

REVIEWER #1

Reviewer Comment	Changes made
(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)?	Indeed, the numbers seem to be mixed up. We have adjusted the abstract with the correct numbers.
(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.	We have rephrased this sentence in the introductory part ("Yet, such a framework can provide an important means to assess the consequences of climate change for human welfare and societal systems, allowing to relate impacts of climate change to other development aspects and needs and to compare of impacts across sectors."); also we have added a more specific sentence in the objectives part to clarify the scope of the present paper (" For a first implementation of the approach, we focus on the example of water scarcity which has been identified as a major challenge of the future (Grey et al. 2013)."; "After an initial implementation of the approach on a global scale, we show how climate as well as population change may affect overall fulfilment of AHEAD, focussing on changes in water availability")
(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').	A paper on the details and background of the AHEAD elements has just been accepted for publication. Here, a detailed overview of each element is given. We would prefer to direct the reader to this article, instead of adding additional information to the table. We therefore suggest to make sure the doi of the background paper is available before the publication of the final version of this manuscript.
(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?	We have removed this sentence, as the background paper is available shortly and should give all relevant information to understand the development of AHEAD.
(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".	Sentence adjusted.
(6) Page 409, lines 19-20: "Upper and lower thresholds for membership (I1, I2)" – As I1 is smaller than I2 (as can be seen from equations 1-4), you should change the beginning of the sentence to "Lower and upper thresholds for membership (I1, I2)"	Order is updated.
(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.	Sentence dropped.
(8) Page 412, lines 10-12: "the lower threshold I1 should reflect a basic level or resource availability, below which survival would be compromised. The upper threshold I2 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).	We have rephrased this to: "Fuzzified data sets take continuous values from 0 (conditions are inadequate) and 1 (conditions are adequate). For the purpose of determining the fulfilment of AHEAD, fuzzy values near 0 reflect a basic level of resource availability, below which survival would be compromised. Fuzzy values near 1 indicate a level of sufficiency, where basic needs are fully met and conditions are adequate."
(9) Page 412, line 15: "possible satisfiers" – What are satisfiers?	We have added a paragraph to Section 2.1 which briefly discusses the relationship between elements (needs) and satisfiers (data used to represent elements).
(10) Page 412, lines 24-25: "limited factors" – Do you mean limiting factors?	Yes, thank you. Changed accordingly.
(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?	We have extended this paragraph to include a more explicit definition, also including the suggestions in comment #12 , #13 and #33 (Figure 2), giving more details of the procedure.
(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".	See comment #11
(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?	See comment #11
(14) Page 418, line 18-19: "Using the values of the ensemble mean, global mean AHEAD fulfilment 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.	We have extended the results section here, including more details on the distribution of between the subindices, as well as the single elements. As the focus is on the presentation of the index at global scale, we would like to refrain from providing too much country-specific details. Such an analysis would require more detailed knowledge of the country specific situation, also considering cultural differences and more country-specific data. Like any global model, the present calculation of AHEAD can provide information of the relative distribution of conditions between regions, but it cannot necessarily provide country-specific information. With regard to an overview of all data please see comment # 3 in the general comments.
(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".	We apologize for this imprecise documentation. We have adjusted all instances of this to reflect accurate class borders, e.g 0 < 0.2
(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.	We have divided the chapter into 2 parts: (1) the results of current and future AHEAD and (2) the analysis of uncertainty (see #14). We have rephrased much of the paragraph and expect that this also clarifies this point.

