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Earth System Dynamics
Discussions

# *Interactive comment on* "Climate impacts on human livelihoods: where uncertainty matters in projections of water availability" *by* T. K. Lissner et al.

**Anonymous Referee #1**

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GENERAL COMMENTS

The article presents the AHEAD index, which allows a general assessment of the adequateness of human livelihoods at a country level. As the measure is composed of 15 elements and even more indicators covering various human needs, it is possible to find out how changes in a single variable affect overall livelihood. The authors demonstrate the effects of changes in projected water availability per person and address the question to which extent uncertainties in water availability modelling are relevant for the overall results. Focusing on a transdisciplinary assessment of human livelihoods, projected climate change impacts on those livelihoods and the (non-)relevance of related uncertainties, the paper deals with scientific questions that are relevant within the



scope of the journal. The title clearly reflects the contents of the article, and its abstract provides a concise and complete summary. The amount and quality of references is appropriate; especially in the selection of indicators and membership thresholds do the authors prove comprehensive knowledge in relevant research fields. On the basis of the references, the authors give proper credit to related work, and they clearly indicate their own new contribution. The AHEAD index is a novel tool that appears useful for a general assessment of livelihood conditions at national level based on a range of relevant aspects. Its underlying elements and indicators appear well chosen, and the fuzzification and conjunction via different operators are sophisticated. Actually, the presentation of the AHEAD index and a more detailed analysis of results for the present situation could be an interesting article on its own, even without the consideration of future projections and the role of uncertainties from modelling, which could be dealt with in a follow-up article. The consideration of these additional aspects in one article is ambitious given the limited space. Even though the overall presentation is well structured and the language is fluent, the documentation of results and their calculation partially lacks clearness and preciseness, which makes it difficult for the reader to truly understand the modelled results and associated uncertainties (e.g., see specific comments 16, 20, 24, 25, 33). Furthermore, the authors present their results – which derive from a range of models and climate scenarios and refer to several periods – in an aggregated way without revealing country-specific fuzzy values of the AHEAD index and underlying indicators. A documentation of these values, e.g. in the supplementary material, would allow a more transparent documentation of results (see specific comments 14, 31). Regarding the discussion, the authors should address two possible limitations of the AHEAD index. First, the national scale may distort results in some cases (see specific comment 29). Second, changes in variables such as water availability per person can be filtered out through the MIN operator in the calculation of the overall AHEAD value. As a consequence, the AHEAD index suggests non-relevance of certain developments although they may have severe impacts on human livelihoods in practice (see specific comment 28). So, whereas the presentation of results and their

calculation (including figure 2) needs clarification, the discussion section should address the two aspects mentioned. The authors should also explain, either in the results or the discussion chapter, why uncertainties apparently matter stronger in the baseline assessment than in the future projections according to the AHEAD calculations (see specific comments 23, 35).

SPECIFIC COMMENTS

(1) Page 404, lines 24: "(. . .) for 44 out of 111 countries, the water-specific uncertainty ranges are outside relevant thresholds for AHEAD, and therefore do not contribute to the overall uncertainty about climate change impacts (. . .)" – This information is not mentioned in the manuscript. Did you possibly confuse this information with the following result: "In 44 countries (. . .), uncertainty is relevant to highly relevant" (page 420, lines 27-28)? (2) Page 405, lines 14-16: "Single aspects of climate change and impacts can be put into context by relating them to other development aspects and needs, allowing for a comparison of impacts across sectors." – Readers can get a wrong expectation when reading this statement, because the application of the AHEAD index, as presented in this paper, addresses only potential changes in 'annual internal renewable water resources' per person and related effects on the resulting AHEAD value. It does not deal with impacts of changed water availability on other sectors, i.e. on the other 15 elements that are included in the AHEAD index. So, the survey is no comparison of impacts across sectors. (3) Page 407, lines 16-26: You state that you have identified the set of 16 elements based on a number of approaches, which are listed subsequently. It does not become clear what element is based on which approach. So, the specific origin of each single element remains unclear. You can solve that easily by adding the underlying approaches in a new column in table 1 (next to the column 'Elements'). (4) Page 408, lines 2-3: "Additional literature devoted to the topic, but not directly applicable for the purpose of defining single elements for the present analysis, further supports this set (. . .)." – If the additional literature is not applicable for the definition of elements, how can it support the set of defined elements? (5) Page 409,



