Reviewer 2

General Comments

In this work the authors developed an agent-based model to simulate agents that make decisions related to irrigation management. The agents consider climate and social information to update risk perception and cost of operations, to decide whether to increase or reduce water consumption for irrigation. The agents are located in a river network with a man-made structure that controls water flow. The results show that by considering this environmental and social information along with the perception of risk, agents can replicate water consumption patterns observed in the San Juan river basin. I think this is a very interesting work that provides great methodological tools to develop a coupled hydrological, agent-based model.

The introduction is clear and well supported by the literature. While some points could be made even clearer, the authors did a good job introducing the objectives and the methods proposed.

Response

We want to thank the reviewer for these constructive comments and suggestions which greatly improve the clarity of the entire manuscript. We further condense the Introduction section following the comment from Reviewer 1. Line numbers in this document correspond to the clean version (no track changes) of the revised draft.

I considered the method section to be the most interesting part of this paper. The Bayesian inference (BI) rule provides a great tool that combines robust math and easy applicability to develop the agents' decision-making framework. My main concern with the BI is the assumption or presumption of risk. In the model, when agents ignore incoming information, these agents are labeled as "risk-averse". I do not understand why, by not considering previous information, these agents would be considered risk-averse. My understanding is that risk-averse individuals pay more attention to not have great losses vs. a risk-seeking agent, who would give more importance or weight to potential large gains, thereby discounting loses. I think the authors need to clarify this point.

Response

We agree with the reviewer for the definition of risk-averse. In our reasoning, we define "risk-averse" as "*do not trust the new incoming information because it could be uncertain and rather to stick with her/his own experience*" In other words, an agent is not taking any risk by changing its behavior. The sentence has been modified in the revised draft, please check Line 194 to 196.

Finally, for the methods, a sub-section containing the estimation and calibration methods, and the comparison with real data, is needed. Some aspects of these methods are described when the results were described later in the manuscript, and this created some confusion about the methods that were used.

Response

One sentence has been added to the last paragraph of the Methodology section to remind our readers the model diagnose and the comparison with real data in the case study area (Line 248 to 249).

Both reviewers suggest moving the text for the model diagnose part to the earlier section of the manuscript. Given that the model calibration process requires historical data from the case study area as references, we need to put this section after we describe the case study area. Therefore, we decide to put the original Section 4.1 as the last section of the Case Study in the revised draft. The reasons are two-fold. First, since it is out of the Result section, the confusion that Reviewer 2 described can be avoided. Second, this paper structure rearrangement will follow the suggestion from Reviewer 1 that the order of the outcome presentation is the same as the order of research objectives stated in the last paragraph of Introduction. Please check Line 346 to 415.

The case study is quite interesting and well supported by time-series data. My main comment in this section is about the kind of agents their model is trying to simulate. It is not clear to me who are the "irrigated" and/or "ditch object" -agents. Are these infrastructure operators, managers, or a group of farmers with influence on the decision made to obtain water? The authors can do better explaining these agents.

Response

Agents are groups of farmers in our study. In the RiverWare model set up, they are quantified as several "water use objects" which we named them as irrigation ditches. These agents (or irrigation ditch) are an aggregation of farmers in that specific area and our assumption is that since USBR aggregate these farmers into several single entities, they will make similar management decision in reality. We add an additional explanation in Section 3.2, please check Line 307 to 310.

Another point that I think needs an explanation is how the social and climate factors that each agent considers as important were elicited. Some agents consider extreme precipitation, while others consider "animas precipitation". I also suggest that the authors differentiate between climate vs. social factors in Table 1. This would make the different socio-ecological factors that influence each agents' decisions clearer to the readers.

Response

Precipitation is a preceding factor candidate of all agents. However, depending on the geographical location of agents, they need to consider precipitation at different locations. For example, upstream agents (e.g. the Group 1 in our case) do not need to consider downstream precipitation since that will not affect their water availability. This is an advantage of using ABM which the spatial heterogeneity can be addressed in the model. We add a sentence in the new Section 3.2 to better explain this and also follow the reviewer's suggestion add a description about how climatic and social factor might affect agents' decision. Please check Line 314 to 339.

Also following the reviewer's suggestion, we modify Table 1 with a superscript that distinguishes climatic and social factors. Please check the new Table 1 below and in the new table file.

