

Dübendorf, 18. January 2022

Response to referee # 1 and editors

Dear Referee, dear Editors

Thank you very much for reviewing our manuscript:

Judit Lienert, Jafet Andersson, Daniel Hofmann, Francisco Silva Pinto, Martijn Kuller, “Can MCDA guide transdisciplinary endeavors? A framework applied to co-developing a flood forecasting system in West Africa”. hess-2021-506

This manuscript was written for the HESS Special Issue “**Contributions of transdisciplinary approaches to hydrology and water resources management**”

We are grateful for the work that has gone into reviewing our paper. We know that this takes a lot of time, which receives no direct reward. Your suggestions are very constructive and most welcome. We have done our best to improve the manuscript based on your inputs.

We have addressed your comments one-by-one below. *The referees’ comments are given in Italics*, our response is given in normal font.

We have a general concern regarding coherence between the two referees. Referee # 1 asks for extending several parts (comments # 3 – 9). In contrast, referee # 2 has “major concerns regarding the text length” and proposes to “eliminate the unnecessary parts of the text so that the necessary ones can ‘speak’” (e.g., comments # 3, 8, 27). At the same time, referee # 2 acknowledges that this paper contains a lot of information that could actually be presented in two separate papers (comment # 4).

We agree with referee # 2 that clarification and restructuring increases the papers’ understandability and followed the concrete suggestions, e.g., to rewrite the Abstract and restructure the Introduction (e.g., comments # 3, 4, 5, 6, 8, 22, 26, 28). Specifically, we now follow a traditional set-up for the Introduction (comments # 5, 6, 22, 26).

We do not wish to split the paper into two, because this was what we already had in an earlier version (focusing on the development of the FEWS using MCDA). We think that the more holistic approach encompassing the transdisciplinary framework and MCDA is beneficial and can raise broader interest, especially to readers that are not specialists (on MCDA and transdisciplinary projects). However, we see that the paper is long, and have substantially shortened it by 2’024 words (see referee # 2, comments # 3, 8, 10, 20, 22, 27, 28). For length reasons, we propose to not add additional text, e.g., an overview of

MCDA methods (see referee # 1, comment # 3; and referee # 2, comment # 9). Further shortening seems critical, and we wish to avoid this. Reasons are:

- a) The review of literature from transdisciplinary research and sustainability science is needed as background information and for coming up with a framework. Because we review all this literature, there are many references.
- b) Presenting MCDA is needed for readers of HESS that are likely unfamiliar with an MCDA process. We would not do this in such detail in a Decision Analysis journal. This includes a short review of MCDA in flood management, motivating a typical MCDA process, MCDA method explanations in the Methods section, and a brief overview of main MCDA results in the Results section. We kept this as short as sensibly possible, much additional information is given in the Supplementary Information.
Several comments of referee # 1 indicate that more-detailed information of the MCDA method would be appreciated (comments # 3 – 7). We suggest to refrain from this for reasons of length.
- c) The discussion is long, because we combine all these aspects. Especially section 5.2 “Suitability of the MCDA process for guiding large transdisciplinary projects (RQC)” is long. We shortened it, but more would probably make many insights difficult to understand, and we think that the explanations are needed to “add meat” to Table 4; the table was much appreciated by reviewer # 2 (comment # 34).

We hope that the length is now acceptable, and sincerely hope that we were now able to meet the referees and editors requirements for publication of our paper in HESS.

With best regards,

Judit Lienert

also on behalf of my co-authors, Jafet Andersson, Daniel Hofmann, Francisco Silva Pinto, and Martijn Kuller

Anonymous Referee #1

Citation: <https://doi.org/10.5194/hess-2021-506-RC1>

- 1) *The draft manuscript provided an interesting approach to designing a transnational/regional flood forecasting system using MCDA. This is a rather new approach to integrating user requirements on systems design considering the large scale and engagement of many transnational stakeholders. Whilst, MCDA has been used in environmental topics such as to assess vulnerability, risk and decision making in finding the best solutions.*

The approach built upon the concept of inter and transdisciplinary research, integrating stakeholders' expert opinions with scientifically sound facts. The development of the system started with stakeholder analysis to identify the right stakeholders to include in the process. The requirement for the MCDA was then defined in a participatory manner, the objectives/criteria, attributes/indicator and weights.

In general, the important concepts has been sufficiently described in the manuscript.

Response: Thank you for the overall positive assessment of our work.

- 2) *There is however a concept that I think was misleading. On page 9 line 233 –“ As first step of the MCDA process, we undertook a stakeholder analysis (e.g., Grimble and Wellard, 1997;Lienert et al., 2013;Reed et al., 2009), which is often neglected in MCDA projects.”, Page 25, line 577, “..MCDA...it can be very suitable for identifying stakeholders” and similarly in page 28, line 682-683. In my perspective stakeholder analysis is important when you do any participatory research works and MCDA is a technique to integrate different criteria to select the best possible options. Hence it is not always that MCDA equates to stakeholder identification.*

Response: Thank you; our formulation seems misleading. We fully agree that stakeholder analysis is useful for any type of participatory research. By no means did we mean to imply that the method is unique to MCDA. However, as detailed in various parts of the paper, we understand MCDA as an entire (transdisciplinary) process, which includes stakeholders at various stages of this process. We do not regard MCDA solely as a technique to integrate different criteria.

