water futures and solutions

International Institute for Applied Systems Analysis
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Scenario Focus Group Workshop Report

Results and Outlook

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About WFaS

Water Futures and Solutions (WFaS) is a cross-sector, collaborative global initiative which develops the scientific evidence and applies systems analysis to help identify water-related policies and management practices that work together consistently across scales and sectors with the aim to improve human well-being through enhanced water security. A stakeholder informed, scenario-based assessment of water resources and water demand, employing ensembles of state-of-the-art socio-economic and hydrological models, test the feasibility, sustainability and robustness of portfolios of options that can be implemented today and can be sustainable and robust across a range of possible futures and associated uncertainties we face. The Initiative includes case studies to zoom in on particular issues and regions, and knowledge sharing networks to share policy, management, and technical solutions that have been effective in the bio-physical and socio-economic contexts to which they have been applied, so they can be assessed for application in similar conditions in other regions.

Report Plan

Introduction

Scenario Focus Group

The Scenario Focus Group (SFG) comprises water policy and planning decision makers at national and international level who guide and advise the Water Futures and Solutions Initiative, primarily by identifying key water management challenges, priorities, trends, options, and trade-offs within their regions and advising on where further systems analysis and investigation would be most helpful for understanding externalities and guiding planning decisions. The SFG guides the development of relevant and plausible scenarios across which the sustainability and robustness of potential solution options can be tested. The goals of the first meeting of the SFG were to:

- establish the SFG and understand and adjust the goals of the initiative and SFG process,
- gain mutual understanding of the primary water resource development and use concerns and priorities in different world regions,
- develop possible futures that members of the SFG would like to see investigated and assessed, and
- ensure project impact and relevance as well as the usability of its outputs.

Prototype Scenarios

”Prototype” scenarios based on the IPCC Shared Socio-economic Pathways (SSPs), were presented to start the meeting and initiate discussion. In addition to initiating discussion, the RCPs (Representative Concentration Pathways) and SSPs provided several other advantages as a starting point for scenario discussion and development:

- They are a ready and reliable source of data and modeling results, developed by expert groups and integrated assessment models over many years; developing an alternative starting point would be costly and time consuming to undertake.
- They are designed to be basic narratives that can be extended to full scenarios for a variety of purposes.
- There is an established community and knowledge base around the IPCC socio-economic scenarios, which are used as the basis for impact assessments around the world. They therefore provide a means of ensuring consistency of global scenario efforts across disciplines.

There are also a number of disadvantages to using SSPs as a basis for investigating water futures and options. Many of these were expressed during this first SFG meeting, including:

- The IPCC socio-economic scenarios were built for the climate change community and the primary focus of the narratives is on possible changes to greenhouse gas emissions.
- Water issues, feedbacks, and adaptations are not part of the basic SSP narratives and need to be added. Adding water constraints and feedbacks may result in the need to adjust other SSP assumptions to maintain plausibility and feasibility.
- Because climate science and modeling are dominated by researchers in developed countries, there is a risk that the scenario narratives are skewed to the values and views of those countries, and that the values, priorities, and views of the developing world are not well represented in the SSP narratives.
- SSPs by themselves are not planning scenarios, but “what-if” narratives, and are therefore not directly relevant to water planning.

- The SFG felt that they still have insufficient evidence to justify that the assumptions in some of the SSP narratives are even plausible. Tradeoffs should be better assessed and described. There was also the question of whether we can even draw conclusions, given the low availability and quality of information and data in much of the world.

the SFG provided many valuable critical comments and several recommendations for making water scenarios more meaningful and policy relevant. One of the main conclusions was that the disadvantages of and problems with the SSPs must still be dealt with in order build acceptable water scenarios. Overall, the water scenarios should present a compelling message, helping to bring attention to pressing water problems. They should contribute to the water policy framework for cross-sector integrated sustainable water resource management. To do so, the scenarios should be based on strong and clear scientific evidence in order to better address and explain the assumptions, pathways (how the end states were achieved), and tradeoffs (e.g. between globalization and deforestation). Analyses of water-related intervention options required for a transition to happen (an extensive list was identified during the meeting) are particularly important in connection with the sustainability scenario. Finally, financial aspects should be included to provide reality check for development and implementation of solutions.

Aware of the strengths and limitations of SSPs concerning water resources, the WFaS team set out to develop water scenarios that would modify and extend SSPs while still taking advantage of their strengths. The team started by developing a hydro-economic classification of countries to indicate countries that are faced with similar water resource challenges. The hydro-economic classification limits the complexity linked with developing global, spatially explicit scenarios by enabling basic assumptions to be made for groups of countries before going into more detailed spatial scales.

Desired Outcomes

The SFG perspective on the desired outcomes of the WFaS initiative was also elicited. In addition to the scenario recommendations, the SFG proposed that case studies be prepared in order for global scenarios to adequately reflect regional and local realities. Several areas that need urgent attention were identified, ranging from water governance (planning, stakeholder involvement, economic instruments) through technological innovations and water infrastructure, all of them needed to improve water use efficiency (including groundwater use) for agriculture, cities and ecosystems. Poor countries and populations have to be specifically addressed.

Report Overview

This report presents a summary of the results of the Paris SFG meeting and sets possible directions for further activities. It starts with a stakeholders' vision for the possible impacts of the initiative. Next, major water problems, as emerged during the meeting, are compiled together. It continues with the summary of recommendations on changes in hydro-economic classes and scenarios.

