Taylor & Francis
Taylor & Francis Group

Hydrological Sciences Journal

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/thsj20

The IAHS Science for Solutions decade, with Hydrology Engaging Local People IN one Global world (HELPING)

Berit Arheimer, Christophe Cudennec, Attilio Castellarin, Salvatore Grimaldi, Kate V. Heal, Claire Lupton, Archana Sarkar, Fuqiang Tian, Jean-Marie Kileshye Onema, Stacey Archfield, Günter Blöschl, Pedro L. Borges Chaffe, Barry F.W. Croke, Moctar Dembélé, Chris Leong, Ana Mijic, Giovanny M. Mosquera, Bertil Nlend, Adeyemi O. Olusola, María J. Polo, Melody Sandells, Justin Sheffield, Theresa C. van Hateren, Mojtaba Shafiei, Soham Adla, Ankit Agarwal, Cristina Aguilar, Jafet C.M. Andersson, Cynthia Andraos, Ana Andreu, Francesco Avanzi, Ryan R. Bart, Alena Bartosova, Okke Batelaan, James C. Bennett, Miriam Bertola, Nejc Bezak, Judith Boekee, Thom Bogaard, Martijn J. Booij, Pierre Brigode, Wouter Buytaert, Konstantine Bziava, Giulio Castelli, Cyndi V. Castro, Natalie C. Ceperley, Sivarama K. R. Chidepudi, Francis H. S. Chiew, Kwok P. Chun, Addisu G. Dagnew, B.W. Dekongmen, Manuel Del Jesus, Alain Dezetter, José A. Do Nascimento Batista, Rebecca C. Doble, Nilay Dogulu, Joris P.C. Eekhout, Alper Elçi, Maria Elenius, David C. Finger, Aldo Fiori, Svenja Fischer, Kristian Förster, Daniele Ganora, Emna Gargouri Ellouze, Mohammad Ghoreishi, Natasha Harvey, Markus Hrachowitz, Mahesh Jampani, Fernando Jaramillo, Harro J. Jongen, Kola Y. Kareem, Usman T. Khan, Sina Khatami, Daniel G. Kingston, Gerbrand Koren, Stefan Krause, Heidi Kreibich, Julien Lerat, Junguo Liu, Suxia Liu, Mariana Madruga de Brito, Gil Mahé, Hodson Makurira, Paola Mazzoglio, Mohammad Merheb, Ashish Mishra, Hiba Mohammad, Alberto Montanari, Never Mujere, Ehsan Nabavi, Albert Nkwasa, Maria E. Orduna Alegria, Christina Orieschnig, Valeriya Ovcharuk, Santosh S. Palmate, Saket Pande, Shachi Pandey, Georgia Papacharalampous, Ilias Pechlivanidis, Gopal Penny, Rafael Pimentel, David A. Post, Cristina Prieto, Saman Razavi, Sergio Salazar-Galán, Adarsh Sankaran Namboothiri, Pedro P. Santos, Hubert Savenije, Nura J. Shanono, Ashutosh Sharma, Murugesu Sivapalan, Zhanibek Smagulov, Jan Szolgay, Jin Teng, Adriaan J. Teuling, Claudia Teutschbein, Hristos Tyralis, Ann van Griensven, Andries J. van Schalkwyk, Marit van Tiel, Alberto Viglione, Elena Volpi, Thorsten Wagener, Xiaojun Wang, Lan Wang-Erlandsson, Marthe Wens & Jun Xia

To cite this article: Berit Arheimer, Christophe Cudennec, Attilio Castellarin, Salvatore Grimaldi, Kate V. Heal, Claire Lupton, Archana Sarkar, Fuqiang Tian, Jean-Marie Kileshye Onema, Stacey Archfield, Günter Blöschl, Pedro L. Borges Chaffe, Barry F.W. Croke, Moctar Dembélé, Chris Leong, Ana Mijic, Giovanny M. Mosquera, Bertil Nlend, Adeyemi O. Olusola, María J. Polo, Melody Sandells, Justin Sheffield, Theresa C. van Hateren, Mojtaba Shafiei, Soham Adla, Ankit Agarwal, Cristina Aguilar, Jafet C.M. Andersson, Cynthia Andraos, Ana Andreu, Francesco Avanzi, Ryan R. Bart, Alena Bartosova, Okke Batelaan, James C. Bennett, Miriam

Bertola, Nejc Bezak, Judith Boekee, Thom Bogaard, Martijn J. Booij, Pierre Brigode, Wouter Buytaert, Konstantine Bziava, Giulio Castelli, Cyndi V. Castro, Natalie C. Ceperley, Sivarama K. R. Chidepudi, Francis H. S. Chiew, Kwok P. Chun, Addisu G. Dagnew, B.W. Dekongmen, Manuel Del Jesus, Alain Dezetter, José A. Do Nascimento Batista, Rebecca C. Doble, Nilay Dogulu, Joris P.C. Eekhout, Alper Elçi, Maria Elenius, David C. Finger, Aldo Fiori, Svenja Fischer, Kristian Förster, Daniele Ganora, Emna Gargouri Ellouze, Mohammad Ghoreishi, Natasha Harvey, Markus Hrachowitz, Mahesh Jampani, Fernando Jaramillo, Harro J. Jongen, Kola Y. Kareem, Usman T. Khan, Sina Khatami, Daniel G. Kingston, Gerbrand Koren, Stefan Krause, Heidi Kreibich, Julien Lerat, Junguo Liu, Suxia Liu, Mariana Madruga de Brito, Gil Mahé, Hodson Makurira, Paola Mazzoglio, Mohammad Merheb, Ashish Mishra, Hiba Mohammad, Alberto Montanari, Never Mujere, Ehsan Nabavi, Albert Nkwasa, Maria E. Orduna Alegria, Christina Orieschnig, Valeriya Ovcharuk, Santosh S. Palmate, Saket Pande, Shachi Pandey, Georgia Papacharalampous, Ilias Pechlivanidis, Gopal Penny, Rafael Pimentel, David A. Post, Cristina Prieto, Saman Razavi, Sergio Salazar-Galán, Adarsh Sankaran Namboothiri, Pedro P. Santos, Hubert Savenije, Nura J. Shanono, Ashutosh Sharma, Murugesu Sivapalan, Zhanibek Smagulov, Jan Szolgay, Jin Teng, Adriaan J. Teuling, Claudia Teutschbein, Hristos Tyralis, Ann van Griensven, Andries J. van Schalkwyk, Marit van Tiel, Alberto Viglione, Elena Volpi, Thorsten Wagener, Xiaojun Wang, Lan Wang-Erlandsson, Marthe Wens & Jun Xia (2024) The IAHS Science for Solutions decade, with Hydrology Engaging Local People IN one Global world (HELPING), Hydrological Sciences Journal, 69:11, 1417-1435, DOI: 10.1080/02626667.2024.2355202

To link to this article: https://doi.org/10.1080/02626667.2024.2355202

HYDROLOGICAL SCIENCES JOURNAL
2024, VOL. 69, NO. 11, 1417–1435
https://doi.org/10.1080/02626667.2024.2355202

OPINION

The IAHS Science for Solutions decade, with Hydrology Engaging Local People IN one Global world (HELPING)

Berit Arheimer[a], Christophe Cudennec[b], Attilio Castellarin[c], Salvatore Grimaldi[d], Kate V. Heal[e], Claire Lupton[f], Archana Sarkar[g], Fuqiang Tian[h], Jean-Marie Kileshye Onema[i,j], Stacey Archfield[k], Günter Blöschl[l], Pedro L. Borges Chaffe[m], Barry F.W. Croke[n], Moctar Dembélé[o], Chris Leong[p], Ana Mijic[q], Giovanny M. Mosquera[r], Bertil Nlend[s], Adeyemi O. Olusola[t], María J. Polo[u], Melody Sandells[v], Justin Sheffield[w], Theresa C. van Hateren[x], Mojtaba Shafiei[y], Soham Adla[z], Ankit Agarwal[aa], Cristina Aguilar[u], Jafet C.M. Andersson[a], Cynthia Andraos[bb], Ana Andreu[u], Francesco Avanzi[cc], Ryan R. Bart[dd], Alena Bartosova[a], Okke Batelaan[ee], James C. Bennett[ff], Miriam Bertola[l], Nejc Bezak[gg], Judith Boekee[z], Thom Bogaard[z], Martijn J. Booij[hh], Pierre Brigode[ii], Wouter Buytaert[q], Konstantine Bziava[jj], Giulio Castelli[kk,ll,mm], Cyndi V. Castro[nn], Natalie C. Ceperley[oo], Sivarama K. R. Chidepudi[pp,qq], Francis H. S. Chiew[ff], Kwok P. Chun[rr], Addisu G. Dagnew[ss], B.W. Dekongmen[tt], Manuel Del Jesus[uu], Alain Dezetter[vv], José A. Do Nascimento Batista[ww], Rebecca C. Doble[ff], Nilay Dogulu[xx], Joris P. C. Eekhout[yy], Alper Elçi[zz], Maria Elenius[a], David C. Finger[aaa], Aldo Fiori[bbb], Svenja Fischer[ccc], Kristian Förster[ddd], Daniele Ganora[eee], Emna Gargouri Ellouze[fff], Mohammad Ghoreishi[ggg], Natasha Harvey[hhh], Markus Hrachowitz[z], Mahesh Jampani[iii], Fernando Jaramillo[jjj], Harro J. Jongen[ccc,kkk], Kola Y. Kareem[lll], Usman T. Khan[mmm], Sina Khatami[nnn], Daniel G. Kingston[ooo], Gerbrand Koren[ppp], Stefan Krause[qqq], Heidi Kreibich[rrr], Julien Lerat[ff], Junguo Liu[sss], Suxia Liu[ttt,uuu], Mariana Madruga de Brito[vvv], Gil Mahé[vv], Hodson Makurira[www], Paola Mazzoglio[eee], Mohammad Merheb[b], Ashish Mishra[aa], Hiba Mohammad[xxx], Alberto Montanari[c], Never Mujere[yyy], Ehsan Nabavi[zzz], Albert Nkwasa[aaaa,bbbb], Maria E. Orduna Alegria[cccc], Christina Orieschnig[dddd], Valeriya Ovcharuk[eeee], Santosh S. Palmate[ffff], Saket Pande[z], Shachi Pandey[gggg], Georgia Papacharalampous[hhhh], Ilias Pechlivanidis[a], Gopal Penny[iiii], Rafael Pimentel[u], David A. Post[ff], Cristina Prieto[uu], Saman Razavi[ggg], Sergio Salazar-Galán[jjjj], Adarsh Sankaran Namboothiri[kkkk], Pedro P. Santos[llll], Hubert Savenije[z], Nura J. Shanono[mmmm], Ashutosh Sharma[aa], Murugesu Sivapalan[nnnn], Zhanibek Smagulov[oooo], Jan Szolgay[pppp], Jin Teng[ff], Adriaan J. Teuling[ccc], Claudia Teutschbein[qqqq], Hristos Tyralis[hhhh], Ann van Griensven[aaaa], Andries J. van Schalkwyk[rrrr], Marit van Tiel[ssss,tttt], Alberto Viglione[eee], Elena Volpi[bbb], Thorsten Wagener[uuuu], Xiaojun Wang[vvvv,wwww], Lan Wang-Erlandsson[xxxx], Marthe Wens[yyyy] and Jun Xia[zzzz]

[a]Hydrology Research, Swedish Meteorological and Hydrological Institute (SMHI), Sweden; [b]Institut Agro, INRAE, SAS, Rennes, France; [c]Department of Civil, Chemical, Environmental and Materials Engineering (DICAM), University of Bologna, Bologna, Italy; [d]DIBAF Department, University of Tuscia, Viterbo, Italy; [e]School of GeoSciences, University of Edinburgh, UK; [f]IAHS Ltd, UKCEH Wallingford, Wallingford, UK; [g]National Institute of Hydrology, Roorkee, India; [h]Department of Hydraulic Engineering, State Key Laboratory of Hydroscience and Engineering, Tsinghua University, Beijing, China; [i]WaterNet, North West University, South Africa; [j]School of Industrial Engineers, Université de Lubumbashi, D R Congo; [k]Water Mission Area, US Geological Survey, Reston, Virginia, USA; [l]Institute of Hydraulic Engineering and Water Resources Management, Vienna University of Technology, Austria; [m]Department of Sanitary and Environmental Engineering, Universidade Federal de Santa Catarina, Brazil; [n]Institute for Water Futures, Australian National University, Australia; [o]International Water Management Institute (IWMI), Ghana; [p]Linkage, Research Institute for Humanity and Nature, Japan; [q]Department of Civil and Environmental Engineering, Imperial College London, UK; [r]Departamento de Ingeniería, Pontificia Universidad Católica del Perú (PUCP), Lima, Perú; [s]Department of Earth Sciences, Faculty of Sciences, University of Douala, Cameroon; [t]Faculty of Environmental and Urban Change, York University, Toronto, Canada; [u]DAUCO, Andalusian Institute for Earth System Research, University of Córdoba, Spain; [v]Department of Geography and Environmental Sciences, Northumbria University, Newcastle upon Tyne, UK; [w]School of Geography and Environmental Science, University of Southampton, Southampton, UK; [x]Acacia Water, The Netherlands; [y]Division of Environment and Natural Resources, Norwegian Institute of Bioeconomy Research, Norway; [z]Department of Water Management, Delft University of Technology, The Netherlands; [aa]Department of Hydrology, Indian Institute of Technology Roorkee 247667, India; [bb]Faculty of Engineering, ESIB, Saint Joseph University, Lebanon; [cc]CIMA Research Foundation, Italy; [dd]Sierra Nevada Research Institute, University of California, Merced, USA; [ee]College of Science and Engineering, Flinders University, Australia; [ff]CSIRO, Australia; [gg]Faculty of Civil and Geodetic Engineering, University of Ljubljana, Slovenia; [hh]Water Engineering and Management, Faculty of Engineering Technology, University of Twente, The Netherlands; [ii]Univ Rennes, CNRS, Géosciences Rennes - UMR 6118, Rennes, France; [jj]Department of Hydraulic Engineering and Civil Construction, Faculty of Civil Engineering, Georgian Technical University, Georgia; [kk]Department of Agriculture, Food, Environment and Forestry (DAGRI), University of Florence, Italy; [ll]UNESCO Chair in Hydropolitics, University of Geneva, Switzerland; [mm]Institute for Environmental Sciences (ISE), University of Geneva, Switzerland; [nn]National Center for Atmospheric Research, USA; [oo]Hydrology, Institute of Geography, University of Bern, Switzerland; [pp]Univ Rouen Normandie, UNICAEN, CNRS, M2C UMR 6143, Rouen, France; [qq]BRGM, Orléans, France; [rr]Department of Geography, University of the West of England, UK; [ss]Water, Sanitation, and Hygiene, Millennium Water Alliance, Ethiopia; [tt]Department of Agricultural Engineering, Ho Technical University, Ghana; [uu]Instituto de Hidráulica Ambiental de la Universidad de Cantabria, Santander, Spain; [vv]HydroSciences Montpellier, University Montpellier, CNRS, IRD, IMT Alès,