For instance, we wrote on **p. 2, line 57 (now p. 2, line 50, reformulated in revised version):** “To organize such a transdisciplinary endeavor involving many stakeholders, a comprehensive Multi-Criteria Decision Analysis (MCDA) process can be suitable (Belton & Stewart, 2002; Eisenführ et al., 2010; Keeney, 1982). It should include problem structuring methods (Rosenhead & Mingers, 2001).”

One such problem structuring method is stakeholder analysis. We wish to emphasize that the paper is based on this understanding of MCDA as a transdisciplinary process.

Please see the aims, **p. 6, line 174: “Aim (2):** Evaluate the suitability of participatory MCDA as a transdisciplinary process.”

We addressed your concern by clarifying as follows on **p. 7, line 185:** “As first step of the MCDA process that includes problem structuring, we did a stakeholder analysis (e.g., Grimble & Wellard, 1997; Lienert et al., 2013; Reed et al., 2009), which is often neglected in MCDA. Identifying stakeholders is crucial in any participatory project.”

- 3) *To improve the manuscript, I would suggest providing a brief review of different MCDA techniques such as SAW, TOPSIS, etc. and to elaborate on why the choice of the compensatory method used in FANFAR.*

Response: We understand that it can be interesting to provide an overview of different MCDA methods. However, referee # 2 clearly asked us to shorten the paper, so adding additional text seems counter-productive. Referee # 2 addressed your suggestion (comment # 9): *“I disagree with referee 1 that asks for a review of standard MCDA methods (there are several of these out there). On the other hand, I agree with referee 1 that the choice for the compensatory method should be clarified.”*

We therefore decided to follow referee # 2 with our answer: *“Thank you for supporting a decision that we had made in an earlier version of this manuscript. For length reasons, and because we do not find it necessary, we will not introduce the many different possible MCDA methods. It would entail describing advantages and disadvantages of e.g., AHP, different outranking methods (PROMETHEE, ELECTREE, etc.), and newer approaches such as TOPSIS, additionally to MAVT/MAUT. We cite a classic textbook and a review paper from hydrology that both provide overviews of methods:”*

p. 4, line 112: *“MCDA is well suited to address this challenge and embraces various methodologies to support complex decisions (e.g., Belton & Stewart, 2002; de Brito & Evers, 2016).”*

Response regarding “compensatory method”: We wish to emphasize that we did NOT choose a compensatory method. Rather, MAVT/MAUT is very flexible regarding the mathematical (aggregation) model. It is only fully compensatory if standard linear additive aggregation is used. We describe our non-additive, i.e., non-compensatory approach in the Methods section 3.1.7:

p. 11, line 326: *“While easy to understand, the additive model entails strong assumptions, e.g., that objectives are preferentially independent (Eisenführ et al., 2010). Increasing evidence indicates that many stakeholders do not agree with model implications (Haag et al., 2019; Reichert et al., 2019; Zheng et al., 2016). Additive aggregation implies that good performance on one objective can fully compensate for poor performance on another. In the FANFAR weight elicitation sessions, we asked stakeholders, (...)”*

We agree with both referees that this was unclear. We added this advantage as point (v) to the (new) **literature section 2.2, p. 5, line 125:** (v) *“MAVT and Multi-Attribute Utility Theory (MAUT) are mathematically very flexible. Usually linear additive aggregation is applied, but many non-compensatory models are possible, which may better represent stakeholder preferences (Haag et al., 2019; Reichert et al., 2015; Reichert et al., 2019).”*

- 4) *Similarly, also for the weighting method. Please also elaborate more clearly on how the value function curve for the attributes was derived. In a participatory manner and what is the process? On page 13 line 347, here it presented that seven evenly spaced levels were created for the sub-attribute (worst, very bad, bad, neutral, good, very good, and best). This attribute level was transformed from 0-1 values using linear interpolation. Having a linguistic term, why was the Fuzzy set theory (Chen and Wang 1992) not considered in converting it to crisp number values?*

Response: We fully understand your request, but are in a dilemma here. Providing more information on elicitation procedures will inevitably increase the length of the paper, which we wish to avoid (see comments by referee # 2 regarding length). For weighting, we used standard methods (see our response to your comment # 5).

We described how we elicited the shape of marginal value functions from experts in the **main text, former sect. 2.2.8 (now sect. 3.1.6)**, which covers nearly half a page (**p. 10, lines 286–299**). For reasons of space, we think we should not elaborate further on how the value functions were constructed in the main text. We specifically refer to the **Supplementary Information**. Note, in the case of marginal value functions, we did not ask the workshop participants for their preferences. We often do this in workshops in other case studies, usually using the standard bisection method for elicitation (Eisenführ et al., 2010). However, in the FANFAR case, we were convinced that expert input is required, and that the workshop participants who were not familiar with many of the attributes could not have provided meaningful answers to our elicitation questions. see:

p. 10, line 292: “In FANFAR, most attributes are technical, requiring expert knowledge. We thus elicited shapes of value functions from experts (sect. 3.1.5; details, including figures of value functions, see sect. SI-2.4.1).”

Moreover, the attributes were complex; many of them consisted of several sub-attributes. We provide an overview in **Figure 2**; the sub-attributes are to the far right. The predictions for each attribute and the corresponding value functions were constructed carefully together with the different experts, who had a deep understanding of the FEWS and the respective attributes. Unfortunately, it is not possible to convey this information in a few simple sentences in the main text.