The second part the report presents the perspective of the IIASA team on the analysis that is needed to respond to identified water challenges. A scenario approach was selected for this project due to the importance and uncertainties of global water problems. However the method when applied at the global level poses difficulties that need to be resolved, an important focus of the methodological development of the Initiative. The major obstacles to make global scenarios policy relevant are presented and specific steps for this initiative are suggested. The comments and suggestions received from the SFG greatly assist the WFaS secretariat in prioritizing tasks going forward.

The report is complemented with appendices containing detailed results for the hydro-economic classes, the prototype scenarios and the list of identified most important intervention options. The meeting outcomes were further consolidated in this report and grouped following the project conceptual framework for consistency.

Expected Outcomes

Ensuring High Impact of the Initiative

Participants discussed how to increase project impact. They were primarily interested in ensuring project usefulness for policy making. Below we describe briefly the key ideas that emerged from the discussion.

The project should produce a water policy framework for cross-sectoral, integrated, sustainable water resources management. This framework can be used to explore the consequences of various decision-making paths on water sustainability and human development. It will also provide a set of robust strategies, policies, technologies, and solutions to inform multi-sectoral decision-making. It will also address the need to establish longer term processes for dealing with water security. Finally it will establish priorities and sequence of steps to follow in order to reach sustainable water management. The critical components of this framework will be rigorous water scenarios with clear trends and strong evidence to support narrative elements.

The project needs to provide a compelling message, that will help to bring attention to water problems. This message, in various forms including policy briefs and short videos will be disseminated through professional networks and social media to reach both targeted groups of water managers and policy makers as well as broader audience.

Project outcomes will also contribute to capacity building within local and national institutions to utilize the various tools resulting from the water scenarios work. It is also expected that the project will include many diverse case studies in order to analyze best practices and mistakes to avoid, that can be translated into other areas (countries/communities).

Major Water Problems

What needs attention?

Participants reported major water problems that need attention. Most discussed area have been water governance. It is clear that better water planning is needed together with stakeholders involvement in this planning. Collaboration is critical for dealing with a variety of water challenges. There is a big need to improve international collaboration on water (in the areas of infrastructures, institutions and economic agreements), transboundary water management and cross-sectoral collaboration around water. New instruments need to be developed, tested and applied in the areas of water allocation, water rights, collection of and access to water data and water pricing.

Improvements in governance have to be matched with improvements in technology. There is a need to explore the potential for water sector of the completely new technologies such as nanotechnology.

Water Infrastructure needs to be further developed including infrastructure for water transfers.

Water Pollution remains an important (and in many places growing) threat; new pollutants need to be recognized and coped with.

Managing water sustainably requires further shift towards demand management. The priority areas to deal with are sustainable groundwater management, urban water management, wastewater management and water use efficiency in agriculture. Ecosystems should also be treated as water users.

On a broader level, water managers increasingly need to cope with climate change impacts, consider and prepare for dealing with social consequences of water crisis in demography (water implications on migration and vice versa), health (new waterborne diseases) and equity (focus on poor nations – so as not to widen the gap even further).

Water Scenarios – recommendations

Hydro-economic classes, Scenarios and Solutions Options

During the workshop the presented Water Scenarios (based on SSPs with their corresponding water dimensions) and hydro-economic classes, received many valuable critical comments and several recommendations for making water scenarios more meaningful and policy relevant. One of the main conclusions was that the disadvantages of and problems with the SSPs must still be dealt with in order build acceptable water scenarios. Overall, the water scenarios should present a compelling message, helping to bring attention to pressing water problems. They should contribute to the water policy framework for cross-sector integrated sustainable water resource management. To do so, the scenarios need to better address and explain the pathways (how the end states were achieved), and tradeoffs should be clearly visible not only between the scenarios but also within scenarios. Strong and clear scientific evidence is needed to support narrative elements such as assumptions, connections, and tradeoffs within scenarios (e.g. between globalization and deforestation). Analyses of water-related intervention options (an extensive list has been identified during the meeting – see appendix 3) required for a transition to happen are particularly important in connection with the sustainability scenario. Finally, financial aspects should be included to provide reality check for development and implementation of solutions that should be measured against agreed benchmarks. The specific recommendations for changes and improvements in scenarios and hydro-economic classes are listed in appendices 1 and 2. The integral part of the sustainability scenario are specific water solution options that are listed in appendix 3.

Setting Direction

Water Analysis that is needed in the world right now

We still live in a divided world (mostly North-South). Countries and regions differ with respect to their investment capacity and hydrological variability. These differences have profound consequences that are not fully embraced in policy development and practice.

The path to a sustainable water world is not obvious. Various trade-offs need to be prioritized and resolved or maybe new integrative solutions identified? The trade-offs include:

- energy production vs water saving,

- small vs big storage,
- increasing food production vs. groundwater sustainability,
- ecosystems needs vs. economic development,
- investing in urban areas vs rural livelihoods (development, storage, irrigation).

Water security is a central concept guiding required transformation. However it is still not defined quantitatively (in a broadly agreeable way) and there exist many definitions that highlight different aspects of this complex idea. Should water security be defined as a water effect on GDP? Or maybe water effect on lives lost? Alternatively one could link it with insurance or points of shelter. There is a clear need for further exploration, discussion and eventually broad agreement on the definition of water security.

