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Rethinking responses to the world's water crises

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The world faces multiple water crises, including overextraction, flooding, ecosystem degradation and inequitable safe water access. Insufficient funding and ineffective implementation impede progress in water access, while, in part, a misdiagnosis of the causes has prioritized some responses over others (for example, hard over soft infrastructure). We reframe the responses to mitigating the world's water crises using a 'beyond growth' framing and compare it to mainstream thinking. Beyond growth is systems thinking that prioritizes the most disadvantaged. It seeks to decouple economic growth from environmental degradation by overcoming policy capture and inertia and by fostering place-based and justice-principled institutional changes.

The proportion of people with access to safe drinking water globally has doubled over the past 50 years. Nevertheless, the rate of progress in safe water access is insufficient to deliver Sustainable Development Goal (SDG) 6 by 2030: "Ensure availability and sustainable management of water and sanitation for all." For example, at least half of people in each of sub-Saharan Africa, South Asia, Southeastern Asia, and Latin America and the Caribbean are estimated not to have access to safely managed drinking water services[1], while global human water withdrawals have increased about 5-fold over the past 50 years.

SDG 6 is unattainable unless deficiencies in water governance[2], including policy capture and inertia and a lack of systems thinking[2], are corrected to decouple economic growth from water withdrawals[3]. This requires (1) governments and donors to invest more in supporting water supply systems and ensuring that they are fit for purpose, people and place, especially in rural and remote areas[4]; (2) urgent action to prevent the degradation of rivers, aquifers and other water bodies from unsustainable withdrawals and pollution; (3) water allocation towards just and sustainable water access for the most disadvantaged;

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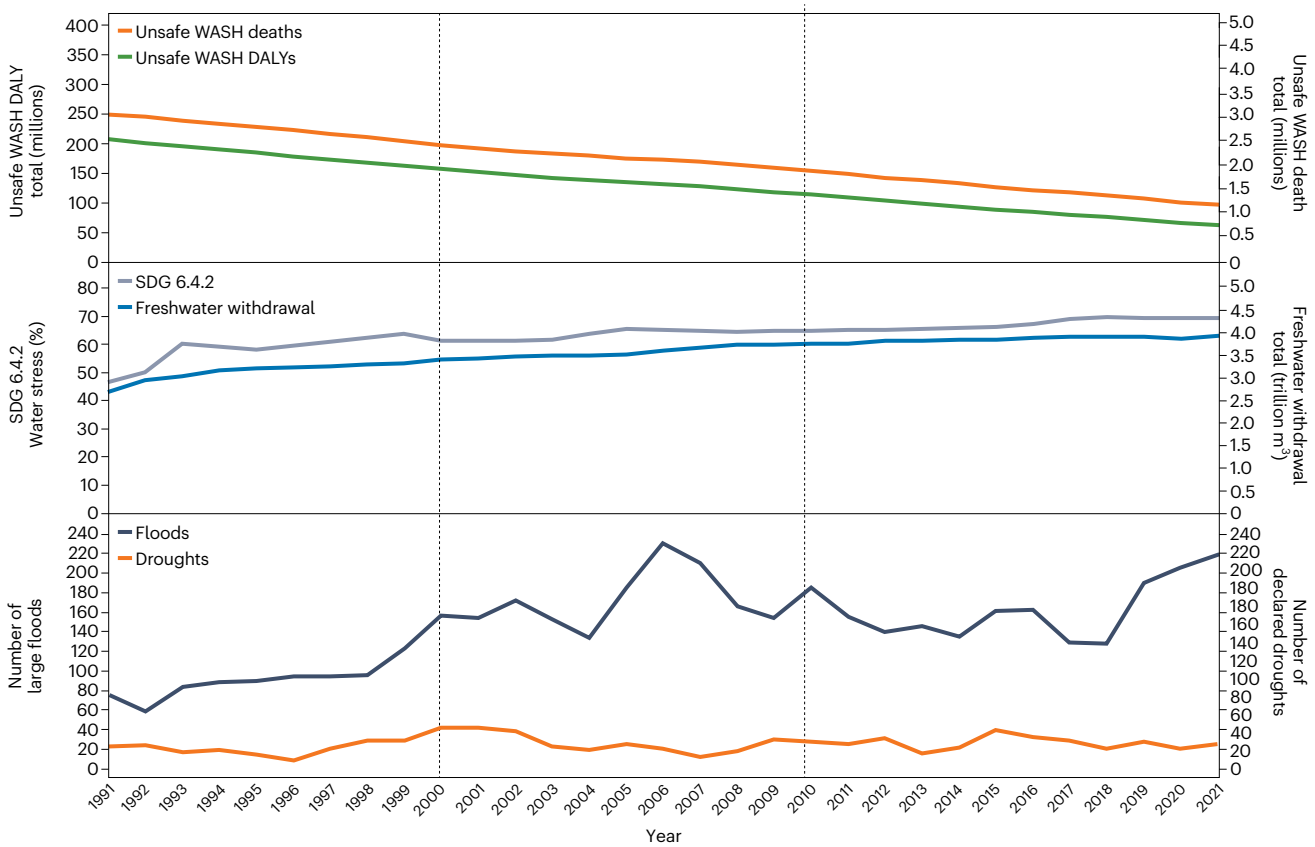

