A Summary of Revisions and Responses on “Optimizing Implementation Orders of Watershed Best Management Practices with Time-varying Effectiveness under Stepwise Investment” (Paper #2022WR032986)

With regards to comments from the Editor:

“In agreement with the reviewers, there is some additional framing and analysis to be done for publication. Particularly, the case study is a very small watershed that may not be representative (as reviewer 2 points out) and thus generalizable -- a second case would be ideal.

Finally, the organization and writing of the paper could use improvement as pointed out by reviewers 1 and 3.

These improvements will make the paper in a place for publication with WRR which strives to publish work that the readership can use either in methods for their own research or as evidence that a research path is worth pursuing.”

Thanks for the editor’s comments. We found the reviewers’ comments helpful in revising the manuscript and have carefully considered and responded to each comment. The main contribution of this manuscript is proposing a novel idea to optimize implementation orders of BMPs under stepwise investment. The proposed framework based on this idea is free of BMP types (e.g., urban or agricultural, structural or non-structural BMPs), watershed models, optimization algorithms, and applied watershed scales. Although the case study was conducted in an agricultural watershed with a small area, key steps are representative in applying the proposed framework, e.g., BMPs are selected according to local governance experience, sampling data and theoretical curves are available to characterize time-varying soil properties and hence representing BMP’s effect during watershed modeling, detailed BMP’s economic data are available from the literature, and the watershed model and optimization algorithm developed in our previous studies are easy to extend to support BMP’s time-varying effectiveness. The current case study has proven the effectiveness of the proposed framework. We believe that the additional new case study will make the manuscript too lengthy and still face the same representativeness question that the case studies cannot cover large combinations among BMP types, watershed models, and watershed scales. Therefore, instead of adding a new case study, we revised the manuscript to add a new subsection (i.e., Section 4.5) to explicitly discuss the framework’s applicability with a brief example of customizing the SUSTAIN for urban stormwater. We hope this is fine for the editor and reviewers.

On the manuscript structure, we have reorganized Section 3 “Experimental designs” and Section 4 “Experimental results and discussion” according to the reviewers’ comments. We have invited an English professional editor to polish the language before submission. We hope that the language of the revised manuscript is of a higher standard and acceptable to the journal.

Overall, we want to thank you for the opportunity to revise our manuscript. We hope the revised manuscript is more straightforward for readers with diverse expertise to take the core contribution. In a broader sense, this study of extending BMP optimization to spatio-temporal configuration level also emphasizes and concretes the value of integrating physical geographic processes (i.e., watershed response to various spatio-temporal distributions of BMPs) and anthropogenic influences (i.e., stepwise investment). We believe this manuscript will provide the readers with a new idea and the corresponding method design.

With regards to comments from Reviewer #1:

1. ***"Perhaps it is my own bias, but when I read the title and the abstract, I expected this to be about urban hydrology BMPs (e.g., rain gardens, bioretention, permeable pavement, etc). (I think the editor also probably assumed this, as my field is urban hydrology and asked me to review.) I think making it more clear in the title and abstract that this is for optimization of erosion control forest management BMPs (or is there another commonly used term for these?) would prevent future readers from making the same mistake."***

   Thanks for the reviewer's comment. In this study, we proposed a universal framework for optimizing BMP implementation orders under stepwise investment, which is applicable not only to natural watershed BMPs but also to urban hydrology BMPs. In fact, the framework is unrelated to BMP types, watershed models, optimization algorithms, and applied watershed scales. In this study, we implemented and exemplified the framework in an agricultural watershed management issue. To implement this framework in a specific agricultural or urban application, users need only technical or engineering changes on BMP's time-varying effectiveness data and the watershed process model that supports such BMP data.

   When the BMP term is widely accepted and used in both agricultural and urban research communities, we decided to keep the original title. Meanwhile, we added a sentence in the Abstract to distinguish the method design and the specific implementation: "The proposed framework was implemented based on a spatially explicit integrated modeling system (SEIMS) and demonstrated using a small agricultural watershed case study of controlling soil erosion under a 5-year stepwise investment." We also added a new subsection to discuss the applicability of the proposed optimization framework, i.e., Section 4.5. We hope the reviewer will accept this.