Water is deeply connected and intertwined with many other sectors and issues. These connections, often arising in the form of spillovers, are often ignored in planning and analysis, however its consequences can critically important for population growth, global movement of people (migration), food production, global food trade, energy production, ecosystems and cities. All these connections (and many more) need to be studied and quantified more extensively. Some of them may be quite unexpected, for example lack of toilets in schools may hamper girls education leading to overpopulation.

Variability in water supply and demand is still not explored and understood adequately. Too many models and analysis are based on averaged data leading to failed policy recommendations. There is a pressing need to better understand the effects of variability on economic development, addressing possible shocks and ways to cope with them, analyzing buffers that are needed.

Based on the workshop results and IIASA in-house expertise we have put forward a list of the most pressing water challenges:

- Financial development priorities (justifying significance of water investment)
- Economic valuation of water development strategies
- How to improve water use efficiency for food and energy production?
- How to accelerate development and transition to new technologies?
- How to induce behavioral change to make consumption patterns more sustainable lowering water demand?
- How to transform water governance?

Challenges of global scenarios methodology

Application of scenarios – how to make them understandable, relevant and useful for decision makers?

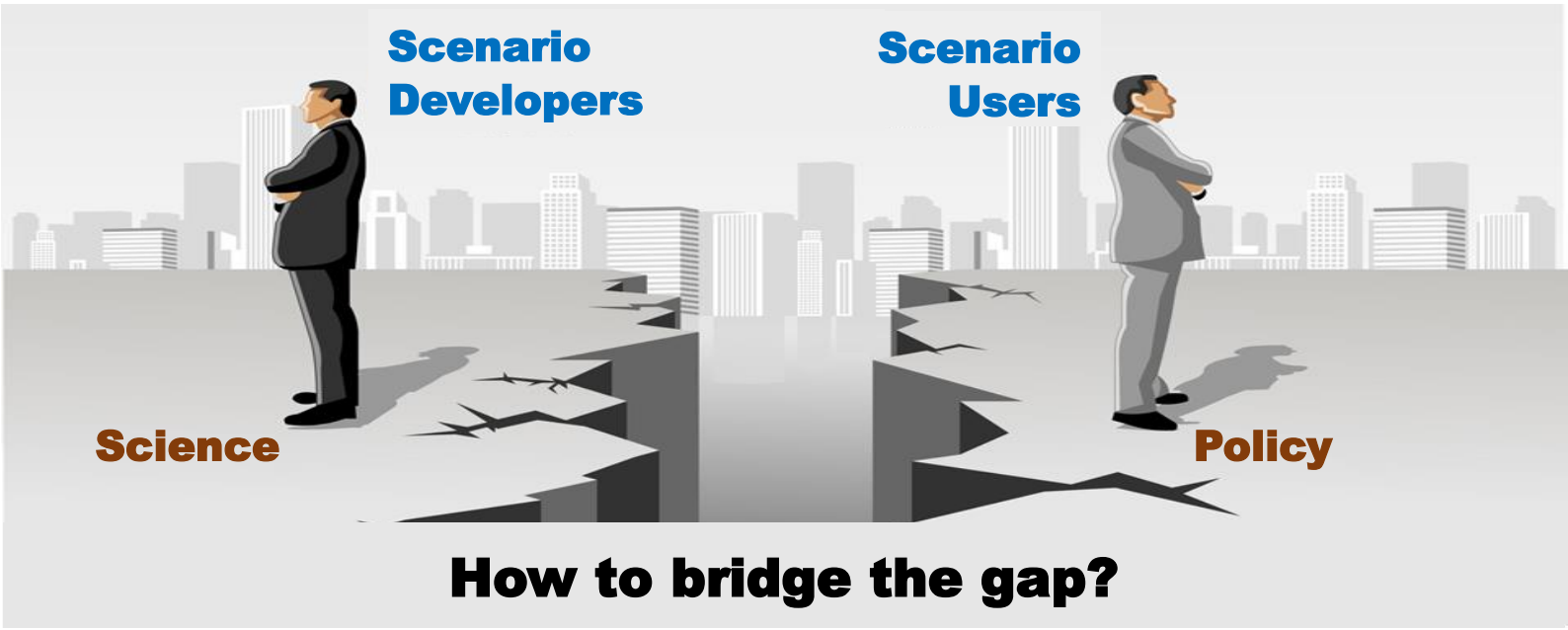
Some of the difficulties that were clearly present at the first SFG meeting in Paris reflect broader challenges in developing and using global scenarios to support policy development.

Global scenarios are significantly different than scenarios established in other decision domains. Although high stakes and deep uncertainties about the future make the case for using the scenario method to prepare ourselves for a wide range of future possibilities, a big challenge remains concerning how to address the specific needs of diverse user groups (see Parsons 2008). Users' engagement is considered critical to the effectiveness of scenarios (van der Heijden 1996). Scenario users jointly delineate their

sphere of influence (where they can effectively make decisions and develop strategies) and a sphere of uncertainty (where they need to agree on most important but uncertain drivers and their possible trends).

When integrating scenarios across sectors and scales globally, the problem becomes for more complex due to overlapping spheres of influence and uncertainty. One single, small stakeholder group cannot be completely representative of all geographical, demographic, economic, institutional experience through all sectors, disciplines and scales. Drivers and decision variables also cannot then be fixed, since the drivers in one sector are the decision variables in another. Finally, scenario producers are not fully aware of the needs of all relevant decision and policy makers.