lines 18-19: "Fuzzified data sets take continuous values between 0 (. . .) and 1 (. . .)." – As the fuzzy data range includes 0 and 1, the formulation should rather be "Fuzzified data sets take continuous values from 0 (. . .) to 1". (6) Page 409, lines 19-20: "Upper and lower thresholds for membership (l1, l2)" – As l1is smaller than l2 (as can be seen from equations 1-4), you should change the beginning of the sentence to "Lower and upper thresholds for membership (l1, l2)" (7) Page 411, lines 6-8: "Further operators available for the aggregation of variables include average operators, such as harmonic, geometric and arithmetic mean (Mayer et al. 1993)." – As you already introduced the arithmetic mean as an operator of your analysis a few lines above, the arithmetic mean should not be mentioned here as one of the further operators available. Furthermore, the reference to harmonic and geometric means appears unnecessary, because they are not relevant for your survey. So, you can drop the whole sentence. (8) Page 412, lines 10-12: "the lower threshold l1 should reflect a basic level or resource availability, below which survival would be compromised. The upper threshold l2 delineates a level of sufficiency, where basic needs are fully met and conditions are adequate." – This is only true for membership functions with linear/curved increase (equations 1 and 3). It is not the case for linear/curved decrease (equations 2 and 4). (9) Page 412, line 15: "possible satisfiers" – What are satisfiers? (10) Page 412, lines 24-25: "limited factors" – Do you mean limiting factors? (11) Page 417, line 23: "inter-model spread" – As the spread is one of the key components of your survey, you need to define what this spread is concerned with. If you do not clearly define this term, it will be difficult for the reader to understand the following uncertainty analyses. Does spread refer to each country's difference between minimum and maximum fuzzy value for water availability/person across all model calculations – comprising all climate scenarios and all periods, including the baseline? Or does it refer to each single period separately? (12) Page 418, line 1-2: "the country-specific result range of fuzzified AHEAD conditions" – What are "fuzzified AHEAD conditions"? I assume that you refer to a country's overall AHEAD value, which is calculated on the basis of the 16 elements from table 1, and not to these elements themselves (or their underlying indicators). But this becomes

clearer only after further reading. So, for a better understanding, you should explain clearly what you mean with the expression "fuzzified AHEAD conditions". (13) Page 417, line 4: "water is not limited" – What do you mean when stating that water is not limited (or that there is "no water limitation" in figure 2). Do you mean that the fuzzy value for water availability is 1? (14) Page 418, line 18-19: "Using the values of the ensemble mean, global mean AHEAD fulfillment is intermediate (0.48)." – The analysis of the present state of human livelihoods according to the AHEAD baseline assessment, which is presented in this paragraph (i.e. till line 28), is quite short and general. As the AHEAD index is a novel measure that integrates aspects from various sectors, a detailed analysis of current livelihood conditions in the world would be an interesting topic for an article even without the consideration of future developments and related uncertainties. Such an analysis could address regional differences in livelihood conditions and their underlying reasons (i.e. specific limiting factors that may be characteristic for certain regions or types of countries) in more detail. However, I respect the author's choice to choose a broader topic for this article, which is associated with restrictions to the analysis of the current state. Nevertheless, I think that the article would profit from more country-specific results about the present state that illustrate how the elements underlying the AHEAD index act in concert and result in an overall AHEAD value (e.g., is there an indicator that has a particular strong influence on the overall AHEAD value?). This could, for example, help to understand the impact of the water availability indicator on the overall AHEAD value, or the "relative strength" of both water indicators. It would also be helpful to add a table to the annex that documents the fuzzified values for all indicators and dimensions with regard to all countries (with a second table that shows all modelling results for water availability across the various models, climate scenarios, and periods). This would make the calculation of the overall AHEAD value much more transparent. (15) Page 418, lines 13-15: "The fuzzified values can be represented according to the degree of membership to the linguistic category of adequacy, ranging from very high (1-0.8), high (0.8-0.6), intermediate (0.6-0.4), low (0.4-0.2) to very low (0.2-0)". – Class borders are not clear. For example, a value