In the **Supplementary Information**, we provide **26 pages** regarding the attributes and marginal value functions. For each of the 10 attributes, we show in detail on 1–2 pages how it was constructed; including about 2 figures and 2 tables for each attribute. This information starts on **p. 26 with section SI-2.4. “Predicting performance of each system configuration”**, and ends on **p. 52 with section SI-2.5 “Marginal value functions”**. We think that this information is useful and provides the raw data background that allows verifying our results and replicating them (if ever anybody would be interested in doing so). However, we do not think that this type of raw data information should enter the main text.

Furthermore, you propose using fuzzy set theory to deal with uncertainty. This is one possibility; we chose to work with **probability theory**. Arguments for using probability theory when working with Multi-Attribute Value Theory (MAVT) or Utility Theory (MAUT) are detailed in the paper Reichert et al. (2015). We think it is out of bounds here to go into further details. Regarding the practical information on how we did it: we provided all necessary details regarding uncertainty of the raw data in the aforementioned sections in the **Supplementary Information**. Each attribute has a sub-header **“Uncertainty of predictions”** where the very interested reader can find this information.

5) *Page 13, line 355, elaborate why two methods for weighting was used for different language groups. Why Swing and Simos?*

Response: Both Swing and Simos’ revised card procedure are standard, well-validated weight elicitation methods, and we provide the according references. Main reason for using two different methods in the language groups is practical. Weight elicitation was run in two parallel sessions in the workshops: one decision analyst (J. Lienert) speaks French, and is most familiar with Swing (or the Trade-off method), which is why Swing was used in the French speaking groups. The other analyst (F. Silva Pinto) speaks English and is most familiar with Simos’ card procedure. Additionally, we were interested if results might be different.

A justified criticism could be that using different weight elicitation procedures might lead to systematic biases between the groups, since there is some experimental evidence that different weight elicitation procedures might lead to different weights. We have published

a paper on this: Lienert et al. (2016). However, although this can be relevant, in FANFAR it was most important to cover a broad range of possible preferences and test, whether such different preferences might lead to another best performing alternative. As the results of the sensitivity analyses showed, this was not the case: even when using maximal and minimal values of weights elicited from the workshop participants in cases where they were uncertain, the results concerning best-performing system configurations were robust. Please see the results of the sensitivity analyses in sect. 4.7.

Additionally, there is no evidence for a systematic bias occurring due to using different weight elicitation procedures in the French and English speaking groups. One group deviated most strongly from all other groups, namely the French speaking emergency managers (group 1. *Emergency-F*). This group also deviated very strongly from the two other French-speaking groups (2A. *Hydrology-F* and 2B. *Hydrology-F*). Put differently: the two other French-speaking groups 2A and 2B had weights that were more similar to the English speaking groups. We suggest not putting this information in the main text, since it would make it even longer.

6) *Page 15, line 403, how did you come up with 1,000 Monte Carlo Simulation? Please elaborate on the combinations*

Response:

1'000 Monte Carlo simulation runs is a sufficiently large number to capture also smaller deviations in the results of this type of MCDA. More accuracy regarding the uncertainty over attribute predictions does not necessarily provide additional information about best-performing FEWS configurations). Moreover, 1'000 runs is the maximum available in the ValueDecisions app. We did run the analyses with lower numbers and did not get strongly different results. Nevertheless, we decided to use the maximum 1'000 runs because these gave the best resolution and clearest image of the differences between alternatives.

Please see **Figure 6**, which indicates that 1'000 runs suffice to decide which system configurations systematically achieve the top ranks.

We reported this result, now on **p. 20, line 464**: "Including the uncertainty of expert predictions in MCDA with Monte Carlo simulation clarified results. The FEWS *b. Resource friendly* and *f. Robust* performed well, achieving highest ranks for all stakeholder groups in 1'000 simulation runs (Fig. 6; details Table SI-34). The FEWS *i. Calibrated*, and *j. Calibrated + EO*, achieved good to medium ranks for most groups in most runs. Poor performance was achieved by *a. Status quo* (except group 1. *Emergency-F*), and *d. Fast alerts*, which hit the last ranks in most simulation runs. The remaining FEWS performed somewhere in between."

Because the weights enter the MCDA model on equal footing, these tend to have a stronger influence on the results. In our case, sensitivity analyses indicated that results were especially sensitive to the aggregation model (**see Table 2**), but again this was insufficient to provoke many rank reversals regarding the three best-performing FEWS configurations.

7) *Page 21, line 514, were you able to capture in context why the differences in weight preference? This may give you additional insight into the stakeholders' perspectives.*

Response: Thank you for this important observation. Indeed, we were highly interested in this stakeholder perspective. We were able to discuss with the workshop participants, the

hydrologists and emergency managers, why the objectives were particularly important or unimportant to them. We provided some of this information in the main text, e.g.:

Results, former p. 20, line 499 (now p. 18, line 435): “Again, group 1. *Emergency-F* was exceptional in assigning much lower weights to objectives they considered unimportant (objectives 23, 31, 41, and 43). They argued that the goal in emergencies is to save lives, and FEWS development should focus on achieving fast access to flood alerts (22. *Timeliness*; $w = 0.21$) and on personnel that can deal with this information (42. *Skilled labor*; $w = 0.25$).”

Discussion, former p. 26, line 613 (now p. 24, line 554): “All groups regarded several languages as unimportant in weight elicitation, despite discussing in the plenary that language diversity is crucial. When asked to make trade-offs, they were willing to give up language diversity to achieve accuracy. They were also willing to trade-off higher operation and maintenance costs (except 1. *Emergency-F*) and development time in return for receiving a functioning, precise FEWS.”