CONTACT Berit Arheimer berit.arheimer@smhi.se Hydrology Research, Swedish Meteorological and Hydrological Institute (SMHI), Sweden

Montpellier, France; [ww]Department of Water Resources, State University of Campinas, Brazil; [xx]Hydrology, Water Resources and Cryosphere Branch, World Meteorological Organization (WMO), Geneva, Switzerland; [yy]Soil and Water Conservation Research Group, CEBAS-CSIC, Spain; [zz]Department of Environmental Engineering, Dokuz Eylul University, Türkiye; [aaa]Department of Engineering, Reykjavik University, Iceland; [bbb]DICITA, Roma Tre University, Italy; [ccc]Hydrology and Environmental Hydraulics, Wageningen University & Research, The Netherlands; [ddd]Institute of Ecology and Landscape, Weihenstephan-Triesdorf University of Applied Sciences, Germany; [eee]Department of Environment Land and Infrastructure Engineering (DIATI), Politecnico di Torino, Italy; [fff]Civil Engineering Department, National Engineering School of Tunis, University Tunis El Manar; [ggg]School of Environment and Sustainability, Department of Civil, Geological and Environmental Engineering, Global Institute for Water Security, University of Saskatchewan, Canada; [hhh]Institute for Water Futures and The Fenner School of Environment & Society, The Australian National University, Canberra, Australia; [iii]International Water Management Institute (IWMI), Colombo, Sri Lanka; [jjj]Stockholm University, Sweden; [kkk]Meteorology and Air Quality, Wageningen University, Wageningen, The Netherlands; [lll]Department of Advanced Science and Technology Convergence, Kyungpook National University, Sangju, Gyeongbuk, South Korea; [mmm]Civil Engineering, York University, Canada; [nnn]Department of Infrastructure Engineering, University of Melbourne, Parkville, Australia; [ooo]School of Geography, University of Otago, New Zealand; [ppp]Copernicus Institute of Sustainable Development, Utrecht University, The Netherlands; [qqq]School of Geography, Earth and Environmental Sciences, University of Birmingham, UK; [rrr]Section Hydrology, GFZ German Research Centre for Geosciences, Germany; [sss]Henan Provincial Key Lab of Hydrosphere and Watershed Water Security, North China University of Water Resources and Electric Power, Zhengzhou, Henan, China; [ttt]Key Laboratory of Water Cycle and Related Land Surface Processes, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing, China; [uuu]College of Resources and Environment/Sino-Danish College, University of Chinese Academy of Sciences, Beijing, China; [vvv]Department of Urban and Environmental Sociology, UFZ-Helmholtz Centre for Environmental Research, 04318 Leipzig, Germany; [www]Department of Construction and Civil Engineering, University of Zimbabwe, Harare, Zimbabwe; [xxx]Department of Civil, Environmental, Architectural Engineering and Mathematics (DICATAM), Università degli Studi di Brescia, Brescia, Italy; [yyy]Department of Geography, Geospatial Sciences and Earth Observation, University of Zimbabwe, Harare, Zimbabwe; [zzz]Responsible Innovation Lab, Australian National Centre for the Public Awareness of Science, The Australian National University, Canberra, Australia; [aaaa]Department of Water and Climate, Vrije Universiteit Brussel, Brussels, Belgium; [bbbb]International Institute for Applied Systems Analysis (IIASA), Austria; [cccc]Kansas Geological Survey, University of Kansas, USA; [dddd]UMR G-Eau, IRD, AgroParisTech, BRGM, CIRAD, INRAE, Institut Agro, University of Montpellier, Montpellier, France; [eeee]Hydrometeorological Institute, Odessa State Environmental University, Ukraine; [ffff]El Paso AgriLife Research and Extension Center, Department of Biological and Agricultural Engineering, Texas A&M University, USA; [gggg]Forest Ecology and Climate Change, Forest Research Institute, India; [hhhh]Department of Topography, National Technical University of Athens, Greece; [iiii]Climate Resilient Water Systems, Environmental Defense Fund, USA; [jjjj]Agroecosystems History Laboratory, Universidad Pablo de Olavide, Sevilla, Spain; [kkkk]Department of Civil Engineering, TKM College of Engineering, India; [llll]Centre for Geographical Studies, Institute of Geography and Spatial Planning, Associate Laboratory TERRA, University of Lisbon, Portugal; [mmmm]Department of Agricultural and Environmental Engineering, Bayero University Kano, Nigeria; [nnnn]Department of Civil and Environmental Engineering, University of Illinois at Urbana-Champaign, Illinois, USA; [oooo]Water Resources Laboratory of the Institute of Geography and Water Security JSC, Kazakhstan; [pppp]Department of Land and Water Resources Management, Slovak University of Technology in Bratislava, Slovakia; [qqqq]Department of Earth Sciences, Uppsala University, Sweden; [rrrr]Independent Consultant, South Africa; [ssss]Laboratory of Hydraulics, Hydrology and Glaciology (VAW), ETH Zurich, Switzerland; [tttt]Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), Switzerland; [uuuu]Institute of Environmental Science and Geography, University of Potsdam, Potsdam, Germany; [vvvv]National Key Laboratory of Water Disaster Prevention, Nanjing Hydraulic Research Institute, Nanjing, 210029, China; [wwww]Research Center for Climate Change, Ministry of Water Resources, Nanjing, 210029, China; [xxxx]Stockholm Resilience Centre, Stockholm University, Sweden; [yyyy]Institute for Environmental Studies, Vrije Universiteit Amsterdam, The Netherlands; [zzzz]Research Institute for Water Security (RIWS), Wuhan University, China

ABSTRACT
The new scientific decade (2023-2032) of the International Association of Hydrological Sciences (IAHS) aims at searching for sustainable solutions to undesired water conditions – whether it be too little, too much or too polluted. Many of the current issues originate from global change, while solutions to problems must embrace local understanding and context. The decade will explore the current water crises by searching for actionable knowledge within three themes: global and local interactions, sustainable solutions and innovative cross-cutting methods. We capitalise on previous IAHS Scientific Decades shaping a trilogy; from Hydrological Predictions (PUB) to Change and Interdisciplinarity (Panta Rhei) to Solutions (HELPING). The vision is to solve fundamental water-related environmental and societal problems by engaging with other disciplines and local stakeholders. The decade endorses mutual learning and co-creation to progress towards UN sustainable development goals. Hence, HELPING is a vehicle for putting science in action, driven by scientists working on local hydrology in coordination with local, regional, and global processes.

ARTICLE HISTORY
Received 1 February 2024
Accepted 26 April 2024

EDITOR
K. Soulis

ASSOCIATE EDITOR
(not assigned)

KEYWORDS
Water crises; holistic solutions; co-creation; transdisciplinary; local context; Anthropocene

1 Introduction

The Earth is facing severe problems caused by climate change, global consumption, and population growth that are pushing the Earth system out of safe and just boundaries (e.g. Rockström *et al.* 2023). The rapid changes happening now in the Anthropocene are well documented (e.g. Steffen *et al.* 2011, Seitzinger *et al.* 2015, Bai *et al.* 2016, Zalasiewicz *et al.* 2017, Witze 2023) and undermine critical life support systems (IPBES 2019, UNEP 2019, IPCC 2021, WEF 2022) that may soon put the planet into an emergency state caused by passing irreversible tipping points (Steffen *et al.* 2018, Armstrong McKay *et al.* 2022). The impacts on and intertwinings with the water cycle are accelerating the crisis; freshwater supply often varies between being too much, too little or too polluted for sustainable development (GCEW 2023a, 2023b). The consequences vary greatly among social groups and countries (Biermann *et al.* 2020, Folke *et al.* 2021) and challenge the relevance of current research procedures and scopes in hydrological sciences (Ceola *et al.* 2016, Sivapalan 2018, Di Baldassarre *et al.* 2019).

Hydrological engagement is needed more than ever to address these problems where current water management fails. Water, climate change, biodiversity loss and land use change interact in a crucial juncture faced by the global community, with severe and multidimensional water security issues, that requires immediate and decisive actions (United Nations Educational, Scientific and Cultural Organization (UNESCO) 2012, UN Water 2013, Young *et al.* 2015a, GCEW 2023b). However, the impact on and management of water issues face a high heterogeneity across the planet, and are spread over many actors and organizations. Likewise, scientific knowledge on water-related robustness, resilience and security is fragmented; related data and information are often not Open, unFAIR, not chained and inconsistent (Wilkinson *et al.* 2016, Cudennec *et al.* 2020, 2022a, UNESCO 2021, 2022b), and in situ monitoring is declining (Dixon *et al.* 2022). In addition, there is a substantial lack of synthesis and of easily digestible scientific messages among hydrologists, across disciplines and between scientists, practitioners, decision makers, Indigenous/traditional communities and the general public. Nevertheless, there is a strong wish from scientists to contribute with different perspectives on the hydrological threats the world faces, especially from early career scientists (e.g. van Hateren *et al.* 2023).

Hence, there is a need to coordinate actions from the hydrological sciences community to link local hydrological research with global patterns of the water cycle, and further, to provide science-based watercentric decision support. Key issues that impact hydrology across scales include climate change, energy security and energy transition (with more renewables), and food and nutrition insecurity. Hydrological sciences must therefore better identify local water problems in holistic analysis (i.e. linking local and global scales, linking disciplines and needs, and connecting the dots into systems analysis). This resonates well with the mission of the International Association of Hydrological Sciences (IAHS), which is to "Collectively advance and promote hydrological sciences worldwide – contributing to interdisciplinary understanding of water-cycle processes, sustainable use of water resources and risk mitigation."

In this paper, we analyse the need to scientifically face these challenges, and address the role and duty that IAHS has to serve as a platform when developing water sciences for solutions to the water crisis; IAHS can foster hydrologists who must be bold and push boundaries to make an impact. As a global organization with more than 10 000 individual members from 150 countries, IAHS is of both global and local relevance, connecting people across and within regions (e.g. global, Global North–Global South, North–North, South–South) and locally, in order to provide a synthesis to answer the needs of society for sustainable development, safety and security. Water management has always required more than physical science (e.g. Sivapalan *et al.* 2012, Savenije *et al.* 2014, Lund 2015), but nowadays, concerted actions by hydrological scientists providing water-related knowledge in engagement with other disciplines and stakeholders are more essential than ever for solving fundamental environmental and societal issues, most of which depend on water. To sum up, there is an urgency for an IAHS-led initiative on a Science for Water Solutions Decade.

The overall aim of scientific decades organized by IAHS is to accelerate and capitalize scientific knowledge in a priority field of research. These decades streamline global research efforts and foster coherent engagement and sharing through vivid discussions and synthesis work. IAHS has recently run two successful scientific decades, which accumulated knowledge and triggered new ideas on:

(1) Predictions in Ungauged Basins (PUB): 2003–2012 (Sivapalan *et al.* 2003, Blöschl *et al.* 2013, Hrachowitz *et al.* 2013);
(2) Change in hydrology and society – Everything Flows (Panta Rhei): 2013–2022 (Montanari *et al.* 2013, McMillan *et al.* 2016, Di Baldassarre *et al.* 2019, Kreibich *et al.* 2022).

In this triad (Fig. 1), *the first decade* tackled the problem with data scarcity and transfer of hydrological knowledge in space and time, while *the second decade* addressed the concept of change and human alterations/coevolution with the hydrological cycle. During the participatory community discussion that ignited *the third IAHS decade*, the need for it to be solution oriented became immediately clear, as well as the necessity for the decade to aim at finding a scientific basis for understanding and reducing the effects on local people from the rising global water crisis of the Anthropocene.

It was recognized from the first community consultations that the topic of a decade needs to be broad enough to engage the wider hydrological community but narrow enough for concerted actions. It must be timely and relevant to generate interest and make an impact, as well as attracting funding from research councils and academia. Moreover, the topic of the decade should link to and synergize with other ongoing activities in IAHS, such as work by commissions, committees and working groups. For instance, in the middle of the Panta Rhei Scientific Decade, the IAHS community identified 23 Unsolved Problems in Hydrology (UPH; Blöschl *et al.* 2019) with scientific questions. It is important that the new decade takes stock of these identified hydrological knowledge gaps

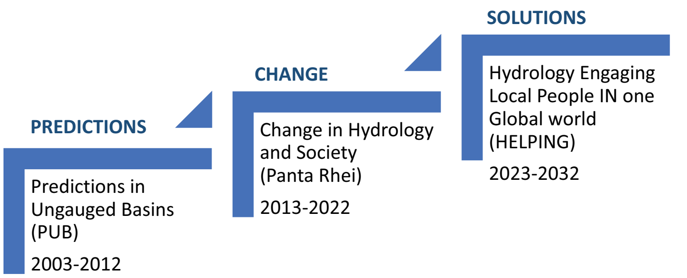

Figure 1. The succession of IAHS scientific decades.

in holistic synthesis of water challenges, as a basis when providing new actionable solution pathways.

The discussions in the IAHS community expressed readiness to make a joint effort in realizing many global Sustainable Development Goals (SDGs) and in conserving Planet Earth the way we know it. Having SDG 6 on "clean water and sanitation" does not mean that hydrological issues are sufficiently considered in Agenda 2030, and in fact, hydrology is hardly considered in SDG 6 despite being essential to achieve it and most of the other SDGs. Below the process is described that formulated the scope of the new decade. Then follow the results from the community consultations during the initial year (2023) with the vision, scope and organization of the work for this third initiative in the triad of IAHS scientific decades.