Another well know problem in developing global scenarios is that such scenarios tend to concentrate on variables that have available global data and can be easily aggregated (Parsons 2008). Variables that depend on local contexts are often discarded.



Despite the challenges, scenarios are useful to support policy-making process at different stages. Many reviews and evaluations of scenarios processes reveal that they have been quite successful in the business context, supporting strategic decisions at all stages of policy cycle. Their impact in the public sector has so far been mostly limited to the first stage of the policy cycle (Volkery and Ribeiro 2009), which can be called an indirect support. The beneficial uses of scenarios in this context are summarized in the table below.

Policy stage	*Form of scenario-based decision support*
Policy issue identification and framing	Stimulating wider debate about possible futures Getting stakeholders engagement and buy-in Clarifying issues importance with respect to stakeholders' needs and expectations Agreeing objectives
Policy measure development	Generating options for future actions Appraising robustness of options for future actions

Policy measure implementation	Using scenario framework and indicators for monitoring of results
Policy evaluation	Using shared understanding about stakeholders' needs, expectations and objectives as well as monitoring results to assess policy effectiveness and efficiency.

The distance from the more direct scenario-based decision support has been even greater for global scenarios. Many scenarios studies were described as "hollow diamonds, that sparkle alluringly but fail to contain real value to the decision-making process." These findings stand in sharp contrast with the clear need for public policy at the global level to address future challenges and uncertainties. Can the success of the private sector in successful application of scenarios to tackle critical strategic problems be replicated?

Although this short analysis may sound pessimistic, many steps can be taken, and potential benefits are substantial even if moderate progress will be done. To this end it is recommended to establish a typology of scenario users and their needs to better tailor scenarios for those needs. Produced scenarios should be more transparent– especially with respect to judgments on uncertain factors. Finally there is need to institutionalize use of scenarios for policy development. Scenarios development and use is not a one-shot effort – its biggest worth lies in continued long term application, helping to achieve long-term goals in spite of complexity and uncertainty.

How to proceed

In 2015, the WFaS Project Team will continue to apply the feedback provided by the SFG to focus its activities on some of the issues raised.

- The adjustment of the scenarios and the scenario process started at the SFG meeting is ongoing, with findings from WFaS also reported back to SSP development teams, to enhance understanding within their development process as well.
- Additional indicators will be applied and tested to enhance the delineation of hydro-economic classes. A related report on defining and integrating food, water, and energy securities is being prepared.
- Summary reports are produced of the trends in the indicators and other variables that are used to help assess the current state and to quantify scenarios assumptions going forward, as well as reporting on the methods and process for making and quantifying specific assumptions. Methods of scaling information for use by different types of models and sectors working at different scales are an important component.

We will place even greater emphasis on analyzing important tradeoffs related to water resource management. A few examples:

- With partners, we have completed a study on policy tradeoffs between Climate, Land, Energy, and Water in Mauritius,
- We been investigating tradeoffs between climate change, water quality, and thermal power production.
- We are now completing an assessment of how water constraints affect the potential energy plans and tradeoffs delineated by the Global Energy Assessment scenarios and vice versa.
- We are developing indicators of and assessing economic tradeoffs and synergies between water infrastructure and management of ecosystem services.

- Options for risk management and improving flood resilience are being investigated in case studies, and we are testing how we might best use macro-scale models for assessing risks and risk management options.
- Our agricultural models and information system are being updated to provide more detailed data and information on the food-water nexus.

Some publications produced by WFaS Project Team members in the past year are listed at the end of the document to indicate some of the topics of ongoing work. Paths forward for the two main topics discussed at the first SFG meeting are shown here:

Hydro-Economic Classes

Based on the recommendations of the SFG, the IIASA team is revising the hydro-economic classes and analyzing and assessing a wider range of indicators for use in the classification.

Scenarios

We envision two possible ways forward. The first would be to develop 3 scenarios: "Sustainability Quest", "Business as Usual" (this title may not work well as different people can easily disagree what BAU means. Alternatively the title "Middle of the Road" can be used) and "Dark Future".

The second would be to develop 2 sets of scenarios: "Conventional Worlds" (a view of the world in 2050 assuming business-as-usual paths and behaviors) and "Worlds We Want to See" (alternatives that leads to satisfying basic human needs in harmony with the natural world). This approach, rather than trying to depict the destinations, would concentrate on how to make a transition from conventional worlds to the worlds we want to see. With the focus on transition pathways, difficult tradeoffs would be explored, eventually resulting in the analysis and types of messages and guidelines important for policy makers. We plan to look specifically into unexplored and non-intuitive pathways that may find unexpected win-win solutions to overcome painful tradeoffs. In all cases the pathways will not only describe destination points but also describe how these destination points were reached.

At the moment, we are planning to combine both methods above, by developing sets of possible future pathways and then working with the SFG in the next meeting to build the "worlds we want to see", which is in many ways an extension of the discussion on the sustainability scenario during the Paris meeting.

The analyzed pathways will explore types of solutions (intervention options) prioritized by stakeholders, taking into account the types of options they are primarily considering in their regions (and therefore the types of tradeoffs they would like to see further investigated in relation to how it may change regional and global dynamics). Then, the IIASA team can analyze those types of options and the tradeoffs among the options for a variety of pathways.