For reasons of space, it was not possible to provide all details of the discussions in the main text. We provided it in the **Supplementary Information: p. 8, Table SI-3**. For each group, we summarized where they agreed (and why, if they spoke about this), and where there were reasons for disagreement. This informed the sensitivity analyses; see main text:

Former p. 14, line 362 (now p. 11, line 307): “We took the mean as main weight and considered strong deviations (difference in weights > 0.2 compared to mean) in sensitivity analyses (sect. 3.1.8). For Simos’ card, two additional weight sets resulted from eliciting a range for one variable. The moderator recorded important comments to inform sensitivity analyses (Table SI-3).”

8) *Page 33, line 791, many were satisfied with its performance during the rainy days of the year 2020. Were you able to gain some information on some numbers of true and false predictions? This may be helpful to correlate with the satisfaction of experts.*

Response: Thank you for this important remark. We are currently carrying out a systematic daily reforecasting experiment covering 1991–2020 for five different model configurations. The experiment is still ongoing, but when results are available, we will publish them and try to link them to the expert satisfaction as suggested. We shortly added this information to the revised Discussion section:

p. 30, line 694: “Stakeholders were quite satisfied with the FANFAR FEWS performance during the 2020 rainy season (Fig. 7). While not meeting requirements of extensive discussions, it was the best available approach. We are currently carrying out a systematic daily reforecasting experiment covering 1991–2020 for five model configurations, and aim to link results to expert satisfaction.”

9) *Page 33, line 805, any discussions on how the FANFAR Flood forecasting system be maintained in the far future?*

Response: This is indeed a very important question for the practical future of the FANFAR FEWS. We included short information in the Discussion section concerning the

main strategy for future sustainability. However, we wish to point out that in-depth discussion of this topic is out of scope of this paper, and will make even longer, which is very much opposed to the comments by reviewer # 2. See new text:

p. 31, line 724: “To secure future sustainability of the FANFAR FEWS, a set of dialogues with potential financiers were held, and 12 proposals were submitted to date. Four were successful so far, providing funding for some parts of FANFAR (e.g. hydrometric stations by AfDB, additional training by Sida and EDF via ECOWAS). The sustainability strategy focuses on financing (of operations, maintenance, dissemination, technical development, etc.) and importantly on long-term collaboration, capacity development, transfer of responsibilities, and on anchoring FANFAR in the routines of West African institutions. As one example of **societal impact**, NIHSA (Nigeria Hydrological Services Agency) reported that an early FEWS warning in September 2020 saved approximately 2’500 lives. The warning helped evacuating five communities before the flood destroyed more than 200 houses.”

10) *I also find that the drafted manuscript needs revisions on the flow of thought in writing. Please see across the manuscript. Numerous contexts are somehow incoherent. Such examples were:*

page 2, line 31, “Worldwide, good operational flood forecast systems, giving accurate, timely, precise, and understandable forecast information and alerts, provide effective and affordable help to anticipate and minimize flood impacts (Perera et al., 2019).”

Response: Thank you for helping us to improve the papers’ coherence. We reformulated these sentences and checked the entire text (not all examples listed here, please see track changes in main text).

p. 1, line 29: “Good flood early warning system (FEWS) help minimizing flood impacts (Perera et al., 2019); good means they give accurate, timely, and understandable information, and are affordable.”

page 29 line 707 “ When creating FANFAR system configurations, it became evident that e.g., frequent power cuts and slow internet in West Africa need consideration. Multi-Attribute Value Theory (Eisenführ et al., 2010) allows later including system configurations (Reichert et al., 2015). “.

p. 27, line 622: “The **context-based principle** of co-production includes asking for constraining factors (Norstrom et al., 2020): when creating FEWS, the necessity of considering the West African situation became evident, including power cuts and slow internet. Moreover, we realized that stakeholders had not created all potentially interesting FEWS configurations. An advantage of Multi-Attribute Value Theory is that options can be included later (Eisenführ et al., 2010; Reichert et al., 2015). The FANFAR consortium created additional FEWS (...).”

Page 27, line 660, I do not see the relevance on mentioning the MCDA in building collaborative research “...In the FANFAR project, building the collaborative research (or project) team with consortium partners from Europe and West Africa was achieved (step 1a, Table 1), but not by MCDA...” The statement somehow does not fit.

p. 25, line 583: “**Building the collaborative research team** cannot be attributed to MCDA, although it was achieved by the FANFAR project (step 1a, Table 3). Two key West African stakeholders were consortium partners from the start: AGRHYMET (...).”

Other comments:

11) *For some parts, the literature, section and abbreviation/text referencing are cited almost every after sentence. This becomes inconvenient to read. Such example is page 42, line 688 “To foster joint understanding, commitment, and trust, many of 31 analyzed transdisciplinary projects provided e.g., trainings, or attractive visualizations of recent research (Schneider et al., 2019). Capacity building can be promoted by working in integrated ways of knowledge coproduction discussed above (Caniglia et al., 2021), or with capacity building courses (Wuelser et al., 2021). The FANFAR project offered many training and capacity building opportunities, which cannot be attributed to MCDA.”*

Response: We understand that reading the text with many literature citations is bumpy. However, we do find it important to cite the appropriate references in the correct places, especially since they come from different fields that are less familiar to most readers of HESS. The examples above stem from the transdisciplinary literature. We think that this unavoidable. However, we carefully checked the text and tried to avoid citations within sentences.

12) *Page 18, line 468, table 2 text description can be presented as a footnote below the table rather than as part of the caption. Same for table 3 and others*

Response: We understood that HESS asks to avoid footnotes wherever possible, and we followed this requirement.

