Response to Reviewer #1

General comments: This paper focuses on the development of water policies in the Central Asian (CA) transboundary rivers. Using the Gini Coefficient, the matching coefficient, the water conflict events, and the structure of water management institutions as indicators, this study reveals the complex management dynamics among the transboundary river basins in CA. The paper is generally well-written and structured, covering a broad range of data sources from both qualitative and quantitative perspectives. However, there are some issues that need to be addressed before acceptance.

-Author response: We would like to thank reviewer #1 for the insightful comments and suggestions. These are very valuable to improve our manuscript, and the revised manuscript will follow the reviewer's recommendations. The followings are our point-by-point response to these comments.

Specific comments: Firstly, what are the major implications this article can deliver in reporting different perspectives of water policies development in the CA? The connections between the Gini coefficient, the matching coefficient, the number of water political events, and conflict/cooperative networks among the CA countries are not clear to me. One potential implication I can think of is that as the Gini coefficients and the matching coefficients indicate mismatches between water resources and socioeconomic development, there is need to establish more cooperative network (rather than conflictive ones) among countries. A more elaborative discussion on how findings from the current situations in this paper should contribute to future management of transboundary rivers in the CA is needed.

-Author response: Thanks for the instructive comment. We will add the implications of our findings to future management of transboundary rivers in CA in the revised manuscript. Firstly, just as you raised, based on the Gini coefficient and the matching coefficient of water and land resources, we have found that the matching degree of water and socio-economic elements (especially water and land resources) in CA is pretty poor. This is an important factor that increases the potential for water conflicts, and the main concern of the water conflictive events in CA is also the competitive utilization of water resources. Therefore, improving the water and land allocation systems and strengthening the water cooperative networks among countries will help reduce water conflicts and promote transboundary river management. Secondly, although there are more water cooperative events than conflictive events in CA, the cooperation mainly belong to weak levels based on our findings, and verbal supports (less effective) accounted for a large proportion (Level 1-2) in the current situation. There should be more high-level cooperation between the five countries, such as the military, economic or strategic supports, and freshwater treaties. The successful management of transboundary rivers in CA depends on deepening the countries' cooperation and trust. In addition, the CA should strengthen cooperation with its neighboring countries (such as Russia and China) in the water cooperative network, and make full use of the assistance of international and regional organizations, because neighboring countries are the key trading partner and play an important role in the water policy reform of CA. We will add specific implications in the discussion part.

Secondly, there is need for more justification about why these indicators are chosen in the method section. Why is the Gini Coefficient, combined with the matching coefficient good indicators for mismatches between water resources and socio-economic development? And how are changes of these coefficients impact on the water events? Are different countries showing different levels of impacts?

-Author response: Thank you for the kind comment. We will explain the choosing criterion with more details in the method section. Gini coefficient is an objective indicator usually used to describe the degree of income distribution inequality. The distribution of water resources is not balanced in the region, which directly affects the agricultural production and economic development, and it is similar to the income distribution inequality. Therefore, the Gini coefficient has been effectively used as an indicator in measuring the degree of imbalance of water resources (Dai et al., 2018; Yan et al., 2016; Liu et al., 2018; Qin et al., 2020), and we used it to quantify the overall matching situation of water and socio-economic elements in CA. But the Gini coefficient cannot reflect the spatial differences among the five countries, so we combined the Gini coefficient with the matching coefficient of water and land resources, to represent the overall and individual matching degree of the five countries.

The matching situation of water resources and socio-economic elements (especially the land resources) in CA has an important impact on water politics. The higher the value of the Gini coefficient (or the smaller the matching coefficient of water and land resources), the worse the matching situation is, and the more likely the country will compete for water resources, so the greater the possibility of water conflictive events occur in the country. Conversely, the better the matching situation is, more water cooperative events may occur in the country. These coefficients are applicable to all five Central Asian countries and levels of impact are assumed to be the same. For example, we have found that Uzbekistan's water and land resources were poorly matched, and it is verified that the Uzbekistan was also at the core of the water conflictive network in our analysis in Section 3.3.3. Therefore, these coefficients effectively reflected the matching situation between water resources and socio-economic development, and were the prerequisite for analyzing the dynamics of water political events in CA. We will add more detailed analysis in the method section.