2. ***"I see no reason why these methods could not be applied to optimize spatial configuration of urban stormwater BMPs, and I think a lot of readers would be interested to see an application of this. I would encourage the authors to think about a second case study that applies the methods in a different (urban) setting - this would really strengthen the paper and widen the interested audience. However, if the authors do not want to do another case study, at least adding a section on further extensions of their proposed methods to other types of BMP optimizations (urban) would help - I would recommend covering at least these points (a) that these methods could be applied in urban settings; (b) describe what inputs would change; (c) describe what might not apply / what might need to be further modified (the hydrologic model for one would need to be greatly modified; maybe discuss how these methods could be implemented in an existing urban hydrology model like SWMM or SUSTAIN (which has a BMP optimization tool already, so how does it compare?))"***

   Thanks for the reviewer's approval and suggestion. The main contribution of this paper is proposing a novel idea to optimize implementation orders of watershed BMPs under stepwise investment. The current manuscript used a case study of agricultural watershed management issues to prove the effectiveness of this framework. The basic idea and the proposed optimization framework are applicable not only to agricultural watershed BMPs but also to urban stormwater or low-impact development BMPs. As mentioned in our response to the general comment from the Editor, we believe that adding a new case study (such as urban settings) will make the manuscript too lengthy. Instead, we added a new subsection to discuss the applicability of the proposed optimization framework, i.e., Section 4.5 in the revised manuscript. The discussion covers the points suggested by the reviewer, briefly illustrated by the customization on SUSTAIN for urban stormwater as an example. We also listed the extension and application of existing optimization frameworks focused on urban BMPs as future work in the 3rd paragraph of the final section. We believe that these revisions can strengthen the paper and widen the readership.

3. ***"I found the "experimental results and discussion" section lacking. Most of the text in this section is just results, and things that someone could glean just from the plots (e.g., the entire section 4.2 is basically is regurgitation of statistics in Figure 9). Please add more discussion - what do your results mean?"***

Thanks for the reviewer's comment. We reorganized the "experimental results and discussion" section by adding discussions about the impacts of stepwise investment and time-varying effectiveness of BMPs on BMP implementation plans, respectively (Sections 4.2 and 4.3).

Section 4.2 discusses three points of the impact of the stepwise investment. Firstly, in the case study, the net present value of the stepwise investment scenarios did not significantly decrease compared with the one-time scenario in the second year. However, from the perspective of the project's start-up fund (i.e., money invested in the first year), taking the stepwise investment has apparent advantages. Secondly, the start-up fund has a positive correlation with overall environmental effectiveness. Finally, an inflection point existed on both Pareto fronts, which may be caused by lower investment in the first year than the second. Therefore, by considering stepwise investments in optimizing BMP implementation plans, the significantly reduced burden on start-up funds would practically improve the flexibility in funding during the entire implementation period. In the meantime, to achieve higher environmental effectiveness, the investments should be made extensively in the first few years (e.g., two or three years in this case study).

Section 4.3 discusses an important practical effect factor during the evaluation of BMP scenarios, i.e., the representation of BMP effectiveness data may over- or under-estimate the overall effectiveness of BMP scenarios. To minimize this bias or error as much as possible, we suggest researchers monitor BMP effectiveness data periodically and thoroughly. Meanwhile, modelers should reasonably quantify time-varying BMP data and utilize it in watershed models.

We also added a section to discuss the applicability of the proposed method (Section 4.5). See our response to the reviewer's 2nd comment.

4. ***"There are a lot of claims that are not well supported (i.e., "using the varying environmental effectiveness of BMPs was not only reasonable but could also reduce uncertainty to a certain degree." What? How did the authors get here from their results?). Please break down results more too."***

   Thanks for the reviewer's correction. Sorry for the misuse of the term "uncertainty". What we want to discuss here is not about the uncertainty since we did not research precisely measuring the "true" environmental effectiveness of BMPs, but the bias in evaluating the BMP scenario's overall effectiveness due to inaccurate representations of each BMP's effectiveness. The bias can be appropriately reduced using reasonable time-varying effectiveness data, regardless of the "true" value. We revised the manuscript accordingly.