Continuing Dialog

The goal of WFaS is to eventually be able to provide the scientific evidence needed to support good and consistent water management decisions across sectors and scales, and to provide that information in a useful format. The more feedback we get from our stakeholders, the closer we can get to that goal. WFaS needs the experience of its stakeholders to inform the Project Team of what they most would like to see assessed, how they see the future developing, the key priorities, challenges, and tradeoffs they face, and the options they have available to manage them, so that WFaS can adjust its analysis accordingly. Please provide feedback to this report, and continue to send input to the WFaS secretariat whenever you think of a need or an issue that you think should be a priority within the WFaS analysis.

References

Parson, E. A. (2008). Useful global-change scenarios: current issues and challenges. *Environmental Research Letters*, *3*(4), 045016.

Volkery, A., & Ribeiro, T. (2009). Scenario planning in public policy: Understanding use, impacts and the role of institutional context factors. *Technological forecasting and social change*, *76*(9), 1198-1207.

Van der Heijden, K. (1996). Scenarios: the art of strategic conversation.

Selected Publications by WFaS Team Members in 2013

Cosgrove W, Wiberg D (2013). Assessing the Future of Water. Options Magazine (Summer 2013). IIASA, Laxenburg, Austria.

Dankers, R., N. W. Arnell, D. B. Clark, P. D. Falloon, B. M. Fekete, S. N. Gosling, J. Heinke, H. Kim, Y. Masaki, Y. Satoh, T. Stacke, **Y. Wada**, and D. Wisser (2013), First look at changes in flood hazard in the Inter-Sectoral Impact Model Intercomparison Project ensemble, *Proc. Natl. Acad. Sci. USA*, 111(9), 3257–3261, doi:10.1073/pnas.1302078110, *Global Climate Impacts: A Cross-Sector, Multi-Model Assessment Special Feature*.

Elliott, J., D. Deryng, C. Müller, K. Frieler, M. Konzmann, D. Gerten, M. Glotter, M. Flörke, **Y. Wada**, S. Eisner, C. Folberth, I. Foster, S.N. Gosling, I. Haddeland, N. Khabarov, F. Ludwig, Y. Masaki, S. Olin, C. Rosenzweig, A.C. Ruane, Y. Satoh, E. Schmid, T. Stacke, Q. Tang, and D. Wisser (2013), Constraints and potentials of future irrigation water availability on agricultural production under climate change, *Proc. Natl. Acad. Sci. USA*, 111(9), 3239–3244, doi:10.1073/pnas.1222474110, *Global Climate Impacts: A Cross-Sector, Multi-Model Assessment Special Feature*.

Ermolieva T, Ermoliev Y, Obersteiner M, Makowski M, **Fischer G** (2013), Dams and catastrophe risk: Discounting in long term planning. In Integrated Catastrophe Risk Modeling: Supporting Policy Processes, A Amendola, T Ermolieva, J Linnerooth-Bayer, R Mechler (Eds) Springer, Dordrecht, Netherlands pp.73-92

Fischer G, Hizsnyik E, van Velthuizen HT, Wiberg D, Hermann S (2013). Climate, Land, Energy & Water Strategies: A Case Study of Mauritius. IIASA, Laxenburg, Austria (April 2013).

Gleeson, T., and **Y. Wada** (2013), Assessing regional groundwater stress for nations using multiple data sources with the groundwater footprint, *Environ. Res. Lett.*, *8*, 044010, doi:10.1088/1748-9326/8/4/044010.

Gregory, J. M., N. J. White, J. A. Church, M. F. P. Bierkens, J. E. Box, M. R. van den Broeke, J. G. Cogley, X. Fettweis, E. Hanna, P. Huybrechts, L. F. Konikow, P. W. Leclercq, B. Marzeion, J. Oerlemans, M. E. Tamisiea,

Y. Wada, L. M.Wake, R. S. W. van de Wal (2013), Twentieth-Century Global-Mean Sea Level Rise: Is the Whole Greater than the Sum of the Parts?. *J. Climate*, *26*, 4476–4499, doi:10.1175/JCLI-D-12-00319.1.

Haddeland, I., J. Heinke, H. Biemans, S. Eisner, M. Flörke, N. Hanasaki, M. Konzmann, **F. Ludwig**, Y. Masaki, **J. Schewe**, T. Stacke, Z. Tessler, **Y. Wada**, and D. Wisser (2013), Global water resources affected by human interventions and climate change, *Proc. Natl. Acad. Sci. USA*, 111(9), 3251–3256, doi:10.1073/pnas.1302078110, *Global Climate Impacts: A Cross-Sector, Multi-Model Assessment Special Feature*.

Howells M, Hermann S, Welsch M, Bazilian M, Segerstroem R, Alfstad T, Gielen D, Rogner H-H, **Fischer G, van Velthuizen HT, Wiberg D**, Young C, Roehrl RA, Mueller A, Steduto P, Ramma I (2013). Integrated analysis of climate change, land-use, energy and water strategies. Nature Climate Change, 3(7):621-626 (July 2013) (Published online 25 June 2013).

