated into the revised manuscript.

Ding, Y., Ren, G., Zhao, Z., Xu, Y., Luo, Y., Li, Q., and Zhang, J.: Detection, causes and projection of climate change over China: An overview of recent progress, Advances in Atmospheric Sciences, 24, 954-971, https://doi.org/10.1007/s00376-007-0954-4, 2007.

Yu, L., Liu, Y., Liu, T., and Yan, F.: Impact of recent vegetation greening on temperature and precipitation over China, Agricultural and Forest Meteorology, 295, https://doi.org/10.1016/j.agrformet.2020.108197, 2020.

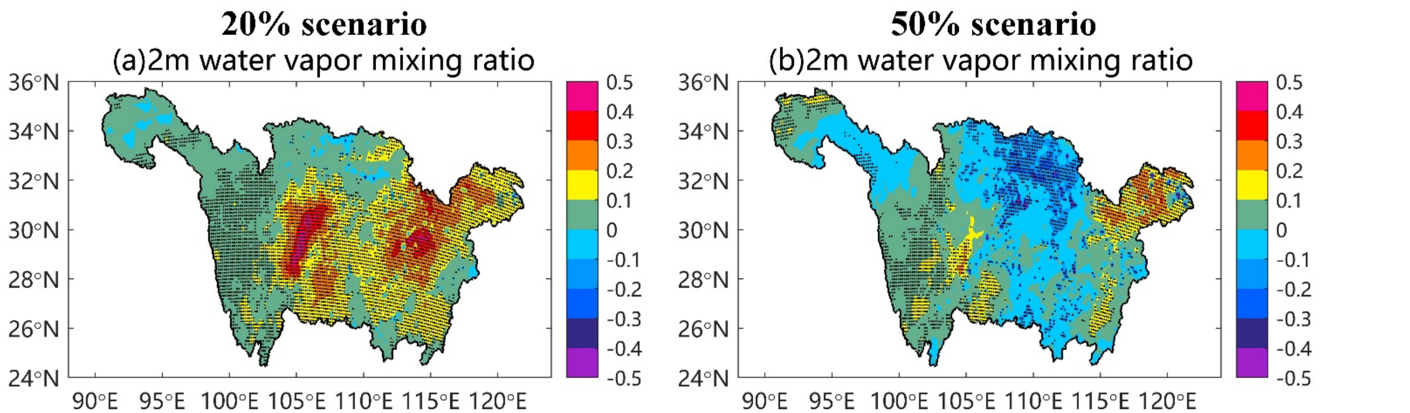

Figure A2. The changes in (a-b) 2m water vapor mixing ratio (g/kg) between the 20% scenario and 2010 scenario, and between the 50% scenario and 2010 scenario. The stippling regions show statistically significance of changes identified by t-test at a 5% significance level.

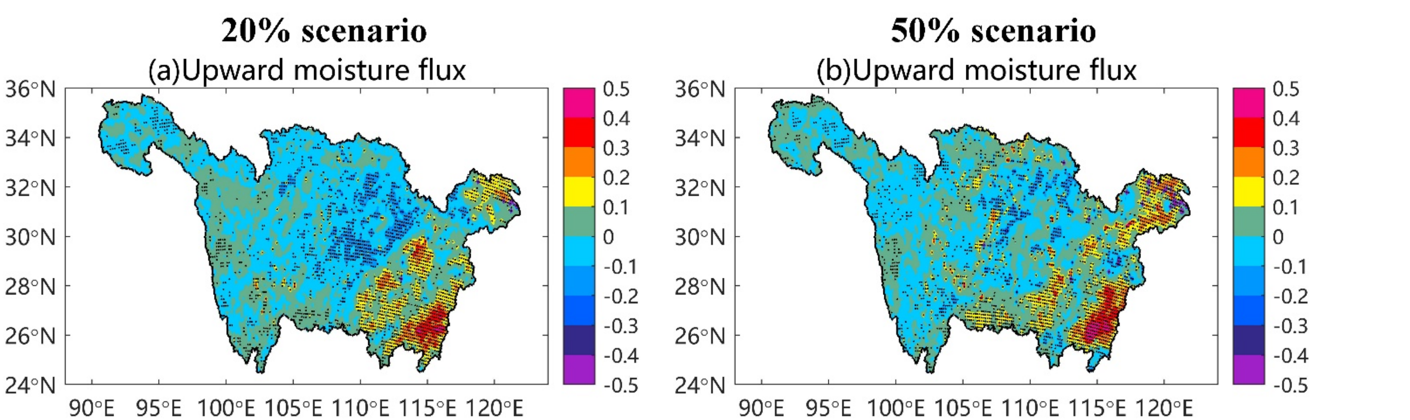

Figure A3. The changes in (a-b) upward moisture flux at the surface (kg/m^2) between the 20% scenario and 2010 scenario, and between the 50% scenario and 2010 scenario. The stippling regions show statistically significance of changes identified by t-test at a 5% significance level.