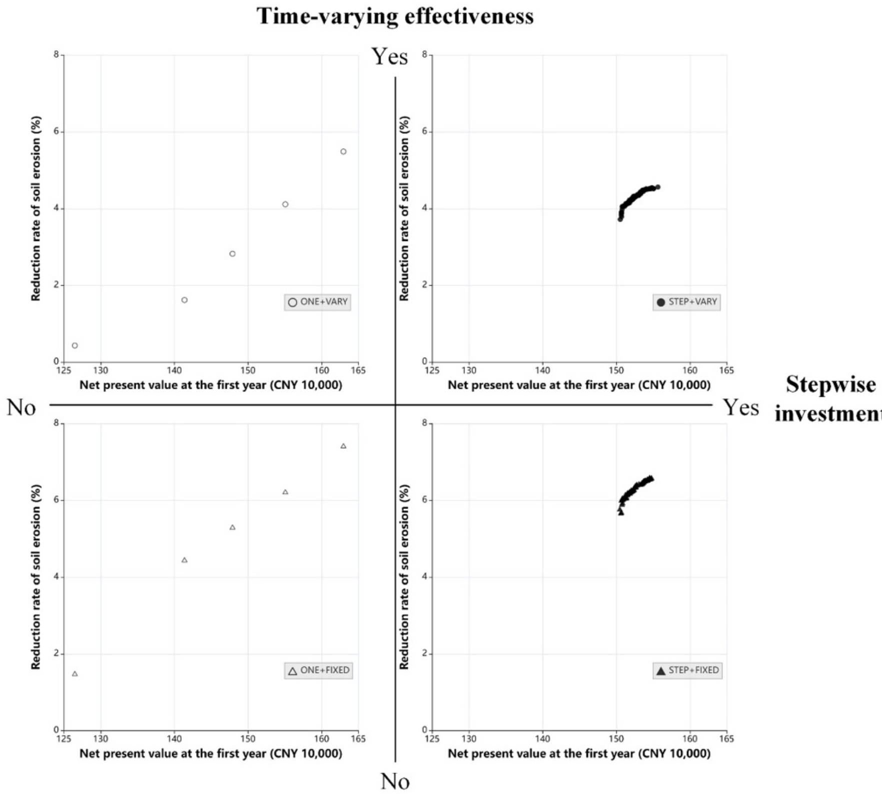
   We also added a new subsection to discuss the impact of using the time-varying effectiveness of BMPs, i.e., Section 4.3.

5. ***"There is only one figure in the results section. I would recommend breaking this down into first talking about results that assume one-time investment + fixed and varying BMP effectiveness, then talking about stepwise investment + fixed and varying BMP effectiveness (or vice versa)."***

   Thanks for the reviewer's suggestion. The plots in the figure (Figure 8 in the revised manuscript) show the overall numerical results of BMP scenarios under the two objectives (i.e., NPV and soil erosion reduction rate) in this case study. This figure intuitively presents comprehensive comparisons considering stepwise investment and time-varying effectiveness, which proves the proposed idea's validity in general. We added two subsections to discuss the results from the two dimensions, i.e., impacts of stepwise investment (Section 4.2) and time-varying effectiveness on BMP implementation plans (Section 4.3), respectively. We hope this organization is straightforward to follow for readers.

6. ***"The scenarios are hard to keep track of and this would help the reader understand the relative impact of stepwise investment. Alternatively, think of creating a 2x2 figure that has stepwise investment (yes, no) on one axis, and time varying BMP effectiveness (yes, no) on the other axis, and plotting results in matrix form."***

   Thanks for the reviewer's comment. As stated in response to the 5th comment from the reviewer, the original Figure 7 (Figure 8 in the revised manuscript) is a compact and effective representation to comprehensively compare the numerical results of the four experiments under two optimization objectives. We think this figure can give a straightforward answer to the scientific problem raised in this study, which should be better than plotting each experimental result in a 2x2 matrix that the reviewer suggested (we tried and showed it below). So, we made Figure 8 in the revised manuscript to keep the original style and modify the symbols to make it easier for readers to distinguish and compare the results of multiple experiments. We hope this will be fine for the reviewer.



7. ***"Lastly, while generally readable, the language is at times difficult to understand, with many extremely long sentences and ambiguous/vague claims; I highlight a few below. The authors may want to seek an outside editor to help read through and identify sentences to be clarified."***

   Thanks for pointing out the language problem. We had chosen the Language Editing services provided by Elsevier to polish the original and the revised manuscripts before submitting them to Water Resources Research. We hope that the language of the current manuscript is qualified.

Specific Section or Lined-Numbered Comments:

8. ***"Line 450 - 454: This entire paragraph is a single sentence; this must be broken up into more sentences."***

   We broke up and condensed the long sentence into three short sentences: "We compared and discussed the four comparative experiments from two perspectives. From the numerical perspective, we evaluated all solutions under two objectives. From the qualitative perspective, we analyzed characteristics of selected solutions considering BMP implementation orders."