References

1. Dai, C., Qin, X. S., Chen, Y., and Guo, H. C.: Dealing with equality and benefit for water allocation in a lake watershed: A Gini-coefficient based stochastic optimization approach, J. Hydrol., 561, 322-334, 2018.
2. Liu, D., Liu, C. L., Fu, Q., Li, M., Faiz, M. A., Khan, M. I., Li, T. X., and Cui, S.: Construction and application of a refined index for measuring the regional matching

characteristics between water and land resources, Ecol. Indic., 91, 203-211, 2018.

3. Qin, J. N., Fu, X., and Peng, S. M.: Asymmetric benefit compensation model for resolving transboundary water management conflicts, Water Resour Manag., 34, 3625-3647, 2020.
4. Yan, F. Q., Zhang, S. W., Liu, X. T., Chen, D., Chen, J., Bu, K., Yang, J. C., and Chang, L. P.: The effects of spatiotemporal changes in land degradation on ecosystem services values in Sanjiang Plain, China, Remote Sens., 8(11), 917, 2016.

Thirdly, the flow among the three result sections should be strengthen. For example, what is the purpose of Section 3.1.1? I understand the authors want to provide a broad picture for the amount of water resources available in the CA river basins, but how this is connected to the remaining Sections 3.2 – 3.3 is not clear.

-Author response: Thank you for the instructive comment. We will strengthen the description of the connections among the three result sections in the revised manuscript. We realize that the purpose of Section 3.1.1 is not discussed in depth in the original version of the manuscript, and we will adjust the expression of this section. In fact, large reservoirs and dams occupy a key position in the water management infrastructure of CA and are vital to the economies of all five countries. The water stored in reservoirs is the main available water resources for agricultural irrigation and power generation in the river basins of CA. Therefore, analyzing the changing trends of inflow and outflow of large reservoirs can reflect the dynamics of available water resources and their development and utilization status, which is the basis for calculating the matching degree of water resources and socio-economic development in Section 3.1.2. On the other hand, humans play a leading role in the regulation and control of reservoirs in CA, and there is a competitive use between power generation in upstream countries and irrigation in downstream countries, so how will the allocation of water resources in reservoirs affect water conflicts and cooperation in the transboundary river basins of CA? Meanwhile, most of the reservoirs are aging and lack adequate maintenance, and the upgrading of water and energy facilities is one of the thorniest issues for the five Central Asian states, thereby what are challenges does it pose for water management in CA? Therefore, the analysis of large reservoirs on different sections of transboundary rivers reflected the ability of human to control water resources, and provides a precondition for the discussion of water management in Section 3.2 and water politics in Section 3.3. We will add more details about the connection in the result section.

Technical corrections:

Line 110 onwards: There are brief introductions about the TFDD database but what about the Water Conflict Chronology and the Interstate Commission for Water Coordination of Central Asia? Any issue when merging of data of different temporal periods?

-Author response: Thank you for the insightful comment. We realize that the descriptions of the Water Conflict Chronology (WCC) and the Interstate Commission for Water Coordination of Central Asia (ICWCCA) databases are not detailed enough in the original manuscript. We will clarify these datasets and their data consistency in the revised manuscript.

Since both the water conflictive and cooperative events of CA recorded in the TFDD database occurred between 1951-2008, we selected the WCC database as the complementary data for water conflictive events and the ICWCCA database for water cooperative events during 2009-2018, respectively. The WCC is a detailed interactive online database that contains global conflicts over freshwater resources, where readers can retrieve and filter water conflicts by time, location, and subject (Gleick and Heberger, 2014). The data on water conflicts in CA cover the period during 1990-2018. To verify the consistency of conflictive events between TFDD and WCC, we compared the conflictive events from these two databases in their common timespan (1990-2008), and found that the conflictive events registered in the two datasets matches well with each other (Fig. s1a). The results indicated that the conflictive events by combining the TFDD and WCC database is reliable.

The ICWCCA is a joint committee established and authorized by the heads of the five Central Asian countries, which is responsible for making binding decisions on issues related to water distribution and utilization in the transboundary river basins of CA (Rahaman, 2012). It contains comprehensive water cooperative events such as conferences and agreements on transboundary rivers in CA since 2000. We also show that the two different datasets (TFDD and ICWCCA) produce similar trends of water cooperative events during 2000-2008 (Fig. s1b). This showed that the cooperative data obtained by merging the ICWCCA database and the TFDD is also reliable. Finally, we classified the levels of the complementary conflictive/cooperative events according to the classification criteria of water political events in TFDD.