2 The community building process (method)

2.1 Strategic planning approach

The third decade started with an intense participatory process during its first year (using IAHS communication channels with members, national committees and partner organizations) engaging the community in co-creation of vision, goals and activities, i.e. defining the scope and setting up the organization. To enable inclusiveness, online meetings in various time zones and open forum discussions were used in addition to physical meetings or splinter meetings at conferences. The Sivapalan Young Scientists Travel Award (SYSTA) mechanism was used to facilitate participation from financially disadvantaged countries and additional grants were provided to early career scientists, to further increase diversity (see Appendix). This inception phase applied a strategic planning approach (ShuHsiang *et al.* 2015) covering three steps to set visions, goals and actions (Fig. 2), which are described in this paper. The implementation phase with evaluation and monitoring will follow but is still a work in progress and thus is not described here.

Step 1

Visions and potential topics were first launched and discussed in a web-based forum that opened in late 2022 (see IAHS website at https://iahs.info/), which was a couple of months before the meetings. The forum attracted about 40 posts and the topics suggested were largely related to observations of environmental change and the fast evolution of technology (e.g. sensors and artificial intelligence), combined with values of human rights to water, biodiversity and empowerment of people. Methods suggested were comparative analysis, system analysis and transdisciplinary approaches to understand and effect the transition.

The more intense community efforts then started with interactive meetings: first, online meetings in three time zones (Oceania/Asia, Europe/Africa, and Americas) that attracted about 50, 40 and 15 participants, respectively. The outcome was reported in plenary at the Cordoba workshop (13 February 2023), along with results from in-person brainstorming around tables, answering 10 questions in total on Why, What and How (see Appendix, Fig. A1). The three-day in-

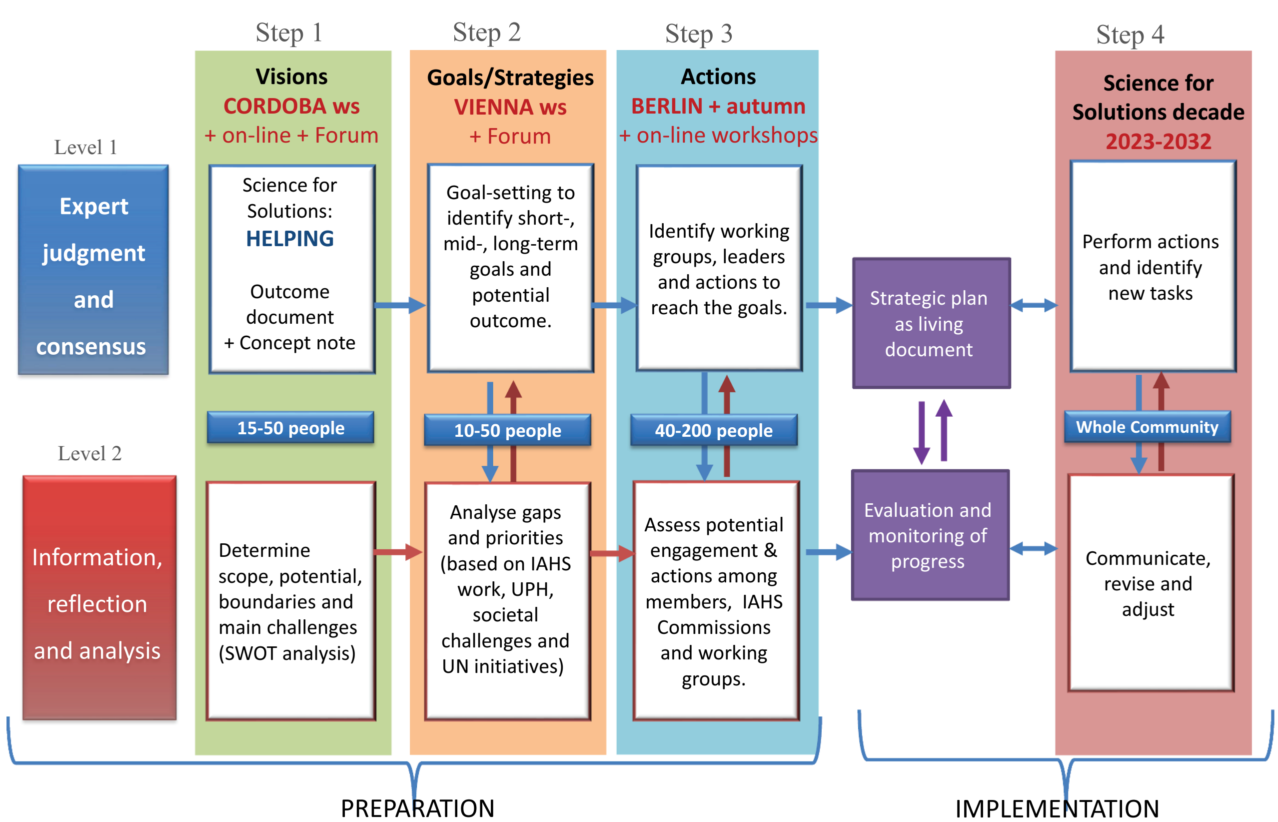

Figure 2. Flowchart of the strategic planning method applied for preparing and implementing the HELPING decade. ws = workshop. The number of people engaged in the process illustrates recommendations by Shu-Hsiang *et al.* (2015).

person workshop in Cordoba (Fig. 3) attracted a diverse group (Fig. A2) of 50 hydrological scientists, who interacted intensively by brainstorming in smaller groups and expressing ideas using Post-it notes and drawings on flip charts, for presentations in plenary, which followed by open discussions. After consolidation, five themes for the next decade were identified and analysed using a SWOT approach (i.e. defining strengths, weaknesses, opportunities and threats). It was agreed that the focus of the next decade should be "Science for Solutions." The results from the meeting were reported in the Cordoba outcome document and published on the IAHS website (https://iahs.info/).

To further consolidate the outcome (Level 2 in Fig. 2), a questionnaire was sent to all IAHS members for guidance on interest in the various topics beyond the participants at the Cordoba meeting. The top two topics as well as two support methods (Fig. 4) then made up the basis for the eventual concept note, which was written by the 15 delegates who led the workshops; the concept note also included the decadal acronym HELPING (Hydrology Engaging Local People IN one Global world).

Step 2

The forum was opened again to receive feedback from the community after the publication of the concept note. This time 15 posts were received, which were all positive and appreciated, for instance, the coherence of the topic with the United Nations (UN) 2023 Water Conference (22–24 March 2023) and its focus on the water crises, but also the emphasis on local engagement and recognitions of Indigenous knowledge, science engagement, and the ambitions to reach beyond the hydrological community. Other physical meetings were then arranged in two splinter meetings of the European Geosciences Union (EGU) General Assembly (27 April 2023) followed by a full-day workshop at the Technical University of Vienna (29 April 2023). This time the focus was to define goals and strategies for the new decade. The meeting involved some 40 people who discussed in smaller groups and reported back on what to achieve and how to get tangible results from the decade (Fig.

Figure 3. Photos from activities and outcome of the Cordoba meeting in early 2023.

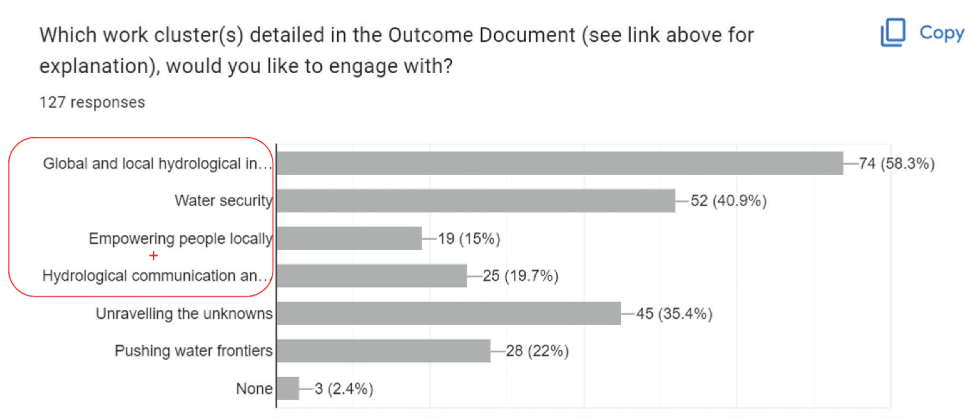

Figure 4. Results from survey administered to all IAHS members on the most popular topics among those defined in Cordoba. The red box marks the top two topics as well as two support actions chosen.

5). The results were consolidated in a variety of potential achievements by a smaller group.

Step 3

To stimulate actions from the community, an open call for working groups addressing the goals was launched as well as an open competition of graphic design for a decadal logo. The progress of the strategic planning was discussed at the The International Union of Geodesy and Geophysics (IUGG)/ IAHS General Assembly in Berlin in July (14 July 2023) and the winner of the HELPING logo competition was identified from voting on 15 contributions by raising hands (Fig. 6).

By the end of 2023, a total of 26 working groups were formatted and briefly described on the IAHS website, where anyone could sign up to participate. The interest in engaging with the groups ranged from eight to 140, with a median value of 56 people per group (see Appendix, Table A1). The groups were categorized according to the themes and an open call for theme leaders was launched with self-nomination, resulting in three well qualified leaders to coordinate and coach the working groups. Two identical webinars were organized (2 and 9 November 2023) for all working group leaders to present their ideas for each other and to the people who had signed up to participate in the working groups. In addition, breakout discussions were held for the working groups to gather and start discussing their tasks; 220 people participated on the first occasion and 125 on the second. Overlaps were identified and some working groups thus decided to merge. Others were identified as mispositioned in a theme and changed to another theme. It was decided to have similar meetings at least once a year to report progress, share perspectives and find synergies. Most working groups began to work immediately, with individual follow-up meetings. Each working group formulates their own science questions with context-related problems to search for solutions during the decade (or part of the decade). The methods involve co-creations with relevant users and producers of knowledge, to easily advance the new knowledge into local actions. To facilitate this process, a specific working group is dedicated to explore various co-creation methods and share lessons learned at an early stage, to then be applied throughout the decade of HELPING activities.

3 The Science for Solution decade (results)

The scientific decade will consolidate the hydrological sciences community, give visibility, and set the trends and agenda for water-related research. It will focus on synthesis work, comparative analysis and transferability of knowledge, to become a vehicle for putting science in action, driven by scientists

Figure 5. Photos from the Technical University of Vienna workshop defining HELPING goals.

Figure 6. Photo from the workshop at the IUGG General Assembly in Berlin when voting on the logo to represent the new Science for Solutions decade HELPING.

working on local hydrology. The new decade will provide understanding of water components in environmental and societal challenges, along with the potential impact of measures for resilience or restoration to reach sustainability progress at global and local scale. In particular, the decade will show how context matters when addressing specific problems to identify whether and how solutions can be transferred in time and space. Hence, knowledge from local scientists, stakeholders and citizens will be put in the centre.

These evidence-based results will fill the urgent need in policy processes for holistic systems thinking to avoid the water crisis in various nexus, e.g. agrifood systems, energy supply, ecosystem health, flood management, transport and navigation, sanitation facilities, drinking sources, industrial usage, mental health and recreation (e.g. AlSaidi and Elagib 2017, Heal *et al.* 2021, Jiang *et al.* 2021, WMO 2021a, 2021b, WWAP 2021, GCEW 2023b). There is an increasing demand for integrated solutions and also informed decisions for fairness and sustainability (e.g. Greve *et al.* 2018, Falkenmark and WangErlandsson 2021). Evidence-based records in comparative studies are essential for understanding dominant drivers (e.g. Kovács 1984, Falkenmark and Chapman 1989, Kuentz *et al.* 2017, Addor *et al.* 2020, Kreibich *et al.* 2022) to transfer knowledge in collaborative learning processes, leaving no one behind (WWAP 2019). Such translational research is also appreciated by leading scientific publishers (e.g. Islam *et al.* 2023).

Water security needs early warning systems, climate indices, and design values from predictions at local and regional scales. The water system on Earth is one unit with complex interactions, which need to be well understood for resilience under Anthropocene (Falkenmark *et al.* 2019, Yu *et al.* 2020, Falkenmark and WangErlandsson 2021) and sustainable development; see for instance the global sanitation crisis (Wen *et al.* 2017), or the socioeconomic footprints in rivers (e.g. Meybeck *et al.* 2023). Both knowledge and transfer of knowledge are context related, and therefore the new decade also needs to encompass capacity development and communication skills among hydrological scientists. Such capacity will facilitate engagement across disciplines and with decision makers to eventually empower operational hydrologists at various levels and at every site on Earth.

The new decade will profit from current technical achievements with artificial intelligence, big data and open science for innovations and evaluations using many sources of information in quality assurance of findings (e.g. Nourani *et al.* 2014). It will liaise with the rising movements in citizen science, new sensors and observations to increase hydrological process understanding and facilitate predictions under novel spatial and temporal conditions (e.g. Gorelick *et al.* 2017, Tauro *et al.* 2018, Du *et al.* 2020, Nardi *et al.* 2022, Manfreda *et al.* 2024).

The new decade will especially highlight the process from scientific research to practical solutions by quantifying remedial effects from e.g. integrating grey, green, and blue infrastructures (e.g. Kapetas and Richard 2020), applying environmental flow levels (e.g. Arthington *et al.* 2023), sustainable groundwater use (e.g. Gleeson *et al.* 2020), and participatory spatial planning (e.g. Nadin *et al.* 2021). Experience from one site may be relevant for meeting challenges in another site under new conditions (e.g. Falkenmark and Chapman 1989, Blöschl *et al.* 2013, Bertola *et al.* 2023). For instance, under climate change new sites in the Global North need to learn how to handle drought and benefit from participatory processes, while sites in the Global South need to consider impact-based forecasts and flood warning systems despite data scarcity. Here North and South can potentially learn from each other and transfer solutions successfully, if context-dependent factors first are identified, understood and considered at implementation (Islam *et al.* 2023).