9. ***"Line 455 - 457: "The numerical evaluation of BMP scenarios under the two objectives in this study referred to figures of scattered points with the two objectives as axes and the quantitative index measuring the overall quality of the Pareto fronts."***

Why is "referred to" in past tense? Is this sentence not referring to the present paper? Also, this sentence is long and confusing. Perhaps the authors mean to say "The BMP scenarios were compared by evaluating the overall quality of their respective Pareto fronts.""

Thanks for the careful checking. We are sorry for the misused tense. The phrase "referred to" should be "refers to". We rearranged the long sentence as: "In this case study, two aspects were considered in the numerical evaluation of BMP scenarios under the two objectives. One is intuitive comparison by plotting Pareto fronts from stepwise investment experiments and BMP scenarios from one-time investment experiments as scattered plots. The other is using quantitative index to measure the overall quality of the Pareto fronts, such as, the commonly used hypervolume index." We hope the revised sentences are easy to understand for readers.

10. ***"Line 499 - 501: "This phenomenon confirmed that uncertainties in BMP effectiveness over time may overestimate the long-term environmental efficiency of watershed management scenarios (Liu et al., 2018)." I am not following this. How do uncertainties in BMP effectiveness always result in overestimation of environmental efficiency? Can the authors claim that their results really show this? Seems like a safer conclusion is that overestimating BMP effectiveness may overestimate long-term environmental efficiency."***

    Thanks for the reviewer's correction. Sorry for the misuse of the term "uncertainty". As stated in response to the 3rd and 4th comments from the reviewer, what we want to discuss here is not uncertainty, but the bias or error in evaluating scenario's overall effectiveness due to different representations of BMP's effectiveness. Utilizing fixed representation of BMP's effectiveness may overestimate or underestimate the "real" effectiveness. Since the "true" effectiveness over time of BMP may hardly to measure, we suggest two ways to minimize the bias or error as much as possible: (1) monitoring BMP effectiveness data periodically and thoroughly; and (2) reasonably quantifying time-varying BMP data and utilizing it in watershed models. We moved this paragraph to the new Section 4.3 "Impact of time-varying effectiveness on BMP implementation plans".

11. ***"Line 501 - 503: Similarly, I am not following the claim that using time-varying environmental effectiveness could reduce uncertainty. There is uncertainty in any estimate of environmental effectiveness, and one could actually argue more uncertainty in a time varying estimate (which could either over or underestimate performance) than in a static estimate (which would more consistently overestimate performance). Can the authors please describe in more detail how their results constrain uncertainty?"***

    Thanks for the reviewer's comment. We think the comment is directly connected to the 10th comment. We revised this sentence and discussed the impact of determining the BMP effectiveness on evaluating the BMP scenario's overall effectiveness (Section 4.3).

12. ***"Line 581 - 582: "The optimized multi-stage BMP scenarios were much more practical and attractive for watershed management decision-making" this is pretty subjective; I would avoid such statements - did the authors interview decision makers to determine that this was more practical and attractive? I recommend sticking to the facts, e.g., "By accounting for time-varying effectiveness and stepwise investment, the optimized BMP scenarios may better reflect reality of BMP performance and costs over time.""***

    Thanks for the reviewer's suggestion. To avoid subjective expressions, we revised the sentence according to the reviewer's suggestion and moved it to the end of the first paragraph of Section 5: "By accounting for time-varying effectiveness and stepwise investment, the optimized multi-stage BMP scenarios may better reflect the reality of BMP performance and costs over time, providing diverse choices for watershed management decision-making."

With regards to comments from Reviewer #2:

1. ***"It is true that effectiveness of BMPs is time varying, but how can we get these time varying data for each BMP?"***

   Generally, environmental efficiency of BMPs can be quantified from two perspectives. The first is measuring the direct effect of BMP on its governance objective, such as the reduction rate of pollutant concentration in the surface flow out of the vegetation filter strip. The other is measuring the effect of BMP on its related geographic variables whose changes indirectly affect the governance objective. For example, measuring improvements in soil properties resulting from returning farmland to forests can be utilized in simulating the increased infiltration and reduced surface flow and soil erosion. However, all these ideal measurements based on field-controlled experiments are often time-consuming, laborious, and expensive, especially for time-varying data. Theoretical analyses based on the mechanisms of BMP (e.g., different theoretical curves shown in Figure 1) can be used as an effective supplement to a few measured data over time.