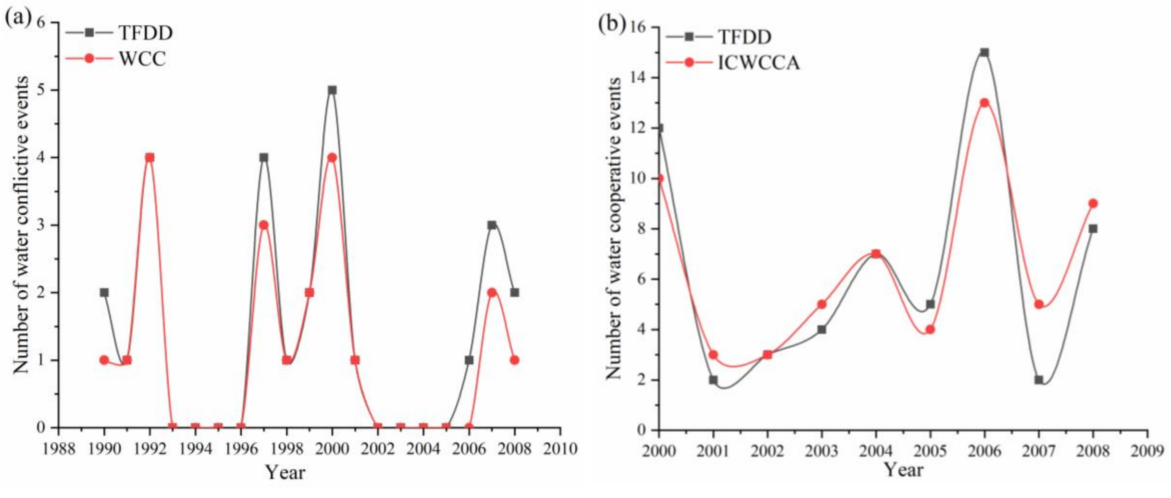

Figure 1: Comparison of the number of water conflictive events in the TFDD and WCC datasets (a) and the number of water cooperative events in the TFDD and ICWCCA datasets (b)

References

1. Gleick, P. H. and Heberger, M.: Water and conflict, in: The world's water, 159-171

January 2014, Washington, DC, Island Press, 2014.
2. Rahaman, M. M.: Principles of transboundary water resources management and water-related agreements in Central Asia: An analysis, Int. J. Water Resour. Dev., 28(3), 475-491, 2012.

Line 135 onwards: Clarifications about "what network" is needed: is the network only limited to among the five CA countries or other countries (as mentioned in Line 280) also included?

-Author response: Thank you for the helpful comment. We will explain it in the revised manuscript. The network covers all the countries that are involved in the water political events on the transboundary rivers of CA, and this network not only exists among the five Central Asian countries but also with other countries throughout the world that have cooperation or conflicts with CA.

Line 347: Please clarify this sentence. Is water resources distribution unified in the CA?

-Author response: Thank you for the insightful comment. We will explain it with more details in the revised manuscript. "water resources distribution unified" means that, CA's water resources were unified distribution by the Moscow government in the former Soviet Union. We realize that the original expression could not be clear, so the sentence will be changed to "water resources of transboundary rivers in CA have undergone the unified distribution during the former Soviet Union, and the separate management by the five Central Asian countries after the collapse".

Line 626 (Figure 6): A timescale indicating which years these institutional changes occurred would be better.

-Author response: Thank you for the kind suggestion. We will add the timescale in Figure 6 and improve the figure for a better presentation.

Line 630 (Figure 7): It is clear that a single linear function is not suitable to represent the trend of the water events (Rˆ2 only 0.02). I would recommend using step-wise regression function.

-Author response: Thank you for the insightful comment. We will revise it in the revised manuscript. Yes, we realize that the single linear regression function has a low R^2 in fitting the trend of water events. The step-wise regression function can effectively retain the most significant independent variable through successive elimination, and needs multiple independent variables. In this study, the aim is to show the temporal trend of water events, so there is no need to apply the step-wise regression function. In fact, we have divided the study period into three stages to present the evolution of water events in the original manuscript: a stable period (1951-1991), rapid increase and decline (1991-2000), and a second stable period (2000-2018). Therefore, we consider it better to delete the single linear function and improve the figure in the revised manuscript.

Line 641 onwards (Figure 9): It would be clearer for the readers if the same map scale is used across all four figures.

-Author response: Thank you the instructive comment. We will update and improve the figure to make it clear.

The whole paper needs to be grammatically checked again.

-Author response: Thank you for the insightful comment. We will check the grammar carefully and modify the errors. We will also improve the language by Halifax Proofreading and editing service (Canada).