Last but not least, the third scientific decade, like the second and first ones and IAHS in general, will inspire and stimulate hydrological scientists to collaborate and codesign research activities (Ceola *et al.* 2015, Zamenopoulos *et al.* 2021), contributing more and better together than individually – hence, inclusiveness is key for success.

3.1 HELPING vision

The vision of the IAHS third scientific decade is to solve fundamental water-related environmental and societal problems by engaging with other disciplines and local stakeholders. Hence, this new decade is action oriented. The acronym HELPING stands for “Hydrology Engaging Local People IN one Global world” and should be understood as:

(1) *Helping* = we need to collaborate, share and help each other to overcome the water crisis. No discipline, scientist, community or decision maker can solve the current or emerging water crisis alone.
(2) *Hydrology* = Hydrological sciences should underpin management and governance of water resources; thus, we need better understanding of impact from global drivers at local scales and local drivers at global scales.
(3) *Engaging* = co-creation of knowledge includes shared capacity, common learning and collective creativity that should be actively contributed to or initiated by hydrologists.
(4) *Local* = water phenomena and problems are often unique at the local scale and solutions must therefore be solved considering local needs, knowledge and context.
(5) *People* = the purpose is to connect people (scientists, practitioners, communicators and the general public) with similar interests to co-create, accumulate and transfer hydrological knowledge worldwide.
(6) *IN one* = together we can advance science faster than individually to overcome shared or similar challenges.
(7) *Global world* = the planet is in an emergency state with complex water-cycle interactions, which needs urgent actions to not leave anybody or any catchment behind.

3.2 Scientific scope

As we embark on the new scientific decade, a crucial phase lies ahead in addressing and understanding the impending global water crisis. This decade presents an extraordinary opportunity to bridge the gap between scientific knowledge and practical solutions to water-related problems, by engaging local hydrological scientists as drivers to ensure that no catchment or hydrologist is left behind in the quest for global sustainable water management, which goes far beyond SDG 6 (Fig. 7).

At the heart of this endeavour lies the pursuit of scientific evidence that elucidates the intricate linkages between hydrological processes operating at both local and global scales. By unravelling these connections, we gain a deeper understanding of how water resources are shaped by the interplay of natural, human-induced, and context-related factors.

This knowledge acquisition is not solely the domain of scientific institutions; it is an inclusive endeavour that necessitates active engagement with local scientific activities. Water resources connect socioeconomic, cultural, and political factors. Acknowledging the diverse experiences and perspectives of communities around the globe is essential for identifying and adapting solutions that resonate with the local conditions. Hence, the intention is to put scientists, stakeholders and citizens centre stage during the decade.

As we gather this wealth of information, a critical step is to synthesize it into a coherent framework that transcends disciplinary boundaries and recognizes the local context. These global syntheses for various water-related problems and solutions will underpin effective water management strategies, providing the foundation for addressing current crises and mitigating future ones.

The new scientific decade is a call of opportunity, fostering an inclusive, contemporary and actionable approach to hydrological research. By embracing local knowledge and synthesizing global understanding, we can empower people and nations. With co-creation we can translate scientific discoveries to practical applications that will protect this precious resource for generations to come.

3.2.1 *Global and local interactions*

We search for solutions to handle the water crisis of the Anthropocene by applying knowledge, which is underpinned by understanding current water systems behaviour and anticipating changes. However, the observed diversity in hydrology around the globe is not well understood using current conceptualization approaches and data sources (e.g. Archfield *et al.* 2015, Sivapalan 2018). Many observed phenomena and discrepancies between scales are not yet explained (e.g. human alterations and feedback to climate or vegetation changes). Therefore, we welcome new coherent global hydrological data and new information at several levels and scales, e.g. global data, national operational databases, and experimental catchments (e.g. Nativi *et al.* 2019, Lindersson *et al.* 2020, Pimentel *et al.* 2023).

Collecting and sharing data in the new decade will provide the basis for synthesis of and accelerated knowledge about water system behaviour, evolutionary loops, human alterations and complexities such as non-linearity, nonstationarity, connectivity, tipping points, system memory and trajectory. Such knowledge will identify water-related risks, opportunities and optimal time and place of measures from a hydrological perspective, for further analysis including of the societal context. Such research could be supported by statistics, machine learning/artificial intelligence (AI) or process-based modelling and may utilize all kinds of data including in situ measurements, remote sensing and citizen science observations. Here we foresee comparative studies and interdisciplinary analysis as well as alignment with open science.

3.2.2 *Holistic solutions for water security*

Water security is defined (UNESCO 2012) as the capacity of a population to safeguard access to adequate quantities of water of acceptable quality for sustaining human and ecosystem health on a watershed basis, and to ensure efficient protection of life and property against water-related hazards (e.g. floods, landslides, land subsidence) and droughts. It is threatened by water scarcity, quality deterioration, floods and hazards. Therefore, these must be forecast and measures should be taken to minimize their impacts in coherence with the local context. Here we recognize the need for understanding and managing water by also analysing the societal environment, such as the political, socioeconomical and cultural situation. We search for transdisciplinary evidence to ensure actionable and transferable solutions to water threats around the globe. We are open to exploring all dimensions of water security, such as undesired quantity and quality, extremes, availability

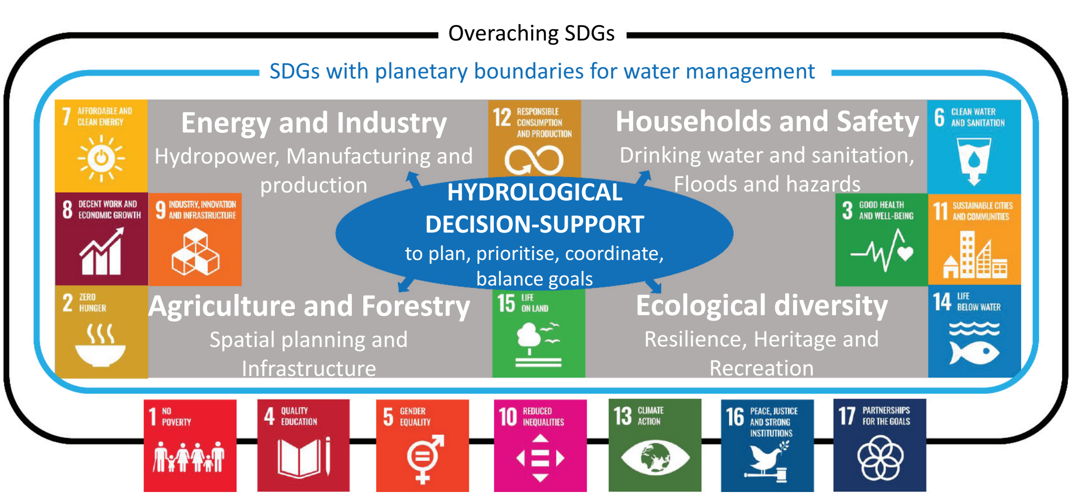

Figure 7. Some societal sectors that should share the water resources in wise decision making based on hydrological decision support to fulfil the UN Sustainable Development Goals.

vs. demands/needs, transboundary water bodies, compound events and cascading effects. Similarly, we address all sorts of innovative solutions, make comparative studies of already implemented solutions, and predict impacts of planned solutions, e.g. by modelling or replacing time with space.

Scale effects and side effects are also important to investigate. Many countries nowadays strive for a green transition of society, with a focus on nature-based solutions and fossil free sectors (e.g. Palmer *et al.* 2015). We trust that research can validate the water system nexus and its links with various sectors, and that this will promote complex water-centric decision making in the policy space to eventually advance sustainable development and enable resilient societies. For smooth implementation of solutions and long-term maintenance, societies need efficient policy processes across sectors with shared frameworks to evaluate impacts on governance, economy, justice, fairness and equality. We therefore appreciate the scientific challenge to find integrated solutions for multiple purposes.

3.2.3 Engaging with people locally

Local specificities may unveil unexpected hydrological processes and interactions that are extremely relevant to both water management and science. We recognize that many water issues may arise from global drivers and policy decisions (e.g. climate change, upstream management changes) but eventually these issues need local solutions and local knowledge when implementing adaptation and mitigation measures. In this, Indigenous knowledge may be applicable and may help in finding solutions (e.g. von der Porten *et al.* 2016, Zvobgo *et al.* 2022, Nóbrega *et al.* 2023), as might local scientific findings in site-specific contexts. New methods are sought for such analysis to be applicable when assessing various actionable solutions to water problems.

We recognize science's increasing value for decision making when going from simple data transfer through interactive information services, towards networking in knowledge–action systems (e.g. Rusca and di Baldassare 2019, Weichselgartner and Arheimer 2019). The world searches for means to translate scientific results into wisdom (e.g. among scientists, practitioners, communicators and the general public) but challenges arise from a culture of information overload and operations in isolation. This is also valid for the hydrological sciences and therefore we encourage training in co-creation to broaden perspectives and accelerate knowledge exchange. We also appreciate new methods in science communication using art (e.g. Li *et al.* 2023), storytelling and games (e.g. Aubert *et al.* 2019), and within HELPING, we search for further scientific evaluation of their impact on attitudes and actions.

3.3 Targets of HELPING research

After identifying the vision and scope, three themes were identified (see section 2.1), for which goals were identified and working groups proposed by the IAHS community (Fig. 8 and Appendix Table A1). The overarching goal for the Science for Solutions decade HELPING was set as: "Understanding hydrological diversity and integrating knowledge across scales and regions." The goals of each theme are further described below.

3.3.1 Theme 1: global and local interactions

This first theme of the HELPING decadal initiative aims to accelerate hydrological understanding of hydrological processes at local and global scales, how they interact, and how they and their interactions affect water resources in the local context. Among numerous potential research questions falling under this theme, a few examples are: (1) What is the influence of local morphology on hydrodynamics? (2) Which local thresholds and feedback mechanisms trigger global transitions and tipping points? and (3) How can we

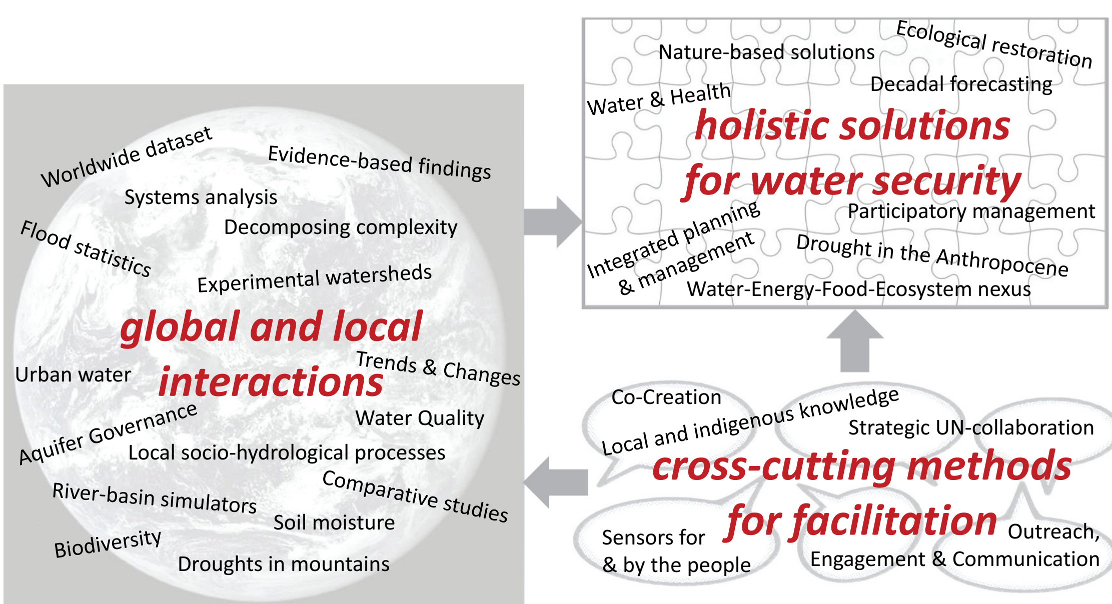

Figure 8. Interactions among the three themes and keywords for their assigned working groups when starting the new decade in 2023.

Table 1. Identified goals HELPING with global and local interactions.

Research goals	Outcome/product goals	Community goals
Understanding local hydrological processes	Case studies populating the Digital Water Globe platform	Synthesis for joint global description of diversity
Understanding differences and similarities between regions	Large-sample datasets; tools for monitoring or assessments	Collaboration between people in similar conditions worldwide
Understanding global–local interactions and their impact on water resources	Methods to link global estimates with local conditions	Recognition when implementing general policy at local level

comprehend surface–groundwater interactions across diverse regions of the world?

Anticipated outcomes from the pursuit of these research questions are expected to be substantial (see Table 1). Specific product goals encompass the creation of case studies populating the Digital Water Globe platform (see Section 4.1.2), the development of extensive datasets, and the design of advanced monitoring and assessment tools. In a broader sense, the entire community can aspire to gain novel insights into the interlinked hydrological cycles and variability of water resources. This will contribute to the scientific discourse on water challenges through the publication of peer-reviewed articles spanning data, methods, models, and assessments. Hydrology will then be better recognized as an essential science seamlessly integrated into each SDG.

3.3.2 Theme 2: holistic solutions for water security

Embarking on the second theme within the HELPING decadal initiative, our aim is to effectively manage existing water crises and proactively mitigate potential future challenges. Specific examples of potential research questions within this theme include: (1) What is the impact of nature-based solutions on the water cycle? (2) Which criteria should guide the selection of measures for high success rates to enhance local water security? and (3) How can we ensure inclusiveness and optimize co-creation across disciplines and local stakeholders for effective problem solving?

The pursuit of these research questions is poised to yield significant outcomes, including the development of a comprehensive catalogue detailing various solutions and their potential effects (Table 2). Furthermore, specific outcomes involve the formulation of guidelines for assessing solutions and the creation of a catalogue specifically focused on nature-based solutions (NBSs) along with their corresponding guidelines. The community goals associated with this endeavour are not restricted to the impacts of solutions and optimal engineering practices, but extend to understanding the local context for transferability so that solutions can be implemented in a sustainable way. The results will be published in peer-reviewed publications covering methods, models, and assessments, and advocating for the visionary perspective where water security is universally recognized as a fundamental human right.