   We have added these explanations to the third paragraph of "Section 2.1 Basic idea".

2. ***"Will it be better that we implement BMPs step by step according to the time?"***

   We think the answer is "It depends, but most likely yes." It is why this manuscript proposed the new multi-objective optimization framework considering stepwise investments. The main contribution of this study is incorporating one critical realistic factor into the optimization of BMP scenarios, that is, the implementation orders of BMPs that are most likely restricted by stepwise investment. We think our study is one step forward in real decision-making support for watershed management. The decision-making process of watershed management is a process of reaching trade-offs between stakeholders with different positions. For maximum and quick environmental effectiveness, the scenario of implementing all BMPs at one time in the first year will be selected undoubtedly. However, it will cause a heavier burden on economic investment. Therefore, if a small amount of sacrifice in environmental effectiveness is acceptable temporally (maybe several years), the stepwise implementation plans that significantly reduce the financial burdens will get more attention. From this perspective, this study emphasized the value of integrating physical geographic processes (i.e., watershed response to various spatio-temporal distributions of BMPs) and anthropogenic influences (i.e., stepwise investment) in the design, implementation, and application of more flexible, robust, and feasible geospatial analysis methods.

3. ***"Line 288-289, The case study area is Youwuzhen watershed, it is only approximately 5.39 km^2. If a large watershed (over 1000 km^2) was chosen, would the framework of this paper be still working? Do some explain."***

   Yes, the proposed optimization framework is a universal framework that is not confined to a specific narrow scale of watersheds. The main technical improvements during implementing the proposed framework involve the quantification of BMP's time-varying environmental effectiveness and its representation in the watershed model, and the BMP scenario cost model. Therefore, technically, any customized watershed model and selected BMPs in any study area can be applied to this framework with necessary BMP data. It is worth mentioning that the primary concern of BMP scenario optimization in a large watershed is the construction of the watershed model and determining the appropriate BMP spatial configuration units. Another important issue of the computational performance of large watershed models can be essentially resolved by utilizing high-performance computing clusters. SEIMS has a two-level parallel computing framework to support inner- and inter-model parallelization. We added this point in the second paragraph of the new Section 4.5 "Applicability of the proposed optimization framework". We listed the extending application in large watersheds as future work in the 3rd paragraph of the last Section of the revised manuscript.

4. ***"Line 331-334, the BMPs in this case were fixed, they were closing measures (CM), arbor-bush-herb mixed plantations (ABHMP), low-quality forest improvement (LQFI) and economic fruit (EF). In my opinion, they are not typical BMPs. How about if both engineering BMPs and non-engineering BMPs are adopted together?"***

   Thanks for the reviewer's comment. We proposed the optimization framework as a universal framework unrelated to BMP types. The ability to support different types of BMPs depends on the specific implementation of the framework, especially the watershed model. That is, the watershed model can represent BMP's time-varying effectiveness which may be quantified by the effect on BMP's governance objective or BMP-related geographic variables (See responses to the 1st comment).

   The four BMPs selected in this case study are representative and successful agricultural BMPs in the study area. Some of them can be regarded as a combination of engineering and non-engineering BMPs, such as the economic fruit (EF). The EF requires not only the construction of level terraces, drainage ditches, storage ditches, and irrigation facilities, but also the plantation of economic fruit, grasses, and Fabaceae plants (See Table 1). In the case study, the environmental effectiveness of each BMP is regarded as a whole to be quantified by BMP-related geographic variables (e.g., soil properties) and utilized in the watershed model.

   Engineering BMPs (also known as structural BMPs) may have significantly different time-varying effectiveness from non-engineering (or non-structural) BMPs. For example, they may take effect immediately after implementation and achieve periodic high effectiveness over time under maintenance operations. Therefore, it will be meaningful to consider structural and non-structural BMPs in practical application cases. We added this point in the second paragraph of the new Section 4.5 "Applicability of the proposed optimization framework". We listed this point as future work in the 3rd paragraph of the last Section of the revised manuscript.

With regards to comments from Reviewer #3:

1. ***Line 24, Two blankets between "management scenario," and "which are..."?***

   Thanks for the careful checking. We confirmed that there is indeed only one blank. Because of the left alignment formatting of the paragraph, the whitespace here looks slightly wider. We have modified the formatting attribute of paragraphs to "justify text".

