**Response to comments**

We really appreciate the Editors and reviewers for providing constructive comments and suggestions which have helped us improve the quality of the manuscript substantially. In the following, we provide our point-to-point responses (in red colored texts) to those comments.

Many thanks and we are looking forward to hearing back from you soon,

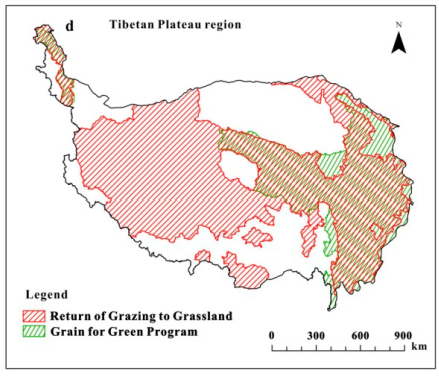
Xingong, on behalf of all the authors.

**Reviewer #1:**

The study of variations in WUE over TP is crucial for the understanding of the carbon-water cycle in this region. This author explored the longterm variations of WUE and attributed them to climate change and human activities. The overall analysis and writing is fine. My main concerns are, 1)the author claimed the important impact of ecological projects on WUE, however, in my opinion, TP has no large scale implication of ecological projects. Grazing practices may have more important influences.  2) Some results are difficult to understand, hence, more explanation should be provided.

Thanks for your comment! Below are our responses to your two major concerns:

1. According to previous studies (Cai et al., 2015; Fan et al., 2010; Feng et al., 2017; Huang et al., 2016; Luo et al., 2018; Wang et al., 2019; Xu et al., 2016), a number of ecological projects have been carried out in the TP, which mainly include the projects of “reduction of livestock”, “Return of Grazing to Grassland”, “Grain for Green Program”, “ecological immigration”, and “rodent management”. As reported by Wang et al. (2019), the main cross-region ecological projects include the projects of “Return of Grazing to Grassland” and “Grain for Green Program”, which are shown in the figure below from Wang et al. (2019). The “Return of Grazing to Grassland” program was carried out in most part of the TP except for the Qaidam Basin (QB) and Yarlung Zangbo River Basin (YZRB), and the “Grain for Green Program” was conducted in most part of the eastern TP. As for the effects of those ecological projects, studies (Cai et al., 2015; Fan et al., 2010; Feng et al., 2017; Huang et al., 2016; Wang et al., 2019; Xu et al., 2016) have shown some ecological restoration effects using different variables such as GPP, NPP, and NDVI.



We agree with the reviewer that grazing is one of the major human activities in the TP and livestock husbandry is the dominant economic activity and the major source of income for the herdsman families in the region. The program of “reduction of livestock”, which is also a major ecological project, has been carried out in the region since 2004 to control livestock number and change grazing practices. The project includes specific measures of banning grazing, rotating grazing, fencing and so on (Cai et al., 2015; Feng et al., 2017; Wang et al., 2019; Xu et al., 2016). As a result, the change in total livestock numbers in the Xizang Autonomous Region and Qinghai provinces from their annual statistic books also confirmed the effects of the ecological project (see Fig. 11 in the manuscript).

2) For the results, more explanations have been added in the revised manuscript. In Section 3.3.2, the reason on why △WUEH is higher in the southeast of YZRB has been provided (Page 22, Line 458-460), and possible explanations on higher △WUEH in the central and north part of IB have also been provided (Page 23, Line 470-473). In Section 3.3.3, possible explanations on higher △WUEH for forest (Page 24, Line 500-504), negative △WUEH for grassland (G) (Page 25, Line 507-509), and minor contribution rate of human activities for cropland (C) (Page 26, Line 532-536) have been provided as well. In addition, in the Discussion, we provide a detailed explanation on the different contributions of climate change and human activities to the variation in WUE for the TP. More explanations on their effects in the IB, PW, and some vegetation types can be found in the Discussion too (Section 4.2, Page 36-37, Line 762-777).

Abstract, "but there may be more intensive ecological destruction leading to ecological degradation, that needs more attention in future ecological protections. " This statement is lack of evidences.