3.3.3 Theme 3: cross-cutting facilities

The third theme revolves around cross-cutting objectives, aiming to enhance capacity within local societies and draw insights from local experiences to ensure the acceptability, affordability, accessibility, and equitability of solutions (i.e. the local societal context). Potential research questions within this theme include: (1) What should guide the selection of methods for co-creation driven by hydrologists in a specific local context? (2) In what way can scientific engagement with society change people's attitudes, behaviours and actions? and (3) How should we apply Indigenous knowledge in scientific analysis with requests for evidence-based facts?

The goals at the product level encompass the integration of new data sources into open data repositories, the creation of a catalogue highlighting local associations, methods, and training for co-creation activities, and the establishment of a database showcasing instances where practical/Indigenous knowledge converges with evidence-based science (Table 3). Achieving these product-level objectives could lead to fufilling community goals such as increased engagement by hydrologists in science communication, in transdisciplinary research and with local stakeholders. It

Table 2. Identified goals HELPING with holistic solutions for water security.

Research goals	Outcome/product goals	Community goals
Understanding potential of and challenges with mitigation methods (for floods, droughts, water quality/pollution)	Catalogue of solutions and potential effects; tools for evaluations	Empowered hydrologists in water security
Understanding sectorial nexus and societal context of problems/solutions	Guidelines for assessments of solutions, which affects several sectors and local context	Participation in transdisciplinary analysis and applied research
Nature-based solutions for achieving water security	Catalogue of NBS and their guidelines	Foster sustainability and green societal transition

Table 3. Identified goals HELPING with cross-cutting goals.

Research goals	Outcome/product goals	Community goals
Integrating new technologies with existing ones	New data sources in open data repositories	Facilitate evaluation/application of current concepts and study new hypotheses
Co-creating hydrological knowledge between people and between disciplines	Catalogue of local associations; Methods and training in co-creation activities; Database of good examples merging practical/Indigenous knowledge with evidence-based science	Engage with local people globally Enhance science communication, inclusiveness, and applications of citizen science Foster transdisciplinary research

would also generate peer-reviewed publications featuring applied showcases and new theories on local prerequisites for actionable solutions, which ultimately foster local ownership in the discovery, implementation, and maintenance of water solutions.

3.4 Organization of the Science for Solutions decade

Work on the decade will remain a bottom-up process empowered by local hydrologists and scientists using open science and local data/methods when solving local water problems. We envisage that the building of local knowledge and cooperation can inform scientists in different areas working in similar situations, for instance when facing unexpected events worldwide (e.g. learning from floods or droughts in one catchment will inform hydrologists and water management in other catchments). To facilitate leadership and continuity throughout the decade, the science for water solutions decade will be organized with a management team and defined theme leaders for groups of collaborative work based on initiatives by the community. Leadership will rotate on a two-year basis. It will be fully open to new initiatives suggested by any IAHS member and such actions will also be open for participation by anyone who wishes to contribute in line with IAHS core values (https://iahs.info/AboutIAHS.do).

To facilitate leadership and continuity throughout the decade, the scientific decade will be organized according to a classical management structure, with defined themes for clusters of working groups to enable collaborative work at multiple levels (Fig. 9). Inclusiveness is one of the core IAHS values, as are active engagement, transparency and personal responsibility in the collaborative process. IAHS recognizes that equality and diversity are required for scientific progress and embraces integrity, trust, and respect as a guarantee for the openness and creativity that is needed to accelerate science.

The new decade strives for tangible results and transparency; therefore, the work will be reported regularly and progress will be followed and monitored by the *Steering Committee* to help the theme leaders with engagement, competences and communication activities, as well as finding synergies and stakeholders or data sources for the various actions. The IAHS communication team will provide information tools, such as the IAHS website, joint publications, social media channels and the Digital Water Globe. A Steering Committee will help engage with other global communities (e.g. in the UN family, in particular the longstanding partners the United Nations Educational, Scientific and Cultural Organization (UNESCO) Intergovernmental Hydrological Programme (IHP), and World Meteorological Organization (WMO)), coordinate with other IAHS activities and give visibility to the ongoing work and findings. The Steering Committee will also assist with any collaborative disagreements and encourage open science, fair data, commitment to Equality, Diversity and Inclusion (EDI) (see the IAHS EDI statement https://iahs.info/AboutIAHS/aboutiahs/), publications, policy briefs and citations. The steering committee is similar to the IAHS management team.

The theme leaders will identify and approve tasks and actions needed to advance their sub-topic of the Scientific Decade; they will follow up on progress and initiate actions, such as workshops, outreach activities, collaborative publications or projects (e.g. comparative studies or ensemble modelling). They will help and guide the appointed *working group leaders*, who are responsible for coordinating specific activities that aim to accelerate knowledge accumulation from the scientific community and, hence, progress within the work clusters.

The working groups are fully open to initiatives from the community and partners, are self-organized and serve as a platform for testing ideas in a cooperative manner. Leading such an action also offers an opportunity for scientists to develop their leadership skills with mentoring from senior scientific leaders. Anyone can start a working group, if it is judged relevant for the decade by the theme leaders and the Steering Committee, and participants can sign up at any point. Theme leaders are sought in an open call, with self-nomination, every second year. This organization will ensure stability and strong connection with IAHS as a whole, but will still allow an agile and evolutionary progress throughout the decade.

4 Setting the scene for urgent and desired actions (discussion)

The ambitious scope and progressive intentions of the HELPING decade cannot be solved by a single community alone but need collaboration among many disciplines, both other geosciences and engineering fields, but also political

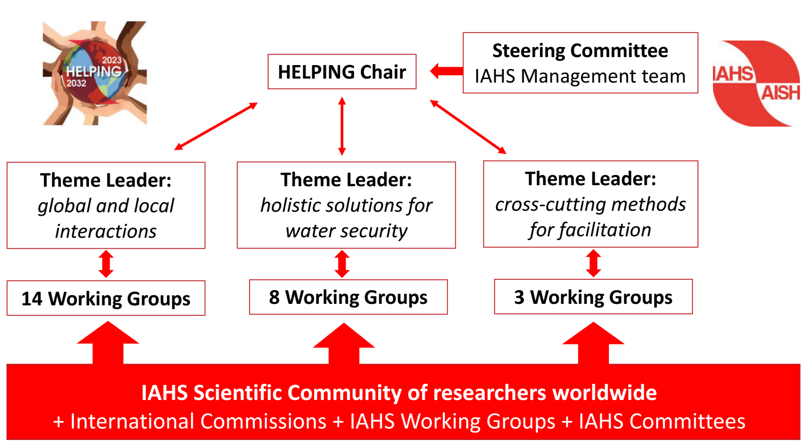

Figure 9. Organization of the IAHS Science for Solutions decade HELPING 2023–2032.

sciences, economy, biology, law, psychology, etc. (which is also implied by the acronym). Furthermore, it cannot be fulfilled by scientists alone, but needs close collaboration with stakeholders, practitioners, policymakers and citizens at various levels around the globe. IAHS must play a crucial role as a central community facilitator, in streamlining and empowering local scientists to contribute to the global agenda for actions that make a difference (Fig. 10). As such, IAHS is a long-term partner of intergovernmental developments.

4.1 Enabling community-based research

4.1.1 The role of IAHS

IAHS supports hydrology and related sciences as a nonprofit, nongovernmental charity, in the form of networking; hence, it is not a conference, research council or a donor. Instead IAHS provides a platform for collective creative work, independent accumulation of knowledge and scientific ownership. The association consolidates voluntary scientific work and provides mechanisms for networking and scientific publications in the field of hydrology with a vision of sustainable development in a changing world (see more at https://iahs.info/). The activities of the decade must therefore be based on already financed projects or institutional work and thus rely on current research trends (which are often underpinned by societal challenges). As IAHS offers the basis for partnership and participation in synthesis or review publications, it can, however, also be an opportunity for attracting external funding and thus create projects in line with the ambitions of the new decade.

The HELPING decade will apply an agile setup with learning in feedback loops over time to allow coevolution during the decade between progress in hydrological sciences and new challenges appearing in society, environment, or other disciplines. The decade supports education and training and will become a fertile breeding ground for continuously evolving new actions. Some working groups may last the full decade, while others may last only a couple of years and new ones may appear. IAHS facilitates engagement by offering an array of services such as conferences, workshops and sessions at other organizations events. In IAHS various hydrological subdisciplines have their own commissions which organize meetings and collaborative work (e.g. synthesis, reviews, opinion papers). Similarly, regional committees connect people in a certain geographical domain in site-specific research, while more temporary working groups gather people in a specific activity. The purpose is to facilitate synthesis work and coordinated actions, such as formulating shared scientific questions (like the Unsolved Problems in Hydrology – UPH; Blöschl *et al.* 2019).

Furthermore, IAHS offers grants to selected early career scientists from financially disadvantaged countries every year to boost inclusiveness through the SYSTA mechanism. IAHS membership is free of charge, with the benefit of connecting to a large community and up-to-date information on events and community achievements through e-news. This is a good opportunity for scientific outreach in the hydrological community, as IAHS has more than 10 000 members in 150 countries. Currently, IAHS Press runs two publications: the *Hydrological Sciences Journal* (HSJ) and the *Proceedings of IAHS* (PIAHS). Previous book series are accessible online and can be purchased in hard copy. IAHS also recognizes eminent scientists with medals and awards for their outstanding research, after nominations from the community every year. Finally, IAHS offers sustainability, with more than 100 years of operation and a solid organizational structure, which is visible on the website, in its statutes and in regular protocols with democratic decision making by the IAHS Bureau. Hence, IAHS provides good facilities for inclusive and coherent scientific efforts during the Science for Solutions decade.

4.1.2 The Digital Water Globe

During the COVID-19 pandemic, IAHS recognized the need for new digital facilities to engage scientists worldwide. Recently, a new tool for scientific sharing was therefore launched: the Digital Water Globe (DWG; https://dwg.smhi.se/dwg), which is an online tool specially designed for, and by, IAHS members to give visibility to (un)published results and research sites and to find peers for collaborating around the world (Fig. 11). The DWG is a web-based software platform where IAHS members share results from case studies, personal

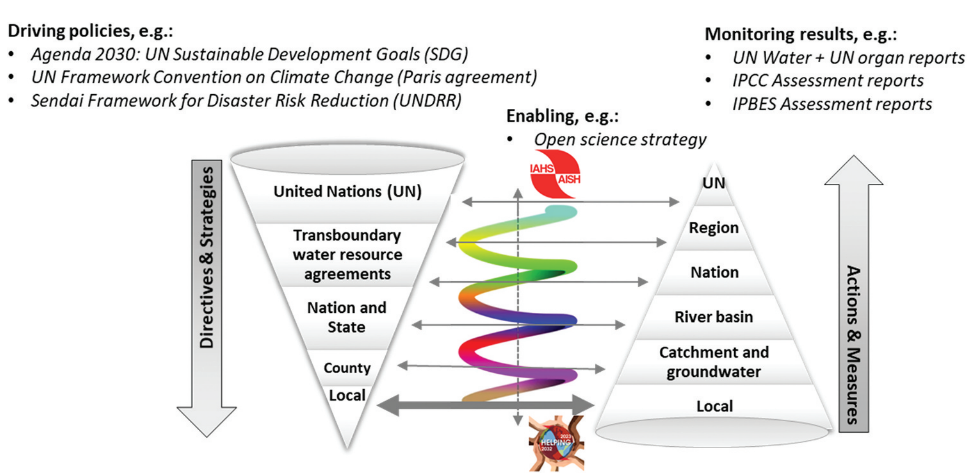

Figure 10. Exploring policy goals (left cone) and water management (right cone) via HELPING research.

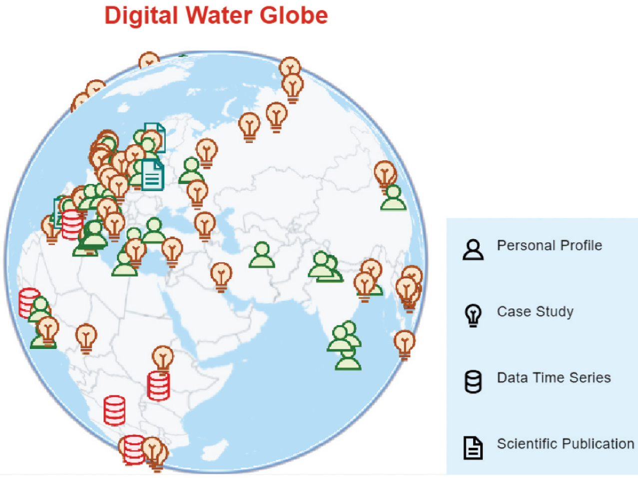

Figure 11. The digital water globe at https://iahs.info/ is populated by scientific results from case studies, personal profiles of IAHS members, and links to open datasets or IAHS publication. Filter functions help the visitor to find and access relevant information from peers.

profiles, IAHS references and links to data repositories. The different items are linked to a geographical position on a global map as well as keywords for quick search using filter functions. The DWG offers co-creation and reexamines the role of scien tific outreach by exploring novel digital ways to interact between scientists and society for mutual understanding and coevolution. The information is kept short and concise, like a digital poster exhibition, with key messages. Filter functions facilitate search and there are links between the items and personal profiles. The DWG will help in finding global and regional patterns from analysing local case studies during the HELPING decade. It will also help with outreach and network ing in the IAHS community and beyond, as the tool is open to any visitor.

4.2 Embracing co-creation and open science

The Science for Solutions decade endorses co-creation, which means inviting stakeholders and users into the creative process to ensure fitness of purpose in design of problem solving. This approach started in the industrial sector (AarikkaStenroos and Jaakkola 2012, Grönroos 2012) but soon spread to governments and the civil society, paving the way for new participatory methods in water-related decision making, e.g. serious games (e.g. Aubert *et al.* 2019, Crochemore *et al.* 2021, Mittal *et al.* 2022) and innovation laboratories (BergvallKareborn and Stahlbrost 2009, Witteveen *et al.* 2023). It is widely recognized that co-creative approaches involving a broad range of competences in "learning by doing together" allow a better understanding of complex problems and facilitate new innovative ideas in an interdisciplinary context.