17	(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.	Thank you, we have rephrased this, indicating the time periods explicitly.
18	(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.	See comment # 3 (general comments) on data documentation.
19	(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.	We have specified the abbreviation where the terms are first mentioned (Section 2.4)
20	(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?	Indeed this refers to a fuzzy water availability of 1. We have added this more specifically to the description of the membership function.
21	(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.	Word dropped
22	(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?	Changes do not differ significantly between the timeslices, so we chose to illustrate the results with 2 time periods only in order to reduce the amount of figures and information. Indeed, since we focus mainly on this latest timeslice we have adjusted the manuscript and now focus on 2090 changes only. We hope that the reviewers agree with this adjustment.
23	(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?	We have rephrased and extended this Section, following this and the following comments. The map has been updated and the hatching is replaced with boxes/arrows that indicate the change for better visibility.
24	(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)?	See #23
25	(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)?	See #23
26	(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.	We have added a paragraph on this to the discussion: "Both, changes in water resources as well as in population have an effect on the per capita resource availability within a country. By selecting average per capita requirements for a life in dignity as the assessment unit, the various pressures exerted on resources can be represented by the approach. In the case of water availability, it is often the increase in population which reduces the adequacy of per capita water availability, rather than reduction in water resources alone."
27	(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.	You are right, the argumentation here is imprecise. The underlying rationale within AHEAD is to reflect that infrastructure is often a limitation to water access in developing countries and is essential additional to resource availability, hence the MIN operator. We have therefore readjusted the paragraph in this regard.
28	(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.	The discussion of this aspect may have been too brief in the manuscript. We have extended the respective paragraph in the discussion to reflect the fact that changes in water availability outside water security thresholds are important to other sectors (see below). Additionally, the extended description of results (see comment #23) takes up this point in more detail. However, for changes of water availability within the thresholds of water adequacy, the relevance of these changes is recognised, regardless of their impact on AHEAD (class C.3: AHEAD low to very low, uncertainty range relevant to FW). The decision tree differentiates countries, where AHEAD does not change, as other aspects show limitations, but uncertainty in water data is relevant (class C3). For classes A and B, AHEAD is high and changes of water availability are outside the thresholds of water security. New paragraph: "It is also important to note that uncertainty ranges outside the thresholds relevant to AHEAD remain important for other water-related decisions, e.g. urban water flow management. While such changes may not directly affect water security, nonetheless other effects may negatively affect the adequacy of human livelihood conditions."
29	(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 fulfilment (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.	We have added the following paragraph to the discussion of the limitations of the paper: "The implementation at country-scale also assumes an even distribution of resources as well as population with country boundaries. Especially in large countries with uneven population distributions or diverse climatic conditions, such country-level averages prove to be a limitation for the assessment of water availability. More detailed analyses at finer resolutions, as for example proposed by Lissner (2014), can provide important further information in this regard."
30	(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.	(1) We have updated the table accordingly. (2) As indicated in footnote 1, page 416, the element 'shelter' cannot be adequately represented with data and is therefore not included in the present analysis. We have specified this again in the caption of the table.
31	(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).	(1) Added to caption (2) Changed, see also comment #15 (3) Please see comment #3 in general comments
32	(32) Page 435, table A2: (1) There is no reference to this table in the manuscript (applies also to figure A2).	We have made sure these are all referenced – the extended results section also refers to these Tables in more detail now.

<p>(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 33 move to another class.</p>	<p>We have extended the explanation of Figure 2 in text according to these suggestions. Point (3): we differentiate the different spreads 0 - &lt;0.2, 0.2 -&lt; 0.5 and &gt;0.5. Even though class boundaries may be passed for classes A and B, at the most this can be one class. The direction of the results therefore remains the same, making uncertainty less important in these cases.</p>
<p>(34) Page 439, figure 4: The bars are very small in the printed 34 version.</p>	<p>We have revised the figure for better readability. We suggest to also rotate the figure, so the bars become larger (depending on final format of publication).</p>
<p>(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 35 comment 23).</p>	<p>We have adjusted the figure for better readability and have extended the results section (see comment #23). Briefly, the reduction of uncertainty is due to reductions in water availability, which leads to very high limitations (water availability = 0) under all scenarios in additional countries.</p>
<p>(36) Page 426, lines 15-18: Reference de Crombrugghe et al. (2009) 36 – 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.</p>	<p>Reference added</p>
<p>37 Technical comments</p>	<p>All technical comments have been changed in the manuscript</p>