of 0.6 belongs to the classes "high" and "intermediate". (16) Page 418, lines 21-22: "While this differs slightly across models and scenarios" – The mention of scenarios comes as a surprise, because you refer to the baseline assessment in this paragraph (I assume that there are no climate change scenarios for the baseline assessment). It will be helpful for the reader if you divide the results chapter in one section about the baseline assessment and another section about the modelling of future conditions including future uncertainties. (17) Page 419, lines 1-2: "Calculations using the full range of ISI-MIP modelling results (. . .)" – I assume that these calculations refer to the future simulations. It would be helpful to the reader if you mention this explicitly. (18) Page 419, lines 6-7: "Generally, the distribution of countries between classes is rather even." – The reader can only believe that, because you do not document the modelling results for the future scenarios. (19) Page 419, line 9: "GCMs and IMs" – Do you refer to global climate models and impact models? This is not clear, because you do not explain these abbreviations. (20) Page 420, line 3: "water security" – What exactly do you refer to with this term (also subsequently in the text)? Various definitions of water security exist in the literature, and they can be quite comprehensive. So, you should briefly define water security. Does water security refer to a fuzzy value of 1 for the 'water' variable/element? (21) Page 420, line 6: "seemingly smaller results ranges" – Please drop the word "seemingly", because the results ranges are indeed smaller, even though they do not lead to different fuzzy values. (22) Page 420, lines 19-20: "We use the value range across all models and scenarios for the classification, but differentiate between the four time slices 2000, 2030, 2060 and 2090." – If you have classified the uncertainties for four time periods, why do you only show results for 2000 and 2090? (23) Page 420, lines 22-23: Where changes occur between baseline and 2090 calculations, these are hatched in the respective colour. – (1) It is difficult to recognize the hatched colors in the small printed illustration. (2) As the 2090 projection includes different climate scenarios in the various models, I would have expected that uncertainties are higher than in the baseline assessment. Surprisingly, only five countries differ in their uncertainty classification, and these countries apparently move

to "better" classes (I assume that the colors of the thin lines represent the future class). What is the reason for the lack of additional uncertainty from the future scenarios? (24) Page 420, line 24-25: "(. . .) in 67 countries the model spread is outside the thresholds for AHEAD fulfilment." – (1) Please explain what AHEAD fulfilment is. Do you mean an overall AHEAD value of 0.8-1 (class "very good"), or do you refer to AHEAD values of exactly 1? (2) Does the whole sentence mean that at according to all models, the respective country does not achieve a "very good" AHEAD value in a certain period (or a value of exactly 1)? (25) Page 420, lines 26-27: "(. . .) water security is below all minimum requirements in all RCPs-IM-GCM combinations" – Do "minimum requirements" refer to fuzzy values below 1 for the 'water' variable/element, which indicates that adequate conditions with regard to 'annual internal renewable water resources' or 'access to improved water source' are not achieved (i.e., at least one of both indicators has a fuzzy value below 1)? (26) Page 421, lines 7-8: "(. . .) the AHEAD approach provides a means to view climate impacts in a wider context." – The studied impacts result also from changes in population size, because the projections of water resources per capita are based on climate scenarios and on population forecasts. Actually, in a range of countries the effects from population changes can be stronger than those from climate change. (27) Page 421, lines 12-15: "(. . .) our approach to combine water resource availability with the access to an improved water resource provides an important way forward to account for the fact that water shortages to some extent can be mitigated by good water infrastructure." – This is not reflected in the AHEAD index: As both indicators are aggregated through a MIN operation (cf. page 421, line 27), water shortages are not compensated by good technical infrastructure. (28) Page 422, lines 4-6: "As exemplified with the example of water availability, an assessment of the relevance of changes for the adequacy of conditions becomes possible." – Even though a decline in water availability may have no effects on the overall AHEAD value, it can still have considerable effects on human livelihoods in practice. For example, if water availability drops from "high" to "low" in a country with air quality classified as "low", this will not change the overall AHEAD value, and the decline can therefore be regarded as



irrelevant from the AHEAD perspective. However, in practice the decline in water availability can have serious consequences for the population and is definitely relevant. You should address this issue in the discussion section. (29) Page 423, line 11-12: "The use of global data and globally applicable thresholds in a fuzzy logic algorithm adds other types of uncertainties and short-comings." – You should briefly discuss how the spatial scale influences results of the analyses. The key variable of your survey, water availability/person can vary considerably within a country. Moreover, countries with low population density may have high water availability/person even though water scarcity limits agricultural activities. For example, Australia shows very high AHEAD fulfillment (fig. 1), which implies that water availability/person is also very high. However, in practice low water availability limits agricultural activities in large parts of the country. (30) Page 433, table 1: (1) According to the explanations on page 415, the lower and upper thresholds for 'solid fuel use' are based on Lillemo and Halvorsen (2013). But in table 1, two other references are documented as sources. (2) The table shows 15 elements, but according to the manuscript (page 404, line 15; page 408, lines 1 and 6; page 421, line 6), the AHEAD index is based on 16 elements. (31) Page 434, table A1: (1) You should mention that the table refers to the baseline period. (2) The class borders are not clear (see comment 15). (3) It would be more transparent to provide a table that shows the fuzzy values for all indicators and countries for at least one model. In this way, the reader can see how the various values aggregate to an overall AHEAD value. Such a table would be long, and I leave it to the authors to decide whether they accept the suggestion. But please note that the present article draft shows only aggregated results to the reader. This makes it difficult to track how the various indicators result in an overall AHEAD value (see comment 14). (32) Page 435, table A2: (1) There is no reference to this table in the manuscript (applies also to figure A2). (33) Page 437, figure 2: This figure is important for the analyses, but it needs clarification, because explanations in the manuscript are scarce. (1) 1st column: What is 'AHEAD spread'? Is it the difference between the maximum and minimum overall AHEAD value across all models and scenarios within a single period? (2) According to the manuscript (page