Current water-related challenges can be sorted into different categories (Winde *et al.* 2023) and each one needs co-creation among scientists, governance, industry, and civil society, which is already well recognized by the IAHS and wider community (e.g. Cudennec and Hubert 2008, Koutsoyiannis *et al.* 2016, WEF 2018, Dixon *et al.* 2022, Kootval and Soares 2020, Kreiling and Paunov 2021). Stakeholders and civil society at play are polycentric and multiform (Ostrom *et al.* 1999), especially at the intersection of common goods, water and knowledge (Boulton 2021, International Science Council (ISC) 2021, UNESCO 2022), and between knowledge systems (UNESCO 2021, Nóbrega *et al.* 2023). Water challenges may cause international conflicts (Kundzewicz and Kowalczak 2009) but more often result in collaboration (Wheeler and Hussein 2021), and HELPING will embrace and explore such potentials using collective creativity.

Co-creation, covering at least co-ideation, co-design, co-implementation and co-evaluation (Pearce *et al.* 2020), may capitalize on existing references in hydrology and other fields to be further explored and applied to address multiple emerging problems of the water sector. Citizen science is actually blooming in water issues, ranging from crowdsourcing to engagement with Indigenous and local people's knowledge, to management processes (Nardi *et al.* 2022). We anticipate that the HELPING decade will serve as a platform to harvest and share lessons, and to elaborate on the conceptualization and practices of co-creation. In this way the decade will empower both scientists and other stakeholders.

Co-creation is closely linked to and dependent on the open science paradigm, which is another example where IAHS plays a significant role. It was rooted in the scientific community itself (e.g. Ceola *et al.* 2015, Wilkinson *et al.* 2016, Carroll *et al.* 2020, Boulton 2021, ISC 2021, Cudennec *et al.* 2022b, Hall *et al.* 2022) and is progressing at policy levels. Noteworthy contributions include UNESCO's recommendation on open science (UNESCO 2021), the WMO unified data policy resolution (WMO 2021c), and broader efforts towards open data at the UN level.

4.3 Alignment with the global agenda

Global action on water should be less rhetorical and more scientific, concluded the recent high-level conference on water at the UN headquarters (Nature Editorial 2023; President of the United Nations General Assembly, 2023) which was a midterm review of the international decade for action "Water for Sustainable Development" 2018–2028, and also timely regarding the inception of the International Decade of Sciences for Sustainable Development 2024–2033. The third IAHS scientific decade therefore goes beyond the search for traditional scientific knowledge by expanding into transformative comprehension, feeding the intergovernmental policy processes with action-oriented facts. The research will extend towards problem-solving strategies aimed at guiding societal development. The scientific understanding of the Anthropocene was already triggered by international scientific cooperation in pioneer foresight studies (Meadows *et al.* 1972, Oki *et al.* 2006, Cosgrove and Cosgrove 2012, Bai *et al.* 2016, TWI2050 2018). The advancements on the scientific front, coupled with explorations of plausible futures, have raised global awareness regarding water-related challenges through multilateral political events and mechanisms (e.g. Rahman 2023). Over the past century, IAHS has played an essential role in consolidating and synthesizing scientific findings, being the only global hydrological community.

Key milestones for a global sustainable development policy, such as the UN water conference in Mar del Plata (1977), the Earth Summit in Rio (1992), the Rio+20 conference (2012), and the UN conference on water in New York (2023), have materialized into several agendas for action and conventions. The current SDG 6 includes water in its name – “clean water and sanitation” – but also establishes intricate linkages with most of the other SDGs (ICSU 2017, UN Water 2018). In fact, water is crucial for realizing all SDGs as well as climate actions (Rahman *et al.* 2023). However, monitoring progress of Agenda 2030 reveals that numerous countries are not on track to meet the water-related targets. The SDG 6 global acceleration framework (UN Water 2020) has consequently identified various instrumental streams encompassing finances, data and information, capacity development, innovation, and governance. Here hydrological sciences should advance through HELPING and play a more active role to ensure water-centric decisions are made based on hydrological understanding in societal transformation.

IAHS maintains a longstanding and robust collaboration with UN organizations such as the WMO and UNESCO through its Intergovernmental Hydrological Programme (e.g. Young *et al.* 2015b, Rosbjerg and Rodda 2019). This partnership bridges science and high-level policies, to facilitate practical national implementation. Contemporary multilateral initiatives that solicit contributions from the self-organized hydrological scientific community include, for instance, the ongoing development of the WMO Global Hydrological Status and Outlook System (HydroSOS), the annual WMO State of the Global Water Resources report (WMO 2023) and the collaborative design by UNESCO, UN agencies, and UN member states for initiating a Science-based Global Water Assessment (Nature Editorial 2023, UNESCO 2023).

Hence, the forthcoming HELPING decade aligns seamlessly with global debates and science-based mechanisms for multilevel assessment, policy design, and research funding. This enables effective implementation and uptake of results towards water security and sustainable development. Furthermore, the cascading of multilateral shared values and knowledge from global to local scales, alongside national commitments, is similar to the multilevel and co-creation approach of HELPING. This framework might thus establish international standards for upholding and overcoming challenges in cooperative efforts and science–policy dialogues at all levels. The ultimate outcome of the Science for Solutions decade will be empowerment through scientific understanding and capacity development, with open access to data and information in various settings for global and local sustainable development.

5 Conclusions

Water-related issues are at the heart of the emergence and acceleration of the Anthropocene, and so strongly underlie security and human rights dimensions. The water crisis has long been recognized by the World Economic Forum as one of the top 10 worst global risks. The hydrological community is eager to contribute to sustainable development and break the disastrous trends. A new scientific decade was therefore suggested to focus on science for solutions to the water crisis, using co-creation processes (driven by hydrologists) with shared knowledge between disciplines and stakeholders for holistic understanding and decision support. As such, the decade seeks to provide actionable knowledge across scales, scientific communities, societal sectors and contexts, focusing on water as a resource or a risk for societal and environmental benefit. This initiative, called HELPING, recognizes that present and emerging water problems need help from many actors in collective creativity to find sustainable solutions.

Hence, the vision is to solve fundamental water-related environmental and societal problems by engaging with other disciplines and local stakeholders. The decade strives to advance hydrological knowledge into actionable pathways and, to this end, IAHS encourages the hydrological community to focus on: (1) global and local interactions using systems analysis, to develop enhanced understanding of local impacts and local people but through a global lens; (2) holistic solutions to the water crisis, embracing nature-based measures, participatory management and nexus analysis including other disciplines and multiple stakeholders; (3) development of methods that appreciate Indigenous and local people’s knowledge, citizen science, engagement and communication, as well as strategic high-level collaboration and outreach, to reach global scientific empowerment in water issues.

The roadmap to the ambitious aim of HELPING includes, for instance, committed efforts in all working groups (currently 25 such groups have been self-organized and initiated by the community), joint search for funding, inclusive collaboration (especially important under the new normal international conditions), and intense science communication empowering local initiatives. IAHS enables these community-based efforts by providing support and facilitation. The new decade presumes co-creation and initiatives with other disciplines and stakeholders, in particular in relation to open science. As such, the new decade is well aligned with other global agendas, within the UN and with international policymakers, donors and scientific publishers. Together we can make it successful.

Acknowledgements

This paper is the result of a nine-month community effort within IAHS, engaging scientists through online meetings, posts in a web forum, participatory exercises in workshops, and discussions at conferences. All active contributors in shaping the new decade have been invited as coauthors to this community paper as the concept herein builds on our shared ideas and collective creativity. We thank everyone who signed up to working groups, ready to serve the scientific community with their knowledge and ideas in collective creativity for finding solutions. We also thank the IAHS secretariat, in particular Tarryn Payne (IAHS Communication Officer), for patient support and active engagement throughout the process. Finally, we thank everyone who contributed to the graphical design competition of the decadal logotype, and especially the winner: Judith Boekee, PhD candidate at the Technical University of Delft. The manuscript was reviewed by Dr Anil Mishra (UNESCO) and Dr Stefan Uhlenbrook (WMO), to whom we are grateful for their constructive feedback.

Disclosure statement

No potential conflict of interest was reported by the authors.

ORCID

Berit Arheimer http://orcid.org/0000-0001-8314-0735
Christophe Cudennec http://orcid.org/0000-0002-1707-8926
Attilio Castellarin http://orcid.org/0000-0002-6111-0612
Kate V. Heal http://orcid.org/0000-0002-1019-748X
Jean-Marie Kileshye Onema http://orcid.org/0000-0002-8387-1121
Stacey Archfield http://orcid.org/0000-0002-9011-3871
Günter Blöschl http://orcid.org/0000-0003-2227-8225
Moctar Dembélé http://orcid.org/0000-0002-0689-2033
Chris Leong http://orcid.org/0000-0001-8847-3782
Giovanny M. Mosquera http://orcid.org/0000-0002-4764-4685
Bertil Nlend http://orcid.org/0000-0001-7961-1901
Adeyemi O. Olusola http://orcid.org/0000-0003-3930-0273
Melody Sandells http://orcid.org/0000-0002-4120-5163
Mojtaba Shafiei http://orcid.org/0000-0001-8894-1208
Cristina Aguilar http://orcid.org/0000-0002-9418-1679
Francesco Avanzi http://orcid.org/0000-0003-4235-2373
Nejc Bezak http://orcid.org/0000-0003-2264-1901
Thom Bogaard http://orcid.org/0000-0002-1325-024X
Martijn J. Booij http://orcid.org/0000-0001-6208-9045
Pierre Brigode http://orcid.org/0000-0001-8257-0741
Konstantine Bziava http://orcid.org/0000-0003-1237-5224
Giulio Castelli http://orcid.org/0000-0002-0209-0869
Manuel Del Jesus http://orcid.org/0000-0003-0703-8960
Nilay Dogulu http://orcid.org/0000-0003-4229-2788
Svenja Fischer http://orcid.org/0000-0002-6118-0223
Emna Gargouri Ellouze http://orcid.org/0000-0003-3211-8452
Mohammad Ghoreishi http://orcid.org/0000-0002-5051-2763
Mahesh Jampani http://orcid.org/0000-0002-8925-719X
Fernando Jaramillo http://orcid.org/0000-0002-6769-0136
Harro J. Jongen http://orcid.org/0000-0002-7538-4796
Sina Khatami http://orcid.org/0000-0003-1149-5080
Junguo Liu http://orcid.org/0000-0002-5745-6311
Mariana Madruga de Brito http://orcid.org/0000-0003-4191-1647
Paola Mazzoglio http://orcid.org/0000-0002-3662-9439
Maria E. Orduna Alegria http://orcid.org/0000-0002-1320-4614
Valeriya Ovcharuk http://orcid.org/0000-0001-5654-3731
Santosh S. Palmate http://orcid.org/0000-0001-9738-1804
Georgia Papacharalampous http://orcid.org/0000-0001-5446-954X
Ilias Pechlivanidis http://orcid.org/0000-0002-3416-317X
Saman Razavi http://orcid.org/0000-0003-1870-5810
Adarsh Sankaran Namboothiri http://orcid.org/0000-0001-8223-043X
Pedro P. Santos http://orcid.org/0000-0001-9785-0180
Nura J. Shanono http://orcid.org/0000-0002-1731-145X
Claudia Teutschbein http://orcid.org/0000-0002-3344-2468
Hristos Tyralis http://orcid.org/0000-0002-8932-4997
Elena Volpi http://orcid.org/0000-0002-9511-1496
Marthe Wens http://orcid.org/0000-0002-0133-5924

References

AarikkaStenroos, L. and Jaakkola, E., 2012. Value cocreation in knowledge intensive business services: a dyadic perspective on the joint problem solving process. *Industrial Marketing Management*, 41 (1), 15–26. doi:10.1016/j.indmarman.2011.11.008.

Addor, N., *et al.*, 2020. Largesample hydrology: recent progress, guidelines for new datasets and grand challenges. *Hydrological Sciences Journal*, 65 (5), 712–725. doi:10.1080/02626667.2019.1683182.

AlSaidi, M. and Elagib, N.A., 2017. Towards understanding the integrative approach of the water, energy and food nexus. *Science of the Total Environment*, 574, 1131–1139. doi:10.1016/j.scitotenv.2016.09.046

Archfield, S.A., *et al.*, 2015. Accelerating advances in continental domain hydrologic modelling. *Water Resources Research*, 51 (12), 10078–10091. doi:10.1002/2015WR017498.

Armstrong McKay, D.I., *et al.*, 2022. Exceeding 1.5°C global warming could trigger multiple climate tipping points. *Science*, 377 (6611), eabn7950. doi:10.1126/science.abn7950.

Arthington, A.H., *et al.*, 2023. Accelerating environmental flow implementation to Bend the curve of global freshwater biodiversity loss. *Environmental Reviews*. doi:10.1139/er20220126.

Aubert, A.H., Medema, W., and Wals, A.E.J., 2019. towards a framework for designing and assessing gamebased approaches for sustainable water governance. *Water*, 11 (4), 869. doi:10.3390/w11040869.

Bai, X., *et al.*, 2016. Plausible and desirable futures in the anthropocene: a new research agenda. *Global Environmental Change*, 39, 351–362. doi:10.1016/j.gloenvcha.2015.09.017.

BergvallKareborn, B. and Stahlbrost, A., 2009. Living lab: an open and citizencentric approach for innovation. *International Journal of Innovation and Regional Development*, 1 (4), 356. doi:10.1504/ijird.2009.022727.

Bertola, M., *et al.*, 2023. Megafloods in Europe can be anticipated from observations in hydrologically similar catchments. *Nature Geoscience*, 16 (11), 982–988. doi:10.1038/s41561023013005.

Biermann, F., Dirth, E., and Kalfagianni, A., 2020. Planetary justice as a challenge for earth system governance: editorial. *Earth System Governance*, 6, 100085. doi:10.1016/j.esg.2020.100085

Blöschl, G., *et al.*, Eds, 2013. *Runoff predictions in ungauged basins – synthesis across processes, places and scales*. Cambridge, UK: Cambridge University Press, 465.

Blöschl, G., *et al.*, 2019. Twentythree unsolved problems in hydrology (UPH) a community perspective. *Hydrological Sciences Journal*, 64 (10), 1141–1158. doi:10.1080/02626667.2019.1620507.