Prieler S, Fischer G, van Velthuizen HT (2013). Land and the food-fuel competition: Insights from modeling. WIREs Energy and Environment, 2(2):199-217 (March/April 2013) (Published online 10 October 2012)

Prudhomme, C., I. Giuntoli, E.L. Robinson, D.B. Clark, N. W. Arnell, R. Dankers, B. Fekete, W. Franssen, D. Gerten, S. N. Gosling, S. Hagemann, D. M. Hannah, H. Kim, Y. Masaki, Y. Satoh, T. Stacke, Schewe, J., J. Heinke, D. Gerten , I. Haddeland, N.W. Arnell, D.B. Clark, R. Dankers, S. Eisner, B. Fekete, F. J. Colón-González, S. N. Gosling, H. Kim, X. Liu, Y. Masaki, F. T. Portmann, Y. Satoh, T. Stacke, Q. Tang, **Y. Wada**, D. Wisser, T. Albrecht, K. Frieler, F. Piontek, L. Warszawski, and P. Kabat (2013), Multi-model assessment of water scarcity under climate change, *Proc. Natl. Acad. Sci. USA*, 111(9), 3245–3250, doi:10.1073/pnas.1222460110, *Global Climate Impacts: A Cross-Sector, Multi-Model Assessment Special Feature*.

Taylor, R. G., B. Scanlon, P. Döll, M. Rodell, R. van Beek, **Y. Wada**, L. Longuevergne, M. LeBlanc, J. S. Famiglietti, M. Edmunds, L. Konikow, T. Green, J. Chen, M. Taniguchi, M. F.P Bierkens, A. MacDonald, Y. Fan, R. Maxwell, Y. Yechieli, J. Gurdak, D. Allen, M. Shamsudduha, K. Hiscock, P. Yeh, I, Holman and H. Treidel (2013), Groundwater and climate change, *Nature Clim. Change*, *3*, 322-329, doi:10.1038/nclimate1744.

Tian Z, Liang Z, Zhong H, Qiu H, **Sun L, Fischer G, van Velthuizen HT, Cao G**, Zhao S (2013). Upside potential versus downside risk in Chinese agriculture under climate change. Intelligent Systems and Decision Making for Risk Analysis and Crisis Response: Proceedings, RACR 2013, C. Huang, C. Kahraman (Eds). 27-29 August 2013, Istanbul, Turkey pp.291-297

Wada, Y., and D. Wisser (2013), Drought in the 21st century: a multi-model ensemble experiment to assess global change, quantify uncertainty and identify 'hotspots', change, *Proc. Natl. Acad. Sci. USA*, 111(9), 3262–3267, doi:10.1073/pnas.1222473110, *Global Climate Impacts: A Cross-Sector, Multi-Model Assessment Special Feature*.

Wada, Y., and L. Heinrich (2013), Assessment oftransboundary aquifers of the world—vulnerability arising from human water use, *Environ. Res. Lett.*, *8*, 024003, doi:10.1088/1748-9326/8/2/024003.

Wada, Y., D. Wisser, S. Eisner, M. Flörke, D. Gerten, I. Haddeland, N. Hanasaki, Y. Masaki, F.T. Portmann, T. Stacke, Z. Tessler, and J. Schewe (2013), Multimodel projections and uncertainties of irrigation water demand under climate change, *Geophys. Res. Lett.*, *40*, 4626–4632, doi:10.1002/grl.50686.

Wada, Y., L. P. H. van Beek, N. Wanders, and M. F. P.Bierkens (2013), Human water consumption intensifies hydrological drought worldwide, *Environ. Res. Lett.*, *8*, 034036, doi:10.1088/1748-9326/8/3/034036.

van Vliet M.T.H., Vögele S., Rübbelke D. (2013) *Water constraints on European power supply under climate change: impacts on electricity prices*. Environ. Res. Lett. 8 035010.

van Vliet, M.T.H., F. Ludwig and P. Kabat (2013), *Global Streamflow and Thermal Habitats of Freshwater Fishes under Climate Change*, Climatic Change,doi10.1007/s10584-013-0976-0

van Vliet M.T.H., Ludwig F., Kabat P. (2013) *Cross-sectoral conflicts for water under climate change: the need to include water quality impacts*. In: Impacts World 2013, International Conference on Climate Change Effects, Potsdam Institute for Climate Impact Research, Potsdam, May 27-30.

Wang, J., Y. Sheng, C. J. Gleason, and **Y. Wada** (2013), Downstream Yangtze River Levels Impacted by Three Gorges Dam, *Environ. Res. Lett.*, *8*, 044012, doi:10.1088/1748-9326/8/4/044012.

Davie, J. C. S., P. D. Falloon, R. Kahana, R. Dankers, R. Betts, F.T. Portmann, D. Wisser, D. B. Clark, A. Itoh, Y. Masaki, K. Nishina, B. Fekete, Z. Tessler, **Y. Wada**, X. Liu, Q. Tang, S. Hagemann, T. Stacke, R. Pavlick, S. Schaphoff, S. N. Gosling, W. Franssen, and N. Arnell (2013), Comparing projections of future changes in runoff from hydrological and biome models in ISI-MIP, *Earth Syst. Dynam.*, *4*, 359-374, doi:10.5194/esd-4-359-2013.