In the discussion, we found, while there are positive effects of ecological projects on vegetation, the negative effects of human activities are still high on GPP and ET (represented as negative △GPPH and △ETH) (Section 4.2, Page 36, Line 755-761; Page 37, Line 790-797). So we speculate that this may be due to the impact of other ecological destruction activities, which have been reported in Luo et al. (2018). We generally agree with the reviewer and have changed the relevant sentences in the Abstract (Page 3, Line 41-42) and in the Conclusions (Page 42, Line 881-883).

Highlights, " Climate change dominates the WUE increase in the TP through increasing GPP and decreasing ET. " Climate change should also promote ET due to strong warming and warming induced surface water.

Thanks for point out this misleading statement. Climate change can promote ET, and its variation caused by climate change is a positive value. The *sensitivity coefficient* of WUE to ET change is negative, so the effect of ET change on WUE caused by climate change is negative, while the effect of GPP change on WUE is positive. We have changed the sentence to “Climate change dominates the WUE increase in the TP with negative effects of ET and positive effects of GPP”. This has been corrected in both the Highlights and conclusions (Page 41, Line 876-877).

Line 114, a citation should be included. He B, Wang H, Huang L, et al. A new indicator of ecosystem water use efficiency based on surface soil moisture retrieved from remote sensing[J]. Ecological indicators, 2017, 75: 10-16.

We have added the citation and reference (Page 4, Line 53).

Line 237-242, there is no need to provide the equations, because MK is a frequently used method.

We have deleted the equations and revised related text. (Page 13, Line 251-260).

Line 304-305, monthly or yearly value of variables were used? Because the growing season over TP is relatively short, I suggest to focused on the analysis of growing season WUE.

We used yearly values in our analysis to facilitate the comparison among different regions and vegetation types. Specifically, there are two reasons for using yearly values:

1. The TP is a very large area with significant differences in terrain, climate, and vegetation types. As such, vegetation growth seasons are quite different in space and for different and even the same vegetation types. Our main purpose of the research is to study the overall effects of climate change and human activities on WUE across the region. Using annual values provides a convenient time scale for the comparison across the region with different vegetation types.
2. Under the influence of climate warming, the phenological characteristics of vegetation on the TP have also changed with indications of earlier germination time and longer growth season (Cong et al., 2017; Dong et al., 2012; Shen et al., 2014; Xu et al., 2011; Zhang et al., 2016). As such, the length of growing season tends to be a dynamic variable which cannot be ignored for studies with a long time period as we do in this research. It would be much more difficult to carry out our study using growing season variables.

For the above two reasons, we choose the annual values for this study. However, we would like to consider using growing season variables in future research.

Line 447, "while that of WUEH was higher in the central and north part of IB, " whether this region is also characterized with strong human activities?

We are sorry that the “WUEH” in the sentence should be “△WUEH” instead. The central and north part of IB has higher △WUEH indicates that, compared to the reference period, human activities caused higher WUE variation in the variation period. High △WUEH implies that variation in WUE is highly sensitive to human activities, rather than high intensity of human activities. The intensity of human activities for this region are actually very low because of its very low population density. With the implementation of the “reduction of livestock” project, the positive effect of human activities in the variation period in this region is relatively significant than in other regions, which leads to a higher △WUEH. We have clarified this in Section 3.3.2, Page 23, Line 470-473.

Line 475," the highest △WUEH occurs in EBF ", This result is very difficult to understand, because forests mainly distributed in mountain areas with weak impacts from human activities.

In the TP, forests are mainly located in the southeast river valleys (see Fig. 1c and 1b in the manuscript), which are also the main areas of forestry. Because of the relatively low altitude, human activities are relatively frequent compared to other regions in the TP. With the implementation of the ecological project of “Grain for Green Program” in those areas, the positive effect of human activities played a significant role in the increase of WUE in EBF. Compared to other vegetation types, forest WUE has the highest annual mean and change slope, and the variation in WUE in EBF was mainly caused by reduced human activities, which has the highest △WUEH. We clarified this in Section 3.3.3, Page 24, Line 500-505.

Section 4.1.3, please explain why air pressure is a main factor influencing WUE, it is not the main factor influencing ET.