Boulton, G.S., 2021. Science as a global public good. International Science Council Position Paper, 21pp, https://council.science/wpcontent/uploads/2020/06/Scienceasaglobalpublicgood_v041021.pdf

Carroll, S.R., *et al.*, 2020. The CARE principles for indigenous data governance. *Data Science Journal*, 19 (1), 43. doi:10.5334/dsj2020043.

Ceola, S., *et al.*, 2015. Virtual laboratories: new opportunities for collaborative water science, Hydrol. *Hydrology and Earth System Sciences*, 19 (4), 2101–2117. doi:10.5194/hess1921012015.

Ceola, S., *et al.*, 2016. Adaptation of water resources systems to changing society and environment: a statement by the international association of hydrological sciences. *Hydrological Sciences Journal*, 61 (16), 2803–2817. doi:10.1080/02626667.2016.1230674.

Cosgrove, C.E. and Cosgrove, W.J., 2012. *The dynamics of global water futures. Driving forces 20112050* [online]. Paris, UNESCO WWAP. Available from: https://unesdoc.unesco.org/ark:/48223/pf0000215377 [Accessed 8 July 2024].

Crochemore, L., *et al.*, 2021. How does seasonal forecast performance influence decisionmaking? Insights from a serious game bull. *Bulletin of the American Meteorological Society*, 102 (9), E1682–E1699. doi:10.1175/bamsd200169.1.

Cudennec, C., *et al.*, 2020. Towards FAIR and SQUARE hydrological data. *Hydrological Sciences Journal*, 65 (5), 681–682. doi:10.1080/02626667.2020.1739397.

Cudennec, C., *et al.*, 2022a. Operational, epistemic and ethical value chaining of hydrological data to knowledge and services. *Hydrological Sciences Journal*, 67 (16), 2363–2368. doi:10.1080/02626667.2022.2150380.

Cudennec, C. and Hubert, P., 2008. Multiobjective role of HSJ in processing and disseminating hydrological knowledge. *Hydrological Sciences Journal*, 53 (2), 485–487. doi:10.1623/hysj.53.2.485.

Cudennec, C., Sud, M., and Boulton, G., 2022b. Governing open science. *Hydrological Sciences Journal*, 67 (16), 2359–2362. doi:10.1080/02626667.2022.2086462.

Di Baldassarre, G., *et al.*, 2019. Sociohydrology: scientific challenges in addressing the sustainable development goals. *Water Resources Research*, 55 (8), 6327–6355. doi:10.1029/2018WR023901.

Dixon, H., *et al.*, 2022. Intergovernmental cooperation for hydrometry – what, why and how? *Hydrological Sciences Journal*, 67 (16), 2552–2566. doi:10.1080/02626667.2020.1764569.

Du, T.L.T., *et al.*, 2020. Streamflow prediction in "geopolitically ungauged" basins using satellite observations and regionalization at subcontinental scale. *Journal of Hydrology*, 588, 125016. doi:10.1016/j.jhydrol.2020.125016.

Falkenmark, M. and Chapman, T., 1989. *Comparative hydrology: an ecological approach to land and water resources*. Paris: Unesco, 479.

Falkenmark, M. and WangErlandsson, L., 2021. A waterfunctionbased framework for understanding and governing water resilience in the

Anthropocene. *One Earth*, 4 (2), 213–225. doi:10.1016/j.oneear.2021.01.009.

Falkenmark, M., WangErlandsson, L., and Rockström, J., 2019. Understanding of water resilience in the Anthropocene. *Journal of Hydrology*, 2, 100009. doi:10.1016/j.hydroa.2018.100009

Folke, C., *et al.*, 2021. Our future in the Anthropocene biosphere. *Ambio*, 50 (4), 834–869. doi:10.1007/s13280021015448.

GCEW (Global Commission on the Economics of Water), 2023a. *Turning the tide: a call to collective action* [online]. https://turningthetide.watercommission.org/ [Accessed 8 July 2024].

GCEW (Global Commission on the Economics of Water). 2023b. The what, why and how of the world water crisis. *In*: *Global commission on the economics of water phase 1 review and findings*. Paris, 94. https://Why-What-How-of-Water-Crisis-Web.pdf.

Gleeson, T., *et al.*, 2020. Global groundwater sustainability, resources, and systems in the anthropocene. *Annual Review of Earth and Planetary Sciences*, 48 (1), 431–463. doi:10.1146/annurevearth071719055251.

Gorelick, N., *et al.*, 2017. Google Earth Engine: planetaryscale geospatial analysis for everyone. *Remote Sensing of Environment*, 202, 18–27. doi:10.1016/j.rse.2017.06.031.

Greve, P., *et al.*, 2018. Global assessment of water challenges under uncertainty in water scarcity projections. *Nature Sustainability*, 1 (9), 486–494. doi:10.1038/s4189301801349.

Grönroos, C., 2012. Conceptualising value cocreation: a journey to the 1970s and back to the future. *Journal of Marketing Management*, 28 (1314), 1314, 15201534. doi:10.1080/0267257X.2012.737357.

Hall, C.A., *et al.*, 2022. A hydrologist's guide to open science. *Hydrology and Earth System Sciences*, 26 (3), 647–664. doi:10.5194/hess266472022.

Heal, K., *et al.*, 2021. Water quality: the missing dimension of water in the waterenergyfood nexus. *Hydrological Sciences Journal*, 66 (5), 745–758. doi:10.1080/02626667.2020.1859114.

Hrachowitz, M., *et al.*, 2013. A decade of predictions in ungauged basins (PUB) a review. *Hydrological Sciences Journal*, 58 (6), 1198–1255. doi:10.1080/02626667.2013.803183.

ICSU (International Council for Science), 2017. *A guide to SDG interactions: from science to implementation*. doi:10.24948/2017.01.

IPBES, 2019, *Global assessment report on biodiversity and ecosystem services of the Intergovernmental science-policy platform on biodiversity and ecosystem Services*. Bonn: IPBES. Zenodo. doi:10.5281/zenodo.5657041.

IPCC, 2021, *Climate change 2021: the physical science basis*. Masson-Delmotte, V, eds. Geneva: IPCC.

ISC (International Science Council), 2021. A contemporary perspective on the free and responsible practice of science in the 21st century. https://council.science/wpcontent/uploads/2020/06/Acontemporaryperspectiveonthefreeandresponsibleperspectiveofscienceinthe21stcentury_paper.pdf

Islam, S., *et al.*, 2023. Looking for theorypractice synthesis for actionable outcomes: a continuing special collection for translational water research. *Water Resources Research*, 59 (12), e2023WR036728. doi:10.1029/2023WR036728.

Jiang, Y., *et al.*, 2021. Chapter 11 – knowledge, research and capacity development as enabling conditions. The United Nations World Water Development Report 2021 'Valuing water', 143–156, https://www.unwater.org/publications/unworldwaterdevelopmentreport2021/

Kapetas, L. and Richard, F., 2020. Integrating bluegreen and grey infrastructure through an adaptation pathways approach to surface water flooding. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 378 (2168), 20190204. doi:10.1098/rsta.2019.0204.

Kootval, H. and Soares, A., 2020. *Road mapping and capacity development planning for national meteorological and hydrological services: a guidebook*. Washington: World Bank. https://openknowledge.worldbank.org/handle/10986/34817.

Koutsoyiannis, D., *et al.*, 2016. Joint editorial – fostering innovation and improving impact assessment for journal publications in hydrology. *Water Resources Research*, 52 (4), 2399–2402. doi:10.1002/2016WR018895.

Kovács, G., 1984. Proposal to construct a coordinating matrix for comparative hydrology. *Hydrological Sciences Journal*, 29 (4), 435–443. doi:10.1080/02626668409490961.

Kreibich, H., *et al.*, 2022. The challenge of unprecedented floods and droughts in risk management. *Nature*, 608 (7921), 80–86. doi:10.1038/s41586022049175.

Kreiling, L. and Paunov, C., 2021. Knowledge cocreation in the 21st century A crosscountry experiencebased policy report. OECD science, technology and industry policy papers, n° 115, OECD Publishing.

Kuentz, A., *et al.*, 2017. Understanding hydrologic variability across Europe through catchment classification, Hydrol. *Hydrology and Earth System Sciences*, 21 (6), 2863–2879. doi:10.5194/hess2128632017.

Kundzewicz, Z. and Kowalczak, P., 2009. The potential for water conflict is on the increase. *Nature*, 459 (7243), 31. doi:10.1038/459031a.

Li, N., *et al.*, 2023. Artistic representations of data can help bridge the US political divide over climate change. *Communications Earth & Environment*, 4 (1), 195. doi:10.1038/s43247023008569.

Lindersson, S., *et al.*, 2020. A review of freely accessible global datasets for the study of floods, droughts and their interactions with human societies. *Wiley Interdisciplinary Reviews: Water*, 7 (3). doi:10.1002/wat2.1424

Lund, J.R., 2015. Integrating social and physical sciences in water management. *Water Resources Research*, 51 (8), 5905–5918. doi:10.1002/2015WR017125.

Manfreda, S., *et al.*, 2024. Advancing river monitoring using imagebased techniques: challenges and opportunities. *Hydrological Sciences Journal*, 1–21. doi:10.1080/02626667.2024.2333846.

McMillan, H., *et al.*, 2016. Panta Rhei 2013–2015: global perspectives on hydrology, society and change. *Hydrological Sciences Journal*, 61 (7), 1174–1191. doi:10.1080/02626667.2016.1159308.

Meadows, D., *et al.*, 1972. *The limits to growth*. London: Chelsea Green Publishing.

Meybeck, M., *et al.*, 2023. Rivers help us to quantify the socioecological functioning of their basin at the Anthropocene: the Seine example (1850–2020). *Comptes Rendus Géoscience*, 355, 1–19. doi:10.5802/crgeos.140.

Mittal, A., Scholten, L., and Kapelan, Z., 2022. A review of serious games for urban water management decisions: current gaps and future research directions. *Water Research*, 215 (118217), 118217. doi:10.1016/j.watres.2022.118217.

Montanari, A., *et al.*, 2013. "Panta Rhei – everything flows": change in hydrology and society – the IAHS Scientific Decade 20132022. *Hydrological Sciences Journal*, 58 (6), 1256–1275. doi:10.1080/02626667.2013.809088.

Nadin, V., *et al.*, 2021. Integrated, adaptive and participatory spatial planning: trends across Europe. *Regional Studies*, 55 (5), 791–803. doi:10.1080/00343404.2020.1817363.

Nardi, F., *et al.*, 2022. Citizens AND hydrology (CANDHY): conceptualizing a transdisciplinary framework for citizen science addressing hydrological challenges. *Hydrological Sciences Journal*, 67 (16), 2534–2551. doi:10.1080/02626667.2020.1849707.

Nativi, S., *et al.*, 2019. Towards a knowledge base to support global change policy goals. *International Journal of Digital Earth*, 13 (2), 188–216. doi:10.1080/17538947.2018.1559367.

Nature Editorial, 2023. Global action on water: less rhetoric and more science. *Nature*, 615 (7954), 766. doi:10.1038/d41586023008865.

Nóbrega, R.L.B., *et al.*, 2023. Codeveloping pathways to protect nature, land, territory, and wellbeing in Amazonia. *Communications Earth & Environment*, 4 (1), 364. doi:10.1038/s43247023010267.

Nourani, V., *et al.*, 2014. Applications of hybrid wavelet–artificial intelligence models in hydrology: a review. *Journal of Hydrology*, 514, 358–377.

Oki, T., Valeo, C., and Heal, K.eds. 2006. Hydrology 2020: an integrating science to meet world water challenges. *In*: *IAHS Publ*. Vol. 300. Wallingford: IAHS Press.

Ostrom, E., *et al.*, 1999. Revisiting the commons: local lessons, global challenges. *Science*, 284 (5412), 278–282. doi:10.1126/science.284.5412.278.

Palmer, M.A., *et al.*, 2015. Manage water in a green way. *Science*, 349 (6248), 584–585. doi:10.1126/science.aac7778.

Pearce, T., *et al.*, 2020. What is the cocreation of new knowledge? A content analysis and proposed definition for health interventions. *International Journal of Environmental Research and Public Health*, 17 (7), 2229. doi:10.3390/ijerph17072229. PMID: 32224998; PMCID: PMC7177645. 26 Mar 2020.

Pecora, S. and Lins, H.F., 2020. Emonitoring the nature of water. *Hydrological Sciences Journal*, 65 (5), 683–698. doi:10.1080/02626667.2020.1724296.

Pimentel, R., *et al.*, 2023. Assessing robustness in global hydrological predictions by comparing modelling and Earth observations. *Hydrological Sciences Journal*, 68 (16), 2357–2372. doi:10.1080/02626667.2023.2267544.

President of the United Nations General Assembly, 2023. Summary of proceedings, united nations conference on the midterm comprehensive review of the implementation of the objectives of the international decade for action "water for sustainable development", 20182028. https://www.un.org/pga/77/wpcontent/uploads/sites/105/2023/05/PGA77SummaryforWaterConference2023.pdf

Rahman, M.F., *et al.*, 2023. As the UN meets, make water central to climate action. *Nature*, 615 (7953), 582–585. doi:10.1038/d41586023007939.

Rockström, J., *et al.*, 2023, Safe and just Earth system boundaries. *Nature*, 619, 102–111. doi:10.1038/s41586023060838.

Rosbjerg, D. and Rodda, J., 2019. IAHS: a brief history of hydrology. *History of Geo and Space Sciences*, 10 (1), 109–118. doi:10.5194/hgss101092019.

Rusca, M. and Di Baldassarre, G., 2019. Interdisciplinary critical geographies of water: capturing the mutual shaping of society and hydrological flows. *Water*, 11 (10), 1973. doi:10.3390/w11101973.

Savenije, H.H.G., Hoekstra, A.Y., and van der Zaag, P., 2014. Evolving water science in the Anthropocene. *Hydrology and Earth System Sciences*, 18 (1), 319–332. doi:10.5194/hess183192014.

Seitzinger, S.P., *et al.*, 2015. International geosphere–biosphere programme and earth system science: three decades of coevolution. *Anthropocene*, 12, 3–16.