Fig. 1 | Too much, too little, too dirty and too stressed: annual measures from 1991 to 2021. 'Too much' includes the number of large-scale floods, and 'too little' includes the number of large-scale droughts, sourced from the EM-DAT: The OFDA/CRED International Disaster Database (https://doc.emdat.be). 'Too dirty' includes deaths and disability due to unsafe water sanitation and hygiene (cumulative number per year), sourced from the Global Burden of Disease Collaborative Network (2021) (https://vizhub.healthdata.org/gbd-results/). 'Too stressed' is total water withdrawals (trillion m^3) per year, and SDG 6.4.2, Water stress is the average annual indicator of water stress (freshwater withdrawals by all economic activities as a percentage of the total renewable freshwater resources available, taking into account environmental flow requirements). The vertical dashed lines demarcate each decade. Data from AQUASTAT—FAO's Global Information System on Water and Agriculture (https://data.apps.fao.org/aquastat/)[75]. WASH, water supply, sanitation and hygiene, DALYs, disability-adjusted-life-years.

(4) integrated bottom-up and top-down local and place-based management; (5) climate adaptation with a resilience framing that accounts for the adverse impacts on water supply and quality from climate change, including from increased frequency and intensity of floods and greater magnitude and length of droughts (Fig. 1); and (6) policies that prioritize interconnected delivery of the targets and indicators of SDG 6.

Water stress, defined as the ratio of total water withdrawals to available renewable freshwater supplies, is increasing (Fig. 1) and is exacerbated, at a catchment scale, by poor water quality[5]. Water stress currently exceeds 80% in large parts of India, China, the Middle East and North Africa, southern Europe, the western United States, Southeast Australia and South Africa[6]. One outcome of water stress and of dams, weirs and reservoirs that disconnect river systems and their associated water withdrawals is that since 1970 the global area of wetlands has declined by about a third, with some regions retaining less than 10% of their original area[7].

Agriculture is responsible for about 70% of the world's freshwater withdrawals; therefore, demand for food, energy and water security must be carefully balanced. This is because, in many regions with high water stress, water withdrawals for irrigation are unsustainable[8] and are increasing both the frequency of low stream flows and groundwater depletion[9]. Compounding these challenges is climate change, which is intensifying regional patterns of overextraction[10] while increasing flooding risks due to more frequent and higher-intensity storms. Under moderate greenhouse gas (GHG) emissions, about one third of the world's population is projected to experience either wetter or drier conditions by 2100[11], while some may experience both more frequent floods and more frequent droughts.

Three framings of the world's water crises

Responses to the world's water crises are influenced by worldviews, or framings—sets of beliefs and values about the world that influence thoughts and actions. We consider three growth framings and their implied responses to managing the world's water crises and delivering SDG 6 targets. These crises are (1) unaffordable and inequitable access to safe drinking water (SDG Target 6.1) and sanitation (SDG Target 6.2); (2) water pollution (SDG Target 6.3) and environmental degradation, including of water-related ecosystems (SDG Target 6.6); (3) water overextraction from both surface and groundwater (SDG Target 6.4), for which improvements in water use efficiency are claimed to be a key response (SDG Indicator 6.4.1); and (4) inadequate protection of water-related ecosystems from unmitigated social–economic–ecological system vulnerabilities (SDG Target 6.6 and SDG Indicator 6.6.1).

We review the possible responses to these water crises using three growth framings: (1) 'economic growth', which considers growth in the economy as central to economic development; (2) 'green growth', which includes both economic growth and the conservation of key environmental assets as necessary for economic development[12]; and (3) 'beyond growth', not yet mainstreamed, which responds to local,

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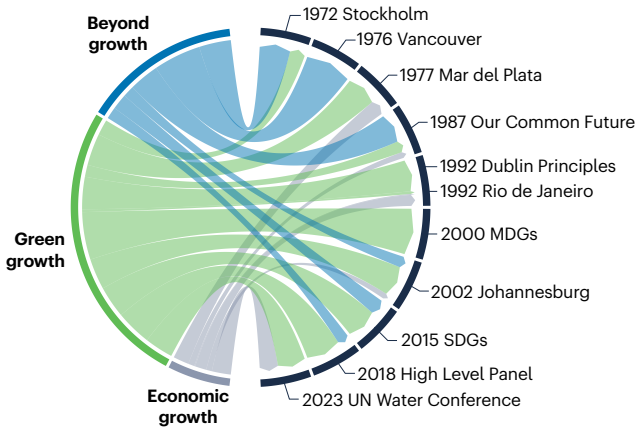

Fig. 2 | Sankey diagram of keywords in UN reports and documents from 1972 to 2023 related to economic growth, green growth and beyond growth. The diagram represents UN-conference-based documents scanned for concepts linked to value, pricing ('price' and 'pricing'), markets and justice (includes 'just'). References to value and markets in the context of the subject meaning were coded manually (for example, simple references such as just money or market sales of crops were not considered if not linked to water/environment). The size of the arrows represents the percentage of the key concept representations related to the different framings within each document. Further details about the construction of this figure and its data sources are provided in Supplementary Section 2. MDGs, Millennium Development Goals.

regional and global environmental degradation[13] by focusing on sustainable and more equitable outcomes achieved through prioritizing institutional and policy reform.