Group	Number of agents	Factors considered in decision-making processes

1. (upstream of the Navajo Reservoir)	2	• mainstem upstream precipitation[c] (180.1 mm, 125.3 mm), • the water level in the Navajo Reservoir[c] (6053.58 ft, 13.37 ft), • number of flow violation at the outlet[c] (38.5, 38.8), • cost-loss ratio[s]
2.a (Animas River without shortage sharing)	5	• tributary (Animas) precipitation[c] (79.2 mm, 38.2 mm), • mainstem upstream precipitation[c] (180.1 mm, 125.3 mm), • the water level in the Navajo Reservoir[c] (6053.58 ft, 13.37 ft), • number of flow violation at the outlet[c] (38.5, 38.8), • cost-loss ratio[s]
2.b (Animas River with shortage sharing)	1	• tributary (Animas) precipitation[c] (79.2 mm, 38.2 mm), • mainstem upstream precipitation[c] (180.1 mm, 125.3 mm), • the water level in the Navajo Reservoir[c] (6053.58 ft, 13.37 ft), • number of flow violation at the outlet[c] (38.5, 38.8), • shortage sharing[s], • cost-loss ratio[s]
3.a (downstream of the Navajo Reservoir without shortage sharing)	3	• mainstem downstream precipitation[c] (82.9 mm, 96 mm), • mainstem upstream precipitation[c] (180.1 mm, 125.3 mm), • the water level in the Navajo Reservoir[c] (6053.58 ft, 13.37 ft), • number of flow violation at the outlet[c] (38.5, 38.8), • NIIP diversion[s] (159,310 ac-ft, 15131 ac-ft mm), • cost-loss ratio[s]
3.b (downstream of the Navajo Reservoir with shortage sharing)	5	• mainstem downstream precipitation[c] (82.9 mm, 96 mm), • mainstem upstream precipitation[c] (180.1 mm, 125.3 mm), • the water level in the Navajo Reservoir[c] (6053.58 ft, 13.37 ft), • number of flow violation at the outlet[c] (38.5, 38.8), • NIIP diversion[s] (159,310 ac-ft, 15131 ac-ft mm), • shortage sharing[s], • cost-loss ratio[s]

I suggest looking at the ODD+D protocol, instead of ODD, to describe the model, because the ODD+D includes the decision-making aspect of the model (Müller et al., 2013). The authors cited this study, but they have not used it.

Response

We modify our ODD document into the ODD+D format, please check the new supplement materials

I consider the discussion to be somewhat weak and not in line with the aim of the study, nor the results. The discussion starts with a reflection about the policies implemented in the study area, but it was only loosely connected to the decisions of the agents, the information these agents considered, and the risk. There is no discussion or reflection about implementing theory-planned behavior, which I think would be a great step to incorporate real theories of human behavior into agent-based models. The authors should highlight this effort. Perhaps the discussion can be constructed around the following question: How do the risk perception, information flow, and costs influence policy outcomes in not only the San Juan river basin, but also in other basins? The discussion should start with a broader statement about the generality of the method and its applicability to other rivers. Then, it should include the implications of the results for policy outcomes, first for the example of the San Juan river, and then for other irrigated areas.

Response

Following the suggestion form both reviewers, we completely restructure the Discussion section. First, most of the original Section 5.1 has been moved to the Case Study which provides a more informative background to our readers about the water conflict situation in the basin. Please check Line 275 to 295. Second, we change the title of the section to "Generalized the modeling framework and policy implementation for other basins" and start this section with a broader statement about the generality of the method and how it addresses the challenges of how the proposed BA-ABM implementing the TPB as a first step to incorporate real theories of human behavior into agent-based models. Please check Line 506 to 522. Third, we use our results in the San Juan River as an example to explain the models' applicability for policy implementation. Please check Line 523 to 535.

Finally, the authors stated in 5.2 that they will discuss future research, yet no specific ideas were provided. In any case, these future directions should be included in the conclusion, rather than the discussion. At a minimum, a real discussion about these ideas, including what would be needed and other considerations, should be included.

Response

We change the title of the revised Section 5.2 as "Model limitations" which we only use this section to discuss the limitations of the current draft such as data availability and model structure in BI mapping as well as extremity. Please check Line 536 to 557.

Following the suggestion from both reviewers, we move the ideas of future research into the Collusion section (Line 582 to 590).

Specific comments

Abstract

I do not consider risk perception and uncertainty to be the same, as the author clearly described in the introduction (Line 107). On line 22, the authors should be more careful when introducing these terms in the abstract.