APPENDIX 1 – Hydro-Economic Classes

Meaningful Classification
stakeholders recommendations

General comments	Measures not clear enough to easily understand River basin level needed (rather than national) Countries categorized together (also some regions within big countries) do not necessarily implement the same policy responses – need to be further considered at a finer level.
Dimensions (Axes)	
X *Hydrological Complexity*	existing indicators + water quality
Y *Economic Capacity*	GDP/capita only
Z *Institutional Capacity*	indicator of the effectiveness of water institutions
Ideas for Z axis indicators (proxies) *Effectiveness of water institutions*	Tertiary education Existing water information/monitoring Time from project initiation to completion # of water infrastructure projects completed

APPENDIX 2 – Reshaping Scenarios

	Sustainability Quest	*Business as Usual*	*Fragmentation*
General Comments	How this scenario came about Goals/benchmarks needed Major transition needed Specific measures depending on local conditions Maintain water focus	Is it BAU or Middle of the Road? Only continuation of trends? Should it be closer to SSP4 (Inequality)? Should there be major problems (collapse) ahead in this scenario? Deterioration is a consequence of BAU Reactive scenario – quick-fix response to disasters Modified (by the group) BAU scenario is unduly pessimistic	Shouldn't be all negative Strong national interest, low international cooperation (South Asia as an example) Local Economic Development
Trade-offs needed between different goals	Social inclusion vs environmental sustainability Economic growth vs environmental sustainability Food production vs sustainable groundwater use Hydro-power vs flood mitigation and ecosystems Nuclear energy and hydro-fracking: energy benefits vs water impacts		
Main Challenges	great transition: paradigm shift on the global scale change in values system towards lower consumption financial system reform identify sources of necessary investments strong regional connections (not just global) need to include stakeholders at every level	Impact of China on the global market Challenges for high growth economies (India, China, Brazil etc.) Increasing protein consumption	Many conflicts between countries Increased demand on natural resources Food insecurity Compromised ecosystems health Poverty as a source of environmental degradation Less money available for investments

Climate Change		Sea level rise – coastal impacts Temperature increase – impacts on food productivity and irrigation regimes	
Water	access to water resource information good balance between top-down and bottom up approaches in water management	Increasing water scarcity, endangered water availability. Groundwater overexploitation.	Lack of legal framework Problematic transboundary water management Lack of funding for water management and infrastructure
NATURE			
Climate Change		Sea level rise – coastal impacts. Temperature increase	
Land Use and Agriculture		Environmental impacts from intensive agriculture.	
Land Productivity	Significant increase in food production.	Lower food productivity due to climate impacts.	Increased food production (not sustainable).
Agricultural Technology			
Ecosystems		Stressed ecosystem services.	Compromised ecosystems health.
ECONOMY			
Economic Development	Rich countries assist poorer countries. Financial system reform.	Less stable global economy. Impact of China on the global market. Challenges for high growth economies (India, China, Brazil etc.).	Local Economic Development. Increased demand on natural resources. Poverty as a source of environmental degradation. Less money available for investments.

GDP	→ Identify sources of necessary investments. → GDP too high in the corresponding SSP.		GDP growing slowly in developing countries, stagnating in developed countries.
Inequalities		Widening gap between rich and poor	
Technology			
Technology Development		Isolated technology breakthroughs.	Low technological development.
Technology Transfer		Limited technology adoption.	Low knowledge and technology transfer.
Energy		Energy production increase without addressing environmental concerns.	
SOCIETY			
Demography			
Population	Youth engagement becomes a driving force for sustainability and equity.	Extreme events increase the number of environmental refugees.	→ How to explain high population growth?
Values, Lifestyles			
Consumption, Diets	Change in values system towards lower consumption.	Increasing protein consumption.	

Governance			
Policy Orientation	Strong regional connections (not only global).	US – market first EU – policy first BRICS – aggressive expansion Africa – highly variable Stronger focus on food security.	Strong national interest, low international cooperation (South Asia as an example).
Quality of Governance	Stakeholders involved at every level.		
Environmental Policy	Valuation of ecosystem services integrated into decision-making.		
Global Cooperation	Intensive and effective global cooperation	More tensions and conflicts. Decreasing collaboration. Stronger regional geo-economic blocks	Many conflicts between countries.
WATER			
Water Governance	Improved water measurement and monitoring capacity. Improved access to water resource information. Good balance between top-down and bottom up approaches in water management.		Lack of legal framework. Problematic transboundary water management. Lack of funding for water management and infrastructure.
Water Technologies	Improved technology for water treatment and distribution.		
Water Infrastructure	More economic resources for water infrastructure and management.		

Available Water Resources	Increase in saline water use.	Increasing water scarcity, endangered water availability. Groundwater overexploitation.	
Water Demand	Strong water demand management. Major investments for improved water efficiency needed. → Water efficiency increase has social and environmental costs - include linkages.		→ Water demand/use – difficult to assess.
Agriculture		Changing irrigation regimes due to climate change.	Irrigation area may increase in some countries.
Energy	Shift to hydropower.		
Freshwater Ecosystems Health		Stressed water ecosystem services.	
WELL-BEING			
Water Security	→ Include livelihoods through water lenses.		
Energy Access	→ Include water impacts on energy security		
Food Security	→ Include water impacts on food security	More famines.	Food insecurity.

APPENDIX 3 – Intervention Options

	Idea	*Application*	*Positive Impacts*	*Risks and Challenges*
Water Governance				
Data, monitoring, forecasting	Transparency and data sharing	Everywhere	Higher water use efficiency Better water use management Conflicts resolution	Embarrassment Political resistance to transparency Challenges the status quo
	Greatly strengthening monitoring of water resources and their use	Everywhere	Improved resources knowledge	Finances Political challenges Risks of data sharing
	Global seasonal climate forecasting to guide global food buffer stock management	Global	Optimizes water use	Political feasibility Science advances
Integrated Management	Integrated Watershed Management (treating catchment areas as a unit) Create economic incentives for local people, private companies and donor countries that result in the implementation of institutional capability to manage the water resources at the river basin scale, coupled with the construction and continuous operation of reservoirs, water supply and sanitation.	Everywhere (rainfed agricultural areas) Upland catchments Poor countries with high hydrological complexity	Avoid soil erosion and filtration of reservoirs and rivers Enrich the health of ecosystems Increase rates of groundwater recharge Decrease intensity of floods Improved food security Increase base flow in rivers	Reduced inflows to reservoirs (mean stream flow) Reducing the amount of water available for use Can create conflict (downstream/upstream) Lack of management capability