13) *Page 19 “..g_Attractive Most attractive in West Africa:...” This I do not understand.*

Response: Thank you for pointing this out. Table 1 (former Table 2) was revised, including simpler names for the FEWS configurations. For reasons of length, not all features can be presented in full detail in the main text; very interested readers are referred to the Supplementary Information. In this example, we changed the name of the FEWS configuration to: “*g. Attractive*”; and the description now includes to whom this system is most attractive: “Most attractive to West African stakeholders: includes many desired features, similar to *h. Fully equipped*, but simpler distribution.”

14) *Page 24 Figure 7. I see no value of information of having colors of dots.*

Response: The colors of the dots represent unique respondents, enabling a comparison of answers across the three questions for each respondent. We attempted to explain this in the figure caption:

p. 21, line 502: “Colored dots represent unique respondents (N = 12; 63% of 19 participants)”.

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Dübendorf, 18. January 2022

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MCDA methods (see referee # 1, comment # 3; and referee # 2, comment # 9). Further shortening seems critical, and we wish to avoid this. Reasons are:

- a) The review of literature from transdisciplinary research and sustainability science is needed as background information and for coming up with a framework. Because we review all this literature, there are many references.
- b) Presenting MCDA is needed for readers of HESS that are likely unfamiliar with an MCDA process. We would not do this in such detail in a Decision Analysis journal. This includes a short review of MCDA in flood management, motivating a typical MCDA process, MCDA method explanations in the Methods section, and a brief overview of main MCDA results in the Results section. We kept this as short as sensibly possible, much additional information is given in the Supplementary Information.
Several comments of referee # 1 indicate that more-detailed information of the MCDA method would be appreciated (comments # 3 – 7). We suggest to refrain from this for reasons of length.
- c) The discussion is long, because we combine all these aspects. Especially section 5.2 “Suitability of the MCDA process for guiding large transdisciplinary projects (RQC)” is long. We shortened it, but more would probably make many insights difficult to understand, and we think that the explanations are needed to “add meat” to Table 4; the table was much appreciated by reviewer # 2 (comment # 34).

We hope that the length is now acceptable, and sincerely hope that we were now able to meet the referees and editors requirements for publication of our paper in HESS.

With best regards,

Judit Lienert

also on behalf of my co-authors, Jafet Andersson, Daniel Hofmann, Francisco Silva Pinto, and Martijn Kuller

Anonymous Referee # 2

Citation: <https://doi.org/10.5194/hess-2021-506-RC2>

- 1) *In this interesting manuscript, the authors have conducted a brilliant participatory MCDA study. The topic is exciting and meaningful. Furthermore, the methodology applied is robust and innovative, and the final outputs are of good quality. The authors are thorough in their investigation (e.g. by conducting uncertainty analysis), which I really appreciate. The graphs and Figures produced summarize well the outcomes. In summary, the research conducted is outstanding.*

Response: Thank you very much for this very positive appreciation of our work.

- 2) *However, the use of abbreviations for the different configurations of the FEWS system makes it very hard to follow.*

Response: We agree and adapted the short names. Please see comments # 7, 30, 31

- 3) *Furthermore, I have some major concerns regarding the text length. It currently has 40 pages, which is too much. Because of that, the article currently lacks focus. Especially the abstract and introduction should be revised to reflect the work that was done. The ability to simplify means eliminating the unnecessary parts of the text so that the necessary ones can "speak".*

Response: We very much appreciate this feedback. Since the paper contains many different aspects, it was difficult to keep the paper short; please see our comment to both referees and the editors in the letter above. We aimed to (a) provide a framework for analyzing MCDA by reviewing the literature from transdisciplinary research and sustainability science, (b) introduce readers not familiar with MCDA to an MCDA process and describe methods and results in sufficient detail; and (c) discuss these aspects, especially the suitability of the MCDA process for guiding large transdisciplinary projects (sect. 5.2).

Apparently, HESS does not have length limits; but simplifying is always a good idea. We followed the concrete suggestions wherever possible. We rewrote the Abstract and revised the Introduction as suggested. We also streamlined the research questions into the two main aspects as proposed (see comment # 4). We reduced the text length by 2'024 words. The manuscript now has 37 pages. We wish to point out that the main text ends on p. 32. We have many references because we review the literature from different fields. Further length reduction would probably mean deleting larger parts of the Discussion sect. 5.2. We think that this might reduce the understandability and wish to avoid this (see letter to editors, above, and comments # 8, 10, 20, 22, 27, 28).

Main comments

- 4) *The abstract should be revised entirely. Currently, it is not possible to follow it due to vagueness. I understand that the authors have done some exciting research and want to show all of it. However, when reading it for the first time, I could not grasp what the paper was about. Please see the specific comments for details on how to improve it. In general, I would say your research has two main complementary goals: (1) the development of the FANFAR flood forecasting system using MCDA and problem structuring, and (2) analyzing the suitability of MCDA in transdisciplinary projects. These could even be two separate papers....*

Response: We revised the Abstract and appreciate your specific comments. Despite the trend to increase the number of publications, we decided not to split the paper into two. We think the more holistic approach is beneficial and can raise broader interest, especially to readers that are not specialists (on MCDA and transdisciplinary projects). Furthermore, we wish to point out that we added goal (2) specifically as a reaction to reviews of an earlier version of the paper, which focused on goal (1).

We appreciate your precise formulation of the two complementary goals of our paper. Thank you! We have used these to structure the research questions in sect. 2.3. We included them in the Abstract, which we have re-written (also see point # 11 below).