ShuHsiang, C., Jaitip, N., and Ana, D.J., 2015. From vision to action–a strategic planning process model for open educational resources. *ProcediaSocial and Behavioral Sciences*, 174, 3707–3714. doi:10.1016/j.sbspro.2015.01.1103

Sivapalan, M., *et al.*, 2003. IAHS decade on predictions in ungauged basins (PUB), 2003–2012: shaping an exciting future for the hydrological sciences. *Hydrological Sciences Journal*, 48 (6), 857–880. doi:10.1623/hysj.48.6.857.51421.

Sivapalan, M., 2018. From engineering hydrology to earth system science: milestones in the transformation of hydrologic science, hydrol. *Hydrology and Earth System Sciences*, 22 (3), 1665–1693. doi:10.5194/hess2216652018.

Sivapalan, M., Savenije, H.H.G., and Blöschl, G., 2012. Sociohydrology: a new science of people and water. *Hydrological Processes*, 26, 1270–1276.

Steffen, W., *et al.*, 2011. The Anthropocene: conceptual and historical perspectives. *Philosophical Transactions of the Royal Society*, A.369842–867. doi:10.1098/rsta.2010.0327.

Steffen, W., *et al.*, 2018. Trajectories of the earth system in the anthropocene. *Proceedings of the National Academy of Sciences*, 115 (33), 8252–8259. doi:10.1073/pnas.1810141115.

Tauro, F., *et al.*, 2018. Measurements and observations in the XXI century (MOXXI): innovation and multidisciplinarity to sense the hydrological cycle. *Hydrological Sciences Journal*, 63 (2), 169–196. doi:10.1080/02626667.2017.1420191.

TWI2050 (The World in 2050 Initiative), 2018. Transformations to achieve the sustainable development goals, *World in 2050 initiative. International Institute for Applied Systems Analysis (IIASA)*, Laxenburg: Austria. www.twi2050.org.

UNEP, 2019. *Global environment outlook—GEO6: healthy planet, healthy people*. Nairobi: Cambridge University Press. doi:10.1017/9781108627146.

UNESCO, 2023. Gamechanger for the UN 2023 water conference: intergovernmental sciencepolicy platform for water sustainability. 9, https://unesdoc.unesco.org/ark:/48223/pf0000384788

UNESCO (United Nations Educational, Scientific and Cultural Organization), 2012. *International hydrological programme (IHP) eigth phase "Water security: responses to local, regional and global challenges" strategic plan IHPVIII (20142021)* [online]. Paris, https://unesdoc.unesco.org/ark:/48223/pf0000218061 [Accessed 8 July 2024].

UNESCO (United Nations Educational, Scientific and Cultural Organization), 2021. *Recommendation on Open Science* [online]. https://unesdoc.unesco.org/ark:/48223/pf0000379949.locale=en. [Accessed 8 July 2024].

UNESCO (United Nations Educational, Scientific and Cultural Organization), 2022. *IHPIX: strategic plan of the intergovernmental hydrological programme: science for a water secure world in a changing environment, ninth phase 20222029* [online]. UNESCO. Available from: https://unesdoc.unesco.org/ark:/48223/pf0000381318. [Accessed 8 July 2024].

UN Water, 2013. Water security and the global water agenda. UN Water Analytical Brief, https://www.unwater.org/sites/default/files/app/uploads/2017/05/analytical_brief_oct2013_web.pdf

UN Water, 2018. Sustainable development goal 6 synthesis report 2018 on water and sanitation. https://www.unwater.org/publications/sdg6synthesisreport2018onwaterandsanitation/

UN Water, 2020. *The sustainable development goal 6 global acceleration framework* [online]. https://www.unwater.org/app/uploads/2020/07/GlobalAccelerationFramework.pdf [Accessed 8 July 2024].

van Hateren, T.C., *et al.*, 2023. Where should hydrology go? An earlycareer perspective on the next IAHS scientific decade: 2023–2032. *Hydrological Sciences Journal*, 68 (4), 529–541. doi:10.1080/02626667.2023.2170754.

von der Porten, S., de Loë, R.C., and McGregor, D., 2016. Incorporating indigenous knowledge systems into collaborative governance for water: challenges and opportunities. *Journal of Canadian Studies*, 50 (1), 214–243.

WEF (World Economic Forum), 2018. *Harnessing the fourth industrial revolution for water* [online]. Available at: https://www.weforum.org/reports/harnessingthefourthindustrialrevolutionforwater/ [Accessed 8 July 2024].

WEF (World Economic Forum), 2022. *The global risk report 2022* [online]. https://wef.ch/risks22 [Accessed 8 July 2024].

Weichselgartner, J. and Arheimer, B., 2019. Evolving climate services into knowledgeaction systems. *Weather, Climate, and Society*, 11 (2), 385–399. doi:10.1175/WCASD180087.1.

Wen, Y., Schoups, G., and Van De Giesen, N., 2017. Organic pollution of rivers: combined threats of urbanization, livestock farming and global climate change. *Scientific Reports*, 7 (1), 43289. doi:10.1038/srep43289.

Wheeler, K.G. and Hussein, H., 2021. Water research and nationalism in the posttruth era. *Water International*, 46 (78), 7–1223. doi:10.1080/02508060.2021.1986942.

Wilkinson, M., *et al.*, 2016. The FAIR guiding principles for scientific data management and stewardship. *Scientific Data*, 3 (1), 160018. doi:10.1038/sdata.2016.18.

Winde, F., *et al.*, 2023. *Policy brief: UN 2023 Water Conference*. Paris: ISC (International Science Council).

Witteveen, L., *et al.*, 2023. Reflecting on four living labs in the Netherlands and Indonesia: a perspective on performance, public engagement and participation. *Journal of Science Communication*, 22 (3), A01. doi:10.22323/2.22030201.

Witze, A., 2023. This quiet lake could mark the start of a new Anthropocene epoch. *Nature*, 619(7970), 441–442, 10.1038/d4158602302234z, PMID: 37433944.

WMO (World Meteorological Organization), 2021a. *2021 State of climate services – water* [online].Available from: https://library.wmo.int/index.php?lvl=notice_display&id=21963#.YVxOUfdBxUO. [Accessed 8 July 2024].

WMO (World Meteorological Organization), 2021b. *WMO vision and strategy for hydrology and its associated plan of action* [online]. Available from: https://library.wmo.int/doc_num.php?explnum_id=11113#page=36 [Accessed 8 July 2024].

WMO (World Meteorological Organization), 2021c. *Unified data policy resolution* [online]. Available at: https://public.wmo.int/en/ourmandate/whatwedo/observations/UnifiedWMODataPolicyResolution [Accessed 8 July 2024].

WMO (World Meteorological Organization), 2023. *State of global water resources report 2022* [online]. Available at: https://library.wmo.int/records/item/68473stateofglobalwaterresourcesreport2022 [Accessed 8 July 2024].

WWAP (World Water Assessment Programme of UNESCO)/UN Water, 2019. *The united nations world water development report 2019 'Leaving* no one behind' [online]. Available at: https://www.unwater.org/publications/unworldwaterdevelopmentreport2019 [Accessed 8 July 2024].

WWAP (World Water Assessment Programme of UNESCO)/UN Water, 2021. The United Nations World Water Development Report 2021 'Valuing water', https://www.unwater.org/publications/unworldwaterdevelopmentreport2021/

Young, G., *et al.*, 2015a. Hydrological sciences and water security: an overview. *PIAHS*, 366, 1–9. doi:10.5194/piahs36612015.

Young, G., et al., 2015b. *Contribution to the shaping of UNESCO's hydrological programmes. In 'Water, people and cooperation – 50 years of water programmes for sustainable development at UNESCO'*. 198–199 Paris:UNESCO.

Yu, Z., *et al.*, 2020. Preface: hydrological processes and water security in a changing world, Proc. *IAHS*, 383, 3–4. doi:10.5194/piahs38332020.

Zalasiewicz, J., *et al.*, 2017. The Working Group on the Anthropocene: summary of evidence and interim recommendations. *Anthropocene*, 19, 55–60. doi:10.1016/j.ancene.2017.09.001.

Zamenopoulos, T., *et al.*, 2021. Types, obstacles and sources of empowerment in codesign: the role of shared material objects and processes. *CoDesign*, 17 (2), 139–158. doi:10.1080/15710882.2019.1605383.

Zvobgo, L., *et al.*, 2022. The role of indigenous knowledge and local knowledge in water sector adaptation to climate change in Africa: a structured assessment. *Sustain Sci*, 17, 2077–2092. doi:10.1007/s1162502201118x.

Appendix

Collecting input to the Concept Note

IAHS AISH

Input for Plenum 1 Feb at 14 hrs CET:

1. What defines a successful Scientific Decade?
2. What do we want to achieve in the long-term and short-term, respectively?

WHY?

Input for Plenum 2 Feb at 10 hrs CET:

3. What are the current drivers/trends in Fundamental and Applied Research?
4. What are the societal needs of scientific results?
5. Where to position IAHS? (vs other global scientific communities)

WHAT?

Input for Plenum 2 Feb at 14 hrs CET:

6. Brainstorm potential topics (and sub-topics/science questions) of the Next decade!
7. Identify short and catchy names
8. Make a brief SWOT analysis for each one (Strengths, Weaknesses, Opportunities, Threats)

Input for Plenum 3 Feb at 10 hrs CET:

HOW?

9. Identify sub-topics, science questions and Results of the Next Scientific Decade!
10. Suggest an organisational structure and communication/work activities (based on previous experiences)

Figure A1. Agenda with discussion points at satellite online meetings and at the Cordoba workshop in early 2023, to answer questions on Why, What and How to set up the next decade. The in-person work was organized in roundtable discussions (eight persons per table) steered by answering the questions and reporting in Plenum, followed by open discussions.

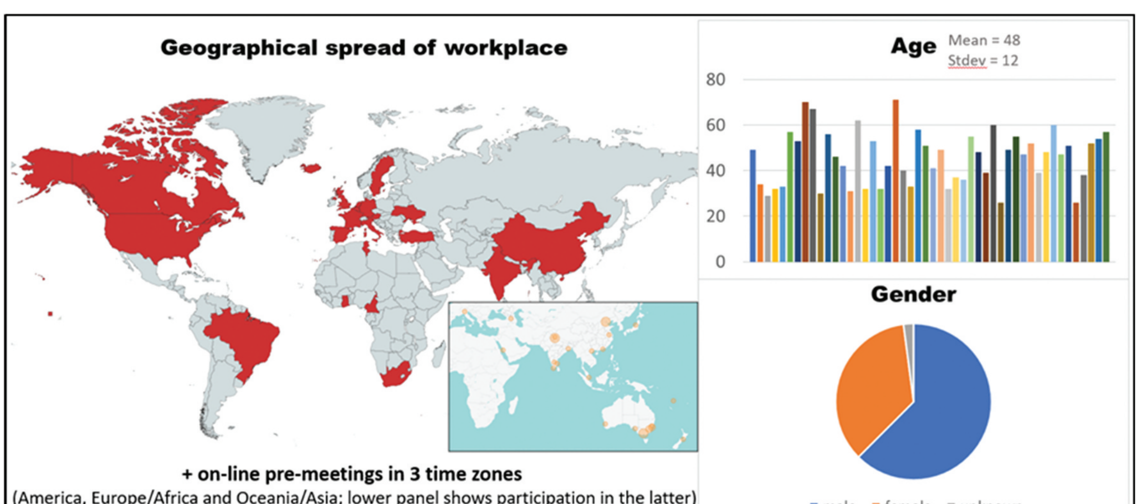

Figure A2. Some metrics on diversity among the scientists participating at the workshop in Córdoba when collecting input for the next decade during three days, 13 February 2023.

Table A1. List of working groups (WGs) per theme, with leaders and number of assigned participants in December 2023. (WG leaders are working with theme leaders).

Theme 1 HELPING with global and local interactions	Theme or WG leader(s)	Number of participants
Theme 1 leader (coordinating WG leaders)	***Justin Sheffield***	***14***
REHYDRATE – REtrieve historical HYDRologic dATa and Estimates	Miriam Bertola, Paola Mazzoglio	75
Decomposing Complexity	Ankit Agarwal	37
Urban Water – Urbanization phenomenon and adequate water management strategies	Bertil Nlend	43
From local to large-scale human–water dynamics	Mohammad Ghoreishi	55
Comparative understanding of runoff generation processes from global experimental watersheds	Fuqiang Tian	81
Water for biodiversity in a changing world	Claudia Teutschbein	53
Understanding drivers and feedbacks of soil moisture variability across scales, from local to global	Justin Sheffield	56
Deep explanation and evaluation of hydrological Changes for local solutions (DEEPHY)	Suxia Liu	64
Effective Aquifer Governance for Agriculture	Maria Elena Orduna Alegria	24
Hydrologic Design – Solutions and Communication	Svenja Fischer	115
Water Quality Under Global Changes	Albert Nkwasa	44
Development and application of river basin simulators	Jun XIA	86
Ensuring evidence-based findings	Benjamin Wullobayi Dekongmen	8
Droughts in Mountain Regions	Francesco Avanzi	135
Theme 2 HELPING with holistic solutions for water security	WG leader(s)	Number of participants
Theme 2 leader (coordinating WG leaders)	***Ana Mijic***	***11***
Drought in the Anthropocene	Marthe Wens	138
Participatory Water Systems	Santosh Subhash Palmate	19
Near-term (annual to decadal) forecasts of water availability	Kristian Förster	46
Acceptance of nature-based solutions and their implementation in guidelines	Junguo Liu, Nejec Bezak	112
The water-energy-food-ecosystem (WEFE) nexus	Claudia Teutschbein, David Christian Finger, Shiv Narayan Nishad	133
Water systems analysis for integrated planning and management	Ana Mijic	78
Stepwise ecological restoration of watersheds	Junguo LIU	44
WATER & HEALTH – Integrated water pollution solutions to tackle the water and health nexus	Stefan Krause	67
Theme 3 HELPING with cross-cutting goals	WG Leader(s)	Number of Participants
Theme 3 Leader (coordinating WG leaders)	***Adeyemi Olusola***	***6***
Strategic UNCollaboration Group (SCGHydro)	Mojtaba Shafiei	44
Outreach, Communication and Science Interfaces	Christina Orieschnig	50
CoCreating Water Knowledge	Giulio Castelli, Wouter Buytaert, Natalie Ceperley	107