Response

From revised the abstract following reviewer's suggestion and more specifically talk about risk perception (Line 10 to 28).

Introduction

Line 59: Why do the authors start with the word "therefore" to introduce planned behavior?

Response

The word "therefore" is deleted.

Line 73: Need to introduce the low-cost rule.

Response

We improve the description of the CL model (including the calculation of taking action based on low-cost concept) in Methodology section given that the Introduction is only intended to provide a high-level idea of what is CL model. Please check Line 217 to 239 in the Methodology section.

Line 89-100. In the abstract, the authors suggest that risk perception is included in the BI rule. They then introduce risk perception when discussing the CL rule. This causes some trouble understanding the model.

Response
Line 90 to 96 was previous studies and directly use the CL model for the risk perception. However, as we summarized in Line 94 to 96, this previous study did not provide a detailed methodology for parameter determination and ignore spatial heterogeneity. Therefore, we want to improve this aspect by the proposed method of using BI mapping to quantify risk perception given that the BI mapping can explicitly consider conditional probability. We highlight this as a gap in the last paragraph of the Introduction section (Line 100 to 104).

Line 128: A line or two is needed stating what "two-way" coupling means. I think they refer to feedback between decisions, perception, and water dynamics. Is this correct?

Response
Since we reorganize the Introduction section, we only briefly mention this term "two-way coupling" in the Introduction section. We provide a detailed description of what we mean by "two-way coupling" in Section 2.1. Please check Line 137 to 143.

Methods
Line 229: A definition of subscripts i and j is needed.

Response
We move this equation to the Supplements Materials as suggested by Reviewer 1. We add the following sentence in the Text S1 to explain "*i*" and "*j*:"

"i is the index for the preceding factor and *j* is the index for the management behavior"

Case Study
Line 313: What does "cfs" stand for? What is this unit?

Response
Add "cubic feet per second." Please check Line 266.

Line 385: What does "matching" the time series mean? Is it based on Least Squares as a Maximum Likelihood? In other words, an explanation is needed on how the comparison between real data and simulated data was carried out.

Response
We reword this as "recreate" the historical trend. Please check Line 348 to 353.

Line 418: An explanation for the Nash-Sutcliffe Efficiency is needed.

Response

The Nash-Sutcliffe Efficiency is widely used in water resource to assess the predictive power of process-based models. We add the original citation into the manuscript (Line 377).

Nash, J. E.; Sutcliffe, J. V. (1970). "River flow forecasting through conceptual models part I — A discussion of principles". Journal of Hydrology. 10 (3): 282–290.

Line 457: The phase including "…multi-objective calibration:.." is not a result. This should be in the methods.

Response

As we mentioned above, we did a complete paper structure reconstruction following the suggestions from both reviewers. This sentence does not fit in the revised draft and has been removed.

Line 585: The statement beginning "The BC-ABM results…" is also not a result. The fact that agents react to climate and socio-economic factors is part of the rules imposed by the model, but it is not a result per se.

Response

Since we restructure the paper, the entire sentence has been removed.

Line 624: I do not understand why the authors introduce multicriteria decision analysis vs. other decision-making tools. It is an important tool, but it is hard to see the connection.

Response

The text about multi-criteria decision analysis in both the Discussion and Conclusion section has been removed completely.

Figure 1: In ABM process 3, what is the question that leads to yes or no? It is related to the opportunity cost, but it needs to be stated in the figure.

Response

We update Figure 1 following suggestions from both reviewers. Please check the new Figure 1 below and in the new figure file.