2. ***In Figure 1, please explain the meanings of sub-figures, a, b,...***

   We added explanations to the sub-figures in Figure 1: "(a)–(f) represent the linear, piecewise linear, logarithmic, exponential, polynomial, and logistic changes of BMP effectiveness over time, respectively."

3. ***Line 202, Please give an example of "X(k) × 1000 + T(k)".***

   To keep the consistent illustration of the reversible encoding method in Figures and Equations in the revised manuscript, we changed the reversible encoding method to "$E = X(k) \times 10 + T(k)$" (included in Equation 2) and added an example in the caption of Figure 3: "if $X(k) = 4$, and $T(k) = 3$, the encoded value is 43."

4. ***It is suggested that the sections 3.1, 3.2, 3.3, 3.4, and 3.5 are integrated to the corresponding position of Section 2 "method" because they also belong to material and methods. Section 2 is revised "Materials and methods". Please superscript of km2 in Line 288.***

   Thanks for your suggestions. In general, this manuscript followed the "IMRaD" structure: the introduction, methods, results, and discussion. This study mainly focuses on designing a new optimization framework for implementation orders of BMPs with time-varying effectiveness under stepwise investment. The Methods section aimed to introduce the proposed method broadly and clearly and thus may include some specific implementation in this study.

   Therefore, in the revised manuscript, we set "Methods" and "Experimental designs" sections other than one "Materials and methods" section to highlight the universal design of the proposed framework, i.e., the proposed method can apply to both agricultural and urban watersheds based on suitable technical chains. The "Experimental designs" with the following "Experimental results and discussion" section together make up the whole case study. We hope this structure is acceptable and helpful for readers.

   The "km2" has been corrected to "km^2".

5. ***In Figure 5, please revise type or color of lines of subbasin to differentiate it from that of 10m contour.***

   We changed the style of 10m contours to the dashed line in Figure 5.

6. ***Line 312, Please denote which soil properties and land use/land cover-related parameters are derived and referenced. What instruments are used to derive soil properties?***

   We revised these sentences to include examples of soil properties and land use/land cover-related parameters: "Each soil type properties were measured from field samplings (e.g., organic matter and mechanical composition; Chen et al., 2013) and derived from the Soil-Plant-Air-Water (SPAW) model (e.g., field capacity and soil hydraulic conductivity; Saxton and Rawls, 2006). Land use or land cover-related parameters were referenced from the SWAT database (e.g., Manning's roughness coefficient; Arnold et al., 2012) and relevant literature (e.g., cover management factor for the universal soil loss equation [USLE]; Chen et al., 2019)".

   We collected the measured data from qualified third-party studies which utilized standard methods, for example, measuring soil organic matter using the potassium dichromate oxidation method and measuring bulk density and porosity using soil sample rings. Therefore, the instrument details are not included in the revised manuscript. We hope this will be fine with the reviewer.

7. ***Line 315, "and precipitation" is suggested to be deleted because it belongs to meteorological data, or "meteorological data" should be revised as others.***

   Thanks for the comment. We revised the introduction of "meteorological data" from data sources, i.e., daily climate data (including temperature, relative moisture, wind speed, and sunshine duration hours) from the nearest national weather station and daily precipitation data from one local monitoring station.

8. ***The last two paragraphs in Section 3.1 should be placed to other section(s) because they are inconsistent with the content of "3.1 Study area and data".***

   Thanks for the comment. We moved and revised the two paragraphs to the new Section 3.3 "Calibrated watershed model and selected BMP scenario from the former study". We also added a figure (Figure 6 in revised version) to illustrate the spatial distribution of the selected BMP scenario from our former study. Also, please see our response to the 13th comment.

9. ***Line 384, Does V(S, t) refer to the amount of soil erosion in outlet of the watershed or a spatial unit? I think it is necessary to obtain the amount of soil erosion in each spatial unit for the optimization. If so, how do you determine it in each spatial unit?***

   The $V(S, t)$ refers to the amounts of sediment yields from hillslope routed into the channel, rather than the sediment exported from the outlet of the watershed. The reason of not using the sediment exported from the outlet of the watershed is excluding the influence of sediment routing process in the channel. We revised this sentence to make this meaning clearly.