Due to the high altitude in the TP, air pressure is very low and vegetation is very sensitive to its change. With the increase of air pressure, more CO2 enters into the stomata of vegetation, which promotes plant photosynthesis, and therefor increases the GPP of vegetation (De Kauwe et al., 2016). Since GPP and WUE have a high correlation, even though air pressure has a small effect on ET, it can significantly affect WUE through GPP. In addition, there is a high positive correlation between air pressure and air temperature, which means the increase in air temperature can also promote vegetation growth. We have clarified this in Section 4.1.3, Page 34, Line 704-711.

**Reference**

Cai H, Yang X, Xu X. Human-induced grassland degradation/restoration in the central Tibetan Plateau: The effects of ecological protection and restoration projects. Ecological Engineering 2015; 83: 112-119.

Cong N, Shen M, Piao S. Spatial variations in responses of vegetation autumn phenology to climate change on the Tibetan Plateau. Journal of Plant Ecology 2017; 10: 744-752.

De Kauwe MG, Keenan TF, Medlyn BE, Prentice IC, Terrer C. Satellite based estimates underestimate the effect of CO2 fertilization on net primary productivity. Nature Climate Change 2016; 6: 892-893.

Dong M, Jiang Y, Zheng C, Zhang D. Trends in the thermal growing season throughout the Tibetan Plateau during 1960-2009. Agricultural and Forest Meteorology 2012; 166: 201-206.

Fan J-W, Shao Q-Q, Liu J-Y, Wang J-B, Harris W, Chen Z-Q, et al. Assessment of effects of climate change and grazing activity on grassland yield in the Three Rivers Headwaters Region of Qinghai-Tibet Plateau, China. Environmental Monitoring and Assessment 2010; 170: 571-584.

Feng Y, Wu J, Zhang J, Zhang X, Song C. Identifying the Relative Contributions of Climate and Grazing to Both Direction and Magnitude of Alpine Grassland Productivity Dynamics from 1993 to 2011 on the Northern Tibetan Plateau. Remote Sensing 2017; 9.

Huang K, Zhang Y, Zhu J, Liu Y, Zu J, Zhang J. The Influences of Climate Change and Human Activities on Vegetation Dynamics in the Qinghai-Tibet Plateau. Remote Sensing 2016; 8.

Luo Z, Wu W, Yu X, Song Q, Yang J, Wu J, et al. Variation of Net Primary Production and Its Correlation with Climate Change and Anthropogenic Activities over the Tibetan Plateau. Remote Sensing 2018; 10.

Shen Z, Fu G, Yu C, Sun W, Zhang X. Relationship between the Growing Season Maximum Enhanced Vegetation Index and Climatic Factors on the Tibetan Plateau. Remote Sensing 2014; 6: 6765-6789.

Wang H, Liu G, Li Z, Wang P, Wang Z. Comparative Assessment of Vegetation Dynamics under the Influence of Climate Change and Human Activities in Five Ecologically Vulnerable Regions of China from 2000 to 2015. Forests 2019; 10.

Xu H-j, Wang X-p, Zhang X-x. Alpine grasslands response to climatic factors and anthropogenic activities on the Tibetan Plateau from 2000 to 2012. Ecological Engineering 2016; 92: 251-259.

Xu W, Gu S, Zhao X, Xiao J, Tang Y, Fang J, et al. High positive correlation between soil temperature and NDVI from 1982 to 2006 in alpine meadow of the Three-River Source Region on the Qinghai-Tibetan Plateau. International Journal of Applied Earth Observation and Geoinformation 2011; 13: 528-535.

Zhang Y, Zhang C, Wang Z, Chen Y, Gang C, An R, et al. Vegetation dynamics and its driving forces from climate change and human activities in the Three-River Source Region, China from 1982 to 2012. Science of the Total Environment 2016; 563: 210-220.

**Reviewer #2:**

In this paper, an analytical framework that combined the attribution method with the elastic coefficient separation method is proposed to assess the impact of climate change and human activities on WUE variation. The two methods involved have been widely used separately to disentangle the impacts of climate change and human activities on the eco-hydrological system (streamflow, evapotranspiration, groundwater, NPP or GPP), and combining them for WUE separation research is novel. In my opinion, the topic is interesting, and suitable for this journal and the methodology and results are basically sound. This paper is generally well-structured as it provides enough technical and experimental details, and the results are well represented and explained. However, there are few critical points that should be addressed. Addressing these comments will improve the quality of the paper. The paper could be accepted for publication considering the following revisions.