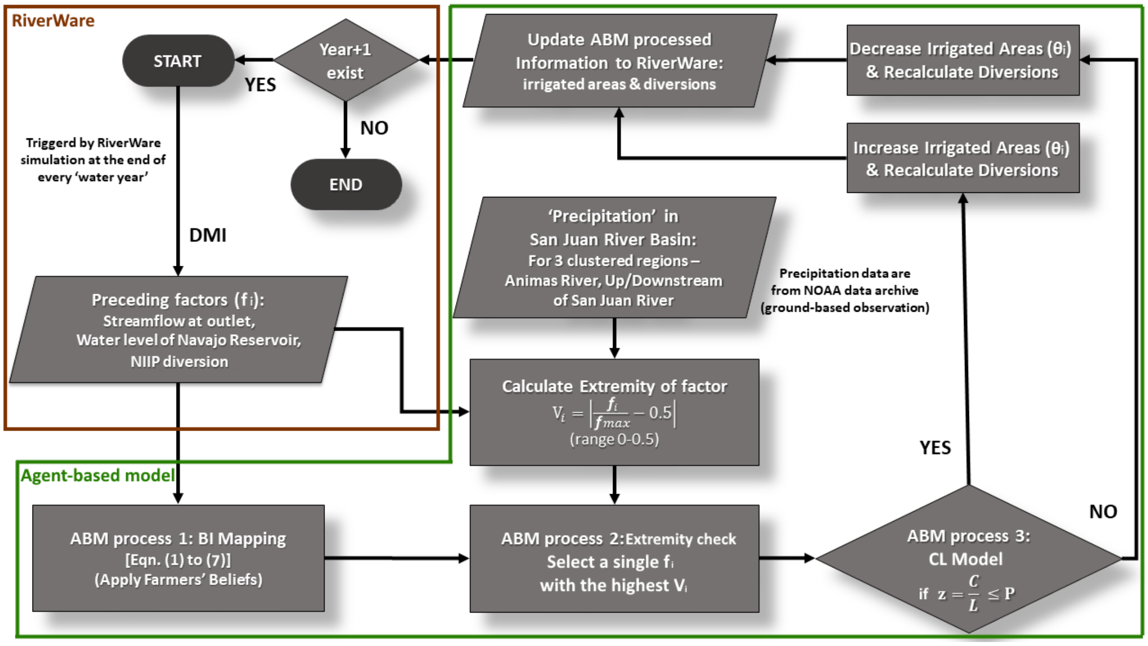
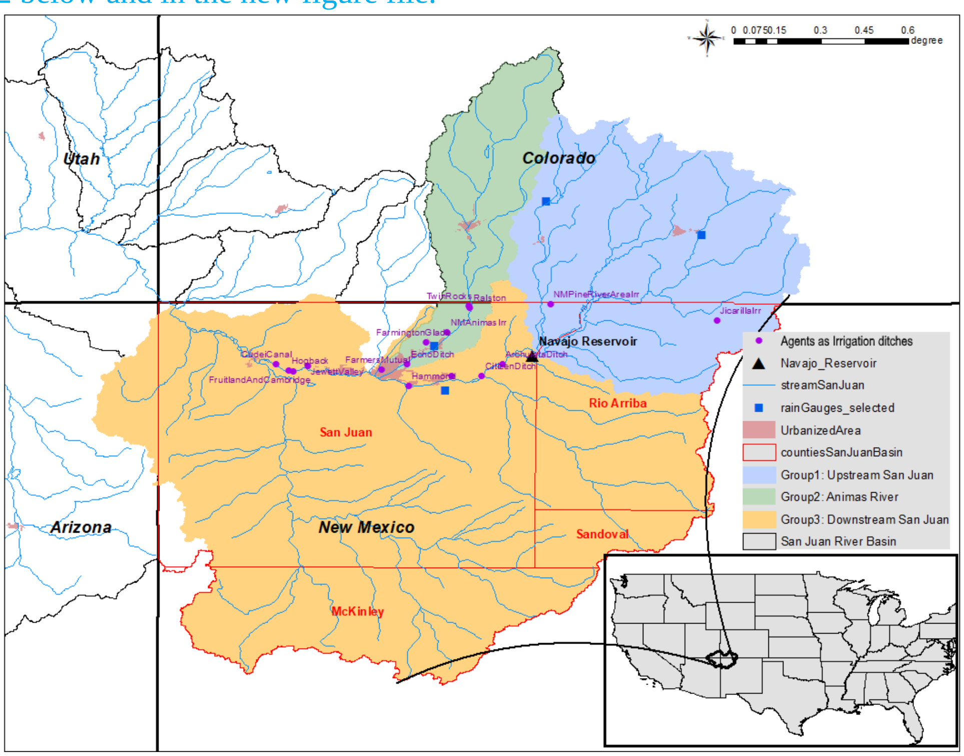


Figure 2: Perhaps a better name for "irrigated agents" is needed.

Response

We update Figure 2 following the suggestion from the reviewer. Please check the new Figure 2 below and in the new figure file.



I hope these comments are useful to the authors.

Response
Again, we want to thank the reviewer for these constructive comments and suggestions which greatly improve the clarity of the entire manuscript.