As shown in our former study (Zhu, Qin, et al., 2019), BMP configuration units are not necessarily consistent with watershed models' basic simulation units (e.g., gridded cells). The watershed model simulates soil erosion on basic simulation units, whose parameters are affected by configured BMPs. We agree with the reviewer that the amounts of soil erosion in each BMP configuration unit configured with each alternative BMP are necessary for the optimization. However, the optimization objective in this study is from the perspective of the entire watershed, not individual BMP configuration unit. Seeking each BMP configuration unit to be configured with the most effective BMP is another basic idea for performing BMP scenario optimization. This idea is often studied in single objective optimization, which can hardly fit the practical needs discussed in this manuscript.

10. ***Line 391, Please give the specific initial construction cost, annual maintenance cost, and annual benefit per unit area of each BMP? Or how did you determine them?"***

The economic data of BMPs in Table 2 in the original manuscript referred to the investigation conducted by Wang (2008). We added citation texts in the proper places in the revised manuscript.

11. Line 350, The sentence is too long. Please divide it into two or more sentences.

We simplified this sentence: "Other derived properties and parameters utilized in the SEIMS model were prepared accordingly, including the total porosity and soil erodibility factor." We hope it will be easy to follow.

12. Line 549, "Figure 9a-c demonstrates" should be "Figures 9a-c demonstrated". Line 552, "Figure 9a-c demonstrates" should be "Figures 9a-c demonstrated".

Thanks for your careful checking. We corrected the misused verb tense in Section 4.4 and other places in the revised manuscript, e.g., "Figures 11d–f demonstrated". Figure 9 in the original manuscript corresponds to Figure 11 in the revised version.

13. In Figure 9, the explanation of (a)-(c) and (d)-(f) in the title of the figure is inconsistent with the content of the figure. How did you determine the spatial units? The seven sub-figures in Figure 9 show the same distributions of BMPs with different time-varying implementation. I think different scenarios should show different BMP distributions and different time-varying implementation in a spatial unit selected from the Pareto front. The spatial units without BMPs for all scenarios are the same. What are land use types in these spatial units? These spatial units are suggested to not be encoded (=0) in a chromosome to reduce a large quantity of calculation loads if they are same.

To perform the optimization on the temporal dimension and evaluate the impact of stepwise investment and time-varying effectiveness of BMPs on the BMP implementation plans, we selected an optimized BMP scenario (Figure 6 in revised manuscript) from Zhu, Qin, et al. (2019) as the fundamental spatial scenario. That is, the case study only optimizes the implementation time of BMP configured on slope position units. Differentiated by the legend of Figure 9 (Figure 11 in the revised manuscript), every sub-figure can be further divided into five sub-figures, each representing the spatial configuration of BMPs implemented yearly. In that way, each sub-figures will have different spatial distributions. However, the figure will become tedious. We added a figure to illustrate the spatial distribution of the selected BMP scenario in the new Section 3.3 in the revised manuscript and kept Figure 9 (Figure 11 in the revised manuscript) as it was. We hope this will be fine with the reviewer.

As stated in response to the reviewer's 9th comment, we adopted different spatial units for configuring BMP and performing watershed modeling. If one slope position unit is configured with BMP, each gridded cell within this slope position unit with suitable conditions (e.g., land use type) for the BMP will update related parameters in watershed modeling. Therefore, each BMP configuration unit may have multiple land use types that are all recorded in the input file of spatial units for running the BMP optimization tool. Interested readers can refer to Zhu, Qin, et al. (2019) for detailed information.

In the circumstance of the case study, these spatial units without BMPs can indeed be excluded from the chromosome to improve computational efficiency. But we have designed a screening step to only allow initialized and regenerated scenarios satisfied constraints to be evaluated (Figure 2), which can also save time for unnecessary execution of watershed models. Besides, keeping the length of chromosome the same as the count of BMP configuration units ensure the generality of the proposed framework to perform spatial and temporal optimization simultaneously.

14. ***"Line 574, "Figure 9c and f" should be "Figures 9c and f". Line 635, "sptio-temporal" should be "spatio-temporal".***

    We fixed these mistakes in the revised manuscript. Thanks for the careful checking.

15. ***The positions of the first names and the family names are different in the references. The "-" is suggested to be deleted in the family names of the reference "Zhu, L.-J., Liu, J., Qin, C.-Z., ..." and other references.***

    Thanks for the careful comment. We thoroughly checked the references and corrected these misused symbols and other formatting errors.