417), the AHEAD spread in the upper box can also be exactly 0.2, and the AHEAD spread in the lower box can also be exactly 0.5. (3) 2nd column: What does 'AHEAD' refer to? Given the spread of AHEAD values (column 1), how do you arrive at a single AHEAD value for each country? Is it its AHEAD value from the baseline assessment, which represents the mean from all model calculations for that period? (4) 3rd column: Why is class B characterized by "AHEAD low to medium"? Its AHEAD value is between 0.2 and 0.8 (column 2), so it should rather be "low to high", because values from 0.6 to 0.8 are classified as high (page 418, figure 3). (5) 3rd column: Why is the uncertainty range relevant for class C3, but not for classes A and B? In all three cases, the AHEAD spread (which is below 0.2) may make a country pass a class threshold and move to another class. (34) Page 439, figure 4: The bars are very small in the printed version. (35) Page 440, figure 5: (1) Changes between the baseline results and those for 2090 occur for five countries, not four countries as is written below the figure. (2) Obviously, uncertainties do matter less for the 2090 period than for the baseline assessment: Ethiopia and Mongolia move from C.3 to C.2, Hungary from B to A, Syria from D.2 to D.1, and Yemen from D.2 to C.3 (assuming that thin lines depict the 2090 results). How is it possible that the inclusion of five different climate scenarios for 2090 does not lead to significantly higher relevance of uncertainty as compared to the baseline assessment? You should address this in the results or the discussion section (see comment 23). (36) Page 426, lines 15-18: Reference de Crombrugghe et al. (2009) – Apparently, you did not take the data directly from this report, but from the database that is described therein. So, you should add the web database in the reference list and refer to it in table 1.

TECHNICAL CORRECTIONS

(1) Page 405, line 17: "climate related" – Words should be connected through a hyphen (2) Page 405, line 26: "policy-process" – Remove the hyphen (3) Page 411, line 16: "Societal Structure": You call this dimension "Social Structure" above and in figure 1. Please use the term consistently. (4) Page 415, line 15: "a limitations" – Should



be singular (a limitation) (5) Page 412, line 17-19: "Some elements can be represented with single datasets and sources given in Table 1 (. . .) also support the use of the respective dataset to represent the element." – Grammar? (6) Page 413, line 5: "PM2.5/10 concentration" – (1) The term is spelled "PM10/PM2.5 concentrations" in table 1. Please use the term consistently. (2) The current database from WHO 2009 apparently stores only data for PM10, not for PM2.5. (7) Page 413, line 6: "The HDI includes (. . .)" – As You mention the Human Development Index (HDI) here for the first time, you should use the full term followed by its abbreviation in parentheses. (8) Page 415, line 5: "access fundamental" – Missing word (access is fundamental) (9) Page 415, line 18: "values between 0 and (100 cap)^-1" – number missing (values between 0 and 100/(100 cap)^-1) (10) Page 415, line 22: "Societal Structure" – See comment 3. (11) Page 418, lines 20 and 25: "Societal Structure" – See comment 3. (12) Page 419, line 15: "can not" – Spelling (cannot) (13) Page 420, line 10: "The third column (. . .) show (. . .)" – Grammar (shows) (14) Page 421, line 5: "these condition" – Grammar (this condition) (15) Page 421, lines 27-28: "(. . .) data needs to be transformed into a comparable format, to enable aggregation." – Drop the comma. (16) Page 422, lines 24-25: "(. . .) as the fuzzification step from column 1 to column 2 in Fig. 4 illustrate." – Grammar (illustrates) (17) Page 423, line 12: "short-comings" – Drop the hyphen. (18) Page 423, line 21: "water related" – Add a hyphen. (19) Page 423, line 23: "The adequate communication of research results in an essential requirement (. . .)" – Replace "in" by "is". (20) Page 424, line 7: "This also due to (. . .)" – Missing word (This is) (21) Page 424, line 8: "(. . .) in field of high policy relevance (. . .)" – Plural (fields) (22) Page 424, line 20: "International Climate Intiative" – Spelling (Initiative) (23) Page 441, figure A1: "membership function" – Plural (functions)

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