5) *The introduction follows a very fuzzy order that makes it harder for the readers to read. The authors come back and forth, which makes the text longer. I would suggest using the traditional “formula” for the introduction: (1) What is the problem? (2) Are there any existing solutions (i.e. in the literature)? (3) Which solution is the best? (4) What is its main limitation? (i.e. What gap am I hoping to fill?) (5) What is the goal of the paper. What do I hope to achieve?*

Response: Thank you for your suggestions. We fully understand the request and we re-structured the Introduction according to a more traditional approach. However, we are combining literature and research gaps from various fields and are following two main aims (see your comment # 4). We hope that we were able to increase the understandability despite this complexity. We restructured the paper as follows:

- We first introduced the specific problem in West Africa (as before):
sect. 1.1 “Floods in West Africa”.
 - For better understandability, we think it is necessary to introduce the FANFAR project directly thereafter, which aims to address this problem in a transdisciplinary project (as before):
sect. 1.2 “Developing a FEWS with stakeholders in the FANFAR project” (new title).
 - As proposed (point # 6, below), we inserted a new sect. 2 “Literature review, research questions”. It contains:
 - Sect. 2.1 “Sustainability science and transdisciplinary research frameworks”.
Rationale: this type of large project in West Africa requires a transdisciplinary approach (moved from former sect. 2.1).
 - Sect. 2.2 “Multi-Criteria Decision Analysis (MCDA) in flood risk research”.
Rationale: MCDA can address the concrete problem of creating a FEWS (moved from former sect. 2.2.1) including arguments for using MCDA/MAVT (moved from first part of former sect. 2.2.2). We added references to the general MCDA sect. to show that it also summarizes literature, and thus does not belong to the specific Methods section.
 - Sect. 2.3 “Aims, research gaps, and research questions” (moved from former sect. 1.3);
note that we addressed comment # 26 below regarding the sequence of research questions.
 - Sect. 3 Methods / sect. 3.1 “Transdisciplinary Multi-Criteria Decision Analysis (MCDA) process” (former sects. 2.2.2 (second part) to 2.2.11).
 - Sect. 3.2 “Conceptual framework for transdisciplinary process”.
For this, we moved the text part from former sect. 2.1.1. We moved former Table 1 to the Results (now Table 3), sect. 4.9, hereby answering the new RQB (see comment # 28 below).
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- 6) *Section 2.2 is, in general, very well written and is a good reference for PhD students. However, the authors mix review and their own methods. I suggest having it very clear when the review ends, and when your method starts. I recommend having a section called "2. Review" or something similar with the items 2.1 and 2.2. and a New section "3. Methods" starting on Line 230. It could be something titled "3.1 Proposed transdisciplinary MCDA" and then you should clarify that it is applied in FANFAR.*

Response: We agree that it can be useful to bundle all literature in one new sect. 2, and have done this. Sect. 2 now includes the review of the sustainability science and transdisciplinary research literature (former sect. 2.1), of the MCDA literature (former sect. 2.2.1), and the first part of sect. 2.2.2 that provides the rationale for using MCDA/MAVT, based on literature. We had not used your proposed structure earlier as we found it easier to follow "topics", i.e., sustainability science and transdisciplinary research, then MCDA. We hope that the suggested re-grouping has clarified the structure (also see comment # 5, above).

- 7) *The coding system used for the objectives and configurations makes it very hard to read the paper. I suggest having real names instead of "a_fast.-dev" use "fast development".*

Response: Done. We agree that our short names and abbreviations were difficult to understand and gave new short names to the FEWS configurations, the objectives, and the stakeholder groups. We kept the letters a, b, c, ... for FEWS configurations, the numbers 11, 12, ... for objectives, and the numbers 1, 2A, 2B, ... for the group names. As suggested in comment # 30, we deleted the "_". Please see the changes in all figures (except Fig. 7), in Table 1 (former Table 2), Table 2 (former Table 3), and the text.

- 8) *In general, the text is too long to follow and read at once. It is, in most cases, easy to understand what the authors mean, so it is not a problem of the English, but of the length. The authors seem to have many ideas, but the text needs to be restructured to highlight what is more important.*

Response: We did our best to shorten and restructure the text. We are happy to follow concrete suggestions for restructuring (see below; comments # 10, 20, 22, 27, 28). We strongly shortened the text, including your suggestions (see comment # 3 above). Deleting more text would mean to seriously delete content, which we wish to avoid. It would be possible to delete further parts of the Discussion, sect. 5.2 "Suitability of the MCDA process for guiding large transdisciplinary projects (RQC)". However, this would mean losing insight into the meaning of the different steps of our proposed transdisciplinary process, which is summarized in the two tables, Table 3 (former Table 1), and Table 4. We think this would be a pity, as the explanations and examples are needed to make the relatively dry summaries understandable and meaningful.

- 9) *I disagree with referee 2 that asks for a review of standard MCDA methods (there are several of these out there). On the other hand, I agree with referee 1 that the choice for the compensatory method should be clarified.*

Response: Thank you for supporting a decision that we had made in an earlier version of this manuscript. For length reasons, and because we do not find it necessary, we will not introduce the many different possible MCDA methods. It would entail describing advantages and disadvantages of e.g., AHP, different outranking methods (PROMETHEE,

ELECTREE, etc.), and newer approaches such as TOPSIS, additionally to MAVT/MAUT. We cite a classic textbook and a review paper from hydrology that both provide overviews of methods:

p. 4, line 112: “MCDA is well suited to address this challenge and embraces various methodologies to support complex decisions (e.g., Belton and Stewart, 2002; de Brito and Evers, 2016).”