Many thanks for your comments.

Major Comments:

1. This manuscript is too long, I highly recommend reduce some descriptive results, as the Figures and Table are more persuasively. It is not necessary describe again and just more concise and telling the major results.

Thanks for the suggestion. We have removed some unnecessary descriptive results and these changes can be found in the following sections:

Section 3.1, Page 18, Line 357-360; Page 18-19, Line 374-376, and Line 379-382.

Section 3.2, Page 20, Line 397-401, Line 413; Page 21, Line 422-424, and Line 427-428.

Section 3.3, Page 22, Line 446-447; Page 24, Line 489-491, Line 504-505; Page 25, Line 514-517, Line 525-528; Page 26, Line 531-532, Line 549-552.

Section 4.2, Page 34, Line 724-726.

2. The introduction can be more concise and focused on the objective of study purpose and present the scientific gap that this manuscript trying to contribute.

Thanks for the suggestion. We moved the background of WUE into the first paragraph of the revised manuscript. After some literature review on the effects of climate change and human activities on the variation in GPP (NPP) and ET in the TP (Line 96-119), we pointed out research gap first in Line 98-100, which is then emphasized and detailed in Line 139-142. In addition, for more succinct, we have deleted some not necessary descriptions (Page 5, Line 71-75, and Line 89-91).

3. About high correlation between WUE (or GPP) and air pressure (Line 672-677). In addition to more CO2 entering the stomata with the air pressure rises, the high correlation between air temperature and air pressure, determined by altitude, also has an impact. The roughly same spatial distribution of the correlation between WUE and air temperature and pressure also proves this (as represented in Fig. S4). Therefore, the correlation between air pressure and temperature should also be mentioned.

Thanks for your observation and reasoning. We have added this on Page 34, Line 708-711.

4. A flow chart of the proposed method could be added. The authors are requested to ensure that the methodology could be applied in other regions by following the flow chart.

Thanks for this very good advice. We have added a diagram to illustrate the conceptual framework, data, major methods and analyses in figure below on Page 17 in revised manuscript.

H:\20200115\02-WUE分离-QTP\202002_返修\FlowChart.tif

5. English can be improved. It is recommended that the authors seek assistance from a native English speaker familiar with the topic and scientific English to improve grammar and syntax of the manuscript.

We have carefully revised the language, grammar and syntax for the entire manuscript.

Specific comments:

Line 67: “NPP = GPP – Ra”, instead of “GPP = NPP – Ra”.

Thanks and we have corrected it.

Line 74: “such as”, insisted of “i.e.”. In addition to the carbon and nitrogen cycles, there are other biogeochemical processes, such as the phosphorus and sulfur cycles.

Thanks and we have corrected it.

Line 86: delete “processes”.

Thanks and we have corrected it.

Line 93: “of”, insisted of “conducted by”.

Thanks and we have corrected it.

Line 94: delete “found that”.

Thanks and we have corrected it.

Line 103: “decreasing trend”, instead of “negative trend”.

Thanks and we have corrected it.

Line 131: delete “trend”.

Thanks and we have corrected it.

Line 142: The methods mentioned here (“attribution approach” and “elastic coefficient separation method”) should have references.

Thanks and we have corrected it.

Line 154: “sub-region” rather than “regions” may be more appropriate.

Thanks and we have corrected it.

Line 210: “form” should be ‘from’, and check throughout the whole manuscript.

Thanks and we have corrected it throughout the entire manuscript.

Line 341: “YZRB has the most abundant vegetation type” instead of “is the most abundant vegetation type”.

Thanks and we have corrected it.

Line 383: “increases” instead of “decreases”, “Fig. 5a” rather than “Fig. 5” may be more accurate.

Thanks and we have corrected it.

Line 433: delete “the”.

Thanks and we have deleted it.

Line 676: The correlation coefficient (r) between GPP and Pres is 0.80 informed from Table 5.

Thanks and we have corrected it.

Line 692: delete “plateau”.

Thanks and we have deleted it.

Line 736: What is “this” here? I think “this degradation” could be more appropriate.

Thanks and we have corrected it.

Line 771: “unequal” rather than “different” may be more accurate.

Thanks and we have corrected it.