	Aquifer Management (mapping, monitoring and artificial recharge)	Groundwater dependent countries	More sustainable use of aquifers Food security Addressing water quality Managing variability in water availability Low-cost options allowing timeliness of water application	Inter-country governance is difficult Risk of corruption Must have water to recharge with Possible groundwater contamination Costs
	Integrated management of hydrological/agricultural/ecological systems	All agricultural areas (rainfed, irrigated etc.)	More efficient use of water More diversification in agriculture	Linking theory with practice Failure to incentivize irrigation efficiency Knowledge and capital access Vested interests
Economic aspects	Expanding on the use of virtual water concept (possible global buffer stock internationally controlled with decentralized stocking)	Water scarce areas	Greater food security Enables virtual water to function as a system Manages regional variability	Political insecurity Vested interests of food corporations
Financial aspects	Water pricing and fiscal measures (staggered tariff) user pays/polluter pays	Everywhere where appropriate	Guaranteeing access for all Better allocation (more efficient, better economic use)	How to guarantee social justice and access for all Risk to the environment Political transition Non commensurable values
	Balance between user pays and public funding for water management. Influence priority of spending		Balance the public good and user based mechanisms for funding	Building this into the models
	Offsets for water use efficiency gains			

Legal aspects	Change in the legal regime of groundwater management	Where there is British common law in prevalence (owner of land owns the groundwater: unrestricted access)	More sustainable use of groundwater Reduce conflict over groundwater Ensuring basic access to groundwater for all	Opposition from those benefiting currently
	Legal regime for transboundary issues (UN convention not being ratified	Global (regional co-operation agreements across the world	Avoids conflict Conflict resolution mechanisms	May be used as a vehicle for imposing global norms that don't fit everywhere Global regime may be abused by powerful nations
	Facilitate transfers of water rights	Water scarce areas	High added value of water	Concentration of water rights Squeezing of small farmers Reduction of water use opportunities (AMM for reference), especially with lumpy investments
Regional co-operation	Transboundary hydro-economic regions	Transboundary rivers	Optimal use of water Reduce conflict	Conflict resolution Lack of political will Clarity about benefits Investment Education Timeframes

Water Technologies				
	Desalination using nanotechnology	Coastal urban areas Saline groundwater areas	Moor efficiency, less costly compared to contemporary desalination technologies Co-operation between countries for development Use variable, renewable energies	Cost Energy intensive pollution
	Nano-biosensors for better water treatment (including the context of new pollutants)	Everywhere (global capacity development)	Health Cost reduction for water treatment	It is not? known when breakthrough in research will come
	Sea water agriculture in coastal areas (technology in development)	Sea side areas with nearby crop/fodder production	Economic (poor countries) Oil seed production (with some success so far)	Not successfully used in agriculture (salinization) Not economical so far New technology in development May not be useable in the short term
	Enhanced ICT for - Monitoring - Sharing information - Planning - Management - Communication	Everywhere	Low-cost remote access to information (live)	Not relevant for deep aquifers or river flows currently Dependency Reliance on unreliable data (e.g. flows, rainfall) Perception that developing world needs appropriate technology
	Research and education	Needs more	Work/consideration	
Water				

Infrastructure				
Water storage	Large storage dams	Countries with highly variable stream flow	Increased water availability Help manage floods	Environmental flows and impact Displacement of people Legal challenge Physical challenge Fiscal challenges Political challenges
	Small dams	Water scarce areas with small holder agriculture	Increased water availability Rural development	Water losses
Water transfers	Inter-basin transfers	Water scare countries	Enables economic and social activity Encourage regional co-operation	Massive displacement of populations (particular to India and Bangladesh) Massive energy costs Potential risk to the monsoon cycle (India) Ecological impacts from changes in water regimes Strong public resistance Serious legal issues Fiscal challenges Conflict potential between basins
Security	Global response to prevent terrorist action against water infrastructure (such as contamination of drinking water supplies)	Global	Protection of the water resources, food production, economies Risk reduction	Lack of transparency in the water sector – may get worse
Available Water				

Resources				
Evaporation	Reduction of open water evaporation from larger reservoirs	Wherever there are large reservoirs	Increased water availability and utilization (e.g. water for hydropower, recreation etc.)	New technology Environmental consequences Other user activities compromised Cost of implementation
	Reduction of open water evaporation from wetlands	Where there is water scarcity and opportunity	Reduce conflict Increased water availability	Environmentalists don't like it
Water Demand				
	Water reuse	In societies where there is high non-consumptive use and water scarcity	Reduce water use Reduce pollution	Health Other effects of using polluted water
Irrigation	Improve irrigation techniques (covered drains, drip irrigation)	Everywhere irrigation is used currently	Greater water efficiency Higher crop production Food security Employment Economic growth	Cost Pollution Tendency to increase irrigation area
	Irrigation management transfer	Where there are large irrigation systems managed by government	Greater water use efficiency Better cost recovery Increased irrigated area at lower cost Improved operation and management of irrigation systems	Bureaucracy Capacity and empowerment of water users associations (inadequate)