In the next sentence, we explain in-depth why we chose MCDA and MAVT/MAUT (points (i) to (vii)):

Former p. 8, line 209 – p. 9, line 225 (now p. 4, line 114): “We chose Multi-Attribute Value Theory (MAVT; Eisenführ et al., 2010; Keeney, 1982) for reasons well documented in literature: (i) developing a complex FEWS requires many decisions such as (...) (vii) MCDA is done stepwise to reduce complexity and increase transparency.”

We wish to emphasize that we did NOT choose a compensatory method. Rather, MAVT/MAUT is very flexible regarding the mathematical (aggregation) model. It is only fully compensatory if standard linear additive aggregation is used. We describe our non-additive, i.e., non-compensatory approach in the Methods sect. 3.1.7:

p. 11, line 326: “While easy to understand, the additive model entails strong assumptions, e.g., that objectives are preferentially independent (Eisenführ et al., 2010). Increasing evidence indicates that many stakeholders do not agree with model implications (Haag et al., 2019a; Reichert et al., 2019; Zheng et al., 2016). Additive aggregation implies that good performance on one objective can fully compensate for poor performance on another. In the FANFAR weight elicitation sessions, we asked stakeholders, (...)”

We agree with both referees that this was unclear. We added this advantage as point (v) to the (new) literature section 2.2:

p. 5, line 125: “(v) MAVT and Multi-Attribute Utility Theory (MAUT) are mathematically very flexible. Usually linear additive aggregation is applied, but many non-compensatory models are possible, which may better represent stakeholder preferences (Haag et al., 2019a; Reichert et al., 2015; Reichert et al., 2019).”

10) *In the conclusions section, the authors re-state many of the findings/discussion, which was a bit repetitive. I suggest having some more “punching” conclusions.*

Response: We appreciate your feedback and shortened the Conclusions to the main points.

Specific comments

11) *Line 11: it is not clear what is the „FANFAR system“ here in the abstract. I suggest rephrasing to add “of the “FANFAR forecasting system”. Perhaps you can use established acronyms such as FEWS to be more specific and avoid repetition/long sentences.*

Response: Done. We changed this in the abstract and used the acronym “FEWS” throughout.

12) *Line 12: Again, it is not clear. Objectives of what? What are these configurations?*

- 13) *Line 15: “we investigated if problem structuring helps focus early technical system development.” What is meant here? Early technical system?*
- 14) *Line 16: What is understood by “full” MCDA”. What would a partial MCDA be? Please be more specific*
- 15) *Line 16: This last objective is a bit disconnected from the others. Hence, I would suggest rephrasing: “Thirdly, to support further research on xxxxx, we critically analyzed...”*
- 16) *Line 19: “MCDA met many requirements to achieve this framework” or something similar*

Response: Thank you for useful suggestions. We rewrote the Abstract and hope that it is now clearer.

- 17) *Line 27: projections of what? Of impacts? Of runoff quantities?*

Response: Done. **p. 1, line 26:** “Climate change projections and mechanisms remain uncertain for West Africa, but there is growing evidence for increased frequency, magnitude, and impact of floods (Nka et al., 2015).”

- 18) *Line 30: I am not sure how meaningful is to add the information “double the number of 2019”. Why is 2019 used as a reference? It would be more robust to have a comparison of the average the last 10 or 20 years.*

Response: We agree and removed this information.

- 19) *Line 35: I suggest adding references to back up this sentence that there are problems in existing systems. These articles could be potentially relevant (please check in detail if relevant before citing):*

- <https://www.sciencedirect.com/science/article/abs/pii/S2212420920312966>
- <https://link.springer.com/article/10.1007/s11069-016-2537-0>
- <https://onlinelibrary.wiley.com/doi/full/10.1111/jfr3.12664>

Response: Thank you for the interesting references. In addition to the already referenced sources (which identify some issues), we now provide a summary report, and also added one of your suggestions to back this up with stakeholders’ perceptions in the region.

p. 2, line 40: “An overview of gaps, needs, and recommendations is provided by WMO (2020). Moreover, stakeholders assigned the lowest score to the overall effectiveness of FEWS in all but one West African country (Lumbroso et al., 2016).”

- 20) *Line 43-53: If possible, I suggest cutting a bit of the text here, as the paper is already very long.*

Response: We shortened the description of the FANFAR project here.

- 21) *Line 54: Please start another line here*

Response: We started a new paragraph.

- 22) *Line 54 to 63: Here, you describe the methodology adopted, which, in my opinion, should be in the methods section. In the introduction you should rather focus on the*

problem at hand. Why it is important to address and how your proposed approach improves the status quo. The justification needed appears only later, in line 63. Perhaps you could invert the order? First the problem that exists and then how you want to address it. Also move parts of the text in lines 54 to the methods session.

Response: We re-structured the Introduction following your suggestions, and shortened it. We found it unnecessary to move the suggested parts to the Methods section (we agree that they are methods); the methods already describe this part. Please also see response to comments # 5 and 6.

23) *Line 75. The aim of the project should be stated when you speak about the project in 1.1. Here, please focus on the aims of the paper.*

Response: We agree with this distinction. However, it is also an aim of the paper (i.e., of the actual MCDA) to find or at least define what constitutes a good FEWS configuration for West Africa. We have rewritten sect. 2.3 Aims, research gaps, and research questions. Research question RQA addresses identifying a robust FEWS configuration despite uncertainty.

24) *Line 79-80. I would remove this sentence as it reads more as a project report than a scientific paper. Not sure how relevant this is*

Response: We agree and removed this sentence. We also removed former research question RQB (in the earlier version of this paper), which belonged to this sentence. Because the paper is too long anyway, and because we agree with your criticism, we decided to remove this aspect. Note that we have fundamentally rewritten sect. 2.3 “Aims, research gaps, and research questions”. Consequently, we also deleted this part in the Discussion, former sect. 2.2 “Early problem structuring focused FANFAR system development (RQB)”.

25) *Line 87: which special issue? Please specify the name of it in addition to the reference. Here you are again stating the problem*

Response: We added the name of the special issue (it is long, however). Regarding “problem”, see next point # 26).

26) *Line 99: why aren't the research questions together?*

Response: In former sect. 1.3 “Aims, research questions, ...” (now sect. 2.3 “Aims, research gaps, and research questions”), we had chosen a different approach. We first stated one specific problem, directly followed by the respective research question. We found this easier for readers than a “classical” sequence. However, we do not have strong feelings about which might be better. We restructured this section and first developed all research gaps, followed by a list of research questions. These are now reduced, and as suggested, follow the two main distinctions (see comment # 4).

27) *Line 100-109: I suggest removing this to reduce the text, but it's a suggestion only.*

Response: We removed the overview of the paper to shorten it.

28) *Item 2.1. These topics have appeared in the abstract but not in the introduction (sustainability and transdisciplinarity). It should appear as one of the research questions too. In general, section 2.1 is well written. Still, I suggest reducing where possible.*

Response: Thank you for appreciating the literature overview of sustainability science and transdisciplinary research. We shortened it, hereby trying not to lose too much information.

As we revised the Introduction, the comment about “sustainability and transdisciplinarity” not being mentioned is probably no longer needed. However, we did mention them:

Former p. 3, line 72 / now p. 2, line 60: “To the best of our knowledge, we are not aware of systematic assessment of MCDA from the angle of transdisciplinary sustainability research.”

We do not quite understand the remark that it should appear in the research questions. It does (RQC):

Former p. 4, line 96 (now p. 6, line 177): “**RQC:** How suitable is a participatory decision analysis process based on MCDA for guiding large transdisciplinary projects? What worked well or less well in FANFAR? Is the proposed framework useful for this type of evaluation?” (note: for simplification last question was added from former RQD).

To answer these two RQ, the literature review is needed. We decided to add an additional **RQB** (replacing former RQB; see point # 24):

p. 6, line 175: “What are main characteristics of existing frameworks from transdisciplinary research and sustainability science that are useful for guiding and evaluating collaborative transdisciplinary projects in hydrology research?”.

The answer is the presentation of our proposed framework in former Table 1 (now Table 3), which we moved to the Results sect. 4.9.

29) *Line 138: why the need to emphasize “Nature Sustainability” here. I Would say that recent articles propose without referring to the journal as a measure of perceived quality.*

Response: We agree and deleted the journal name.

30) *Table 2: It is quite challenging to read this table. Perhaps it could be in landscape format? Using the “ID” does not help as I had to return to the table multiple times Would it be possible to have the full description in the tables and figures “e.g. Fast development” instead of “a_Fast-dev”*

Response: We formatted Table 2 in landscape format, but the HESS template only allows a relatively narrow landscape format. We presume that the typesetters will take care of nice formatting later. Regarding short names and ID, see our response to comment # 7, above (we agree with your criticism). Specifically in Table 2, we gave better short names consisting of entire words. We kept the letters a, b, c, ...

31) *Figure 4: Please remove the _ and add the full legend to the figure.*

Response: Done. Please also see response to comments # 7 and # 30 above; we re-did all Figures with new names and removed “_”.

32) *Line 430: This should be in the results section, not in the methods.*

Response: Done. We moved the number of survey respondents to the Results (sect. 4.8)

33) *Line 567. 12 is a relatively low number of responses. It would be good if in Figure 1 you could add the number of participants in each workshop. This would be good to understand these 12 responses you got.*

Response: We added the number of participants to Figure 1.

The 12 respondents from former p. 24, line 567 correspond to a fraction of 63% (12/19) of the total highest number of participants during this online workshop. We were unfortunately forced to hold the 4th workshop online due to the COVID-19 pandemic, which posed some challenges to our organization. We consider a response rate of 12 as reasonably high given the challenging circumstances. We clarified this in the Results sect. 4.8 as follows:

p. 21, line 491: “Participant numbers in the online workshop varied from 10–19 due to connection problems, which are frequent in West Africa, and related dropouts. The survey was filled out by 12 participants (12/19 = 63%), resulting for 10 objectives in 10 x 12 = 120 responses to each question.”

34) *Table 4: I enjoy the table, it provides an excellent summary.*

Response. Thank you, we appreciate your positive feedback.

35) *Line 839: Value Focused Thinking appeared for the first time here. It should be In the methods.*

Response: You are right. We now introduced Value Focused Thinking in the review sect. 2.2 of MCDA literature and the Methods sect. 3.1.3:

p. 4, line 120: “(iii) MAVT and Value Focused Thinking (Keeney, 1996) base decisions on the objectives that are of fundamental importance to stakeholders.”

p. 9, line 240: “Value Focused Thinking guides this step by focusing on what is fundamentally important to stakeholders (Keeney, 1996).”

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