The three growth framings are visualized in Fig. 2 (as keywords and key publications) through textual analyses of United Nations (UN) publications and conference proceedings, informed by a historical perspective. Figure 2 is illustrative only of the relative nature of the three growth framings, given that there are policy lags between principles espoused in UN publications and agreements and their implementation.

'Economic growth' framing

Economic growth is a measure of the change in the total market value-add of goods and services, expressed as the gross domestic product (GDP), produced in an economy over time. Economic growth has been the predominant prescription for social-economic development and, until at least the 1990s, was widely held to be the only pathway towards progress and prosperity. Nevertheless, in the twenty-first century, a growing number of economists accept that the level (and growth) of GDP is a flawed measure of welfare and progress[14].

Economic growth framing aims to increase prosperity by raising GDP per capita. It is underpinned by "growth theory"[15], which includes three key claims: (1) low-income countries can converge to the levels of per capita income in high-income countries, but only by increasing their produced capital per worker through private and public investments; (2) sustained economic growth, in the long run, requires technological progress, which is increased by investments in research and development; and (3) high-income countries have accumulated higher per capita levels of produced and human capital than low-income countries.

While higher levels of GDP since the 1950s have been accompanied by large improvements in global health (for example, reduced child mortality and morbidity), they have not yet adequately met the needs for improved water supply and sanitation, especially in rural areas. Furthermore, the growth dilemma is that historical patterns of economic growth have contributed to large negative environmental impacts[16], including increased global GHG emissions and the degradation of water-related ecosystems.

'Green growth' framing

Green growth is challenging economic growth as the dominant policy framing in international fora, especially in high-income countries. The Organization for Economic Cooperation and Development defines green growth as "fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which well-being relies"[12]. Actions in support of green growth include (1) pricing environmental costs and benefits not 'internalized' in market transactions (for example, water pollution); (2) repurposing and/or eliminating input subsidies (for example, fertilizer, energy and infrastructure) that degrade water resources, especially in agriculture; (3) removing barriers to improved water outcomes (for example, water pricing that fails to cover the costs of supply)[3,17]; and (4) promoting innovation and 'green' technologies (for example, improved water-use efficiency) to increase productivity and reduce environmental degradation.

Green growth retains per capita GDP growth as a key indicator of policy success and seeks to stimulate green technologies to reduce the intensity of natural resource use per dollar of GDP over time. In several middle- to high-income countries, some of the resources consumed for every dollar of GDP have decreased, and, in a select few countries, outright reductions in the use of certain materials have been observed. Despite these improvements, there has not yet been a decrease in the global consumption of materials[18], global GHG emissions or the total amount of water withdrawals.

Countries that have sought to reduce their environmental footprint have achieved this in part by imports such as through "virtual water"[19] in the form of food and clothing. Given the critical need to rapidly reverse key environmental impacts (for example, global GHG emissions) to avoid potentially catastrophic climate risks[20], there is scepticism that green growth, as currently practised and in the time frame available, can deliver increased human well-being[21]. Nevertheless, 'Green New Deal' policies that incorporate much of the thinking around green growth have become an important policy platform in some countries (such as the United States). The key focus of a Green New Deal is on public-sector spending and policy reform to increase green employment, stimulate green technologies and promote low-carbon manufacturing[22].

'Beyond growth' framing

Beyond growth framing was first presented by Daly[23] but has antecedents in earlier work that identified 'affluent societies' as having unresolved social–economic–environmental problems, including inadequate public services and excessive environmental costs[24], and global projections of the limits and consequences of unrestrained economic growth.

Beyond growth emphasizes (1) the interconnections between the geosphere (for example, GHG emissions and climate impacts), biosphere (for example, resource extraction and pollution) and anthroposphere (for example, energy, knowledge, governance and economic systems, and well-being) that impose local and planetary biophysical limits on human activities; and (2) the fact that decision-making occurs within complex social–ecological systems such that actions can be more effective at improving the state of the world when they are inclusive in terms of who is listened to, what forms of knowledge are accepted as valid, what challenges are considered and what solutions are selected (Fig. 3). That is, beyond growth takes a 'systems thinking' view of the causes and consequences of the state of the world, including the world's water crises; is inclusive; is relational by encompassing place-based decision-making; and is justice-principled in its responses.

Key policy goals of beyond growth include (1) rapid decoupling of economic growth from critical environmental impacts (for example, climate change, biodiversity loss and groundwater depletion), including the global material footprint[18]; and (2) reduced intergenerational inequalities associated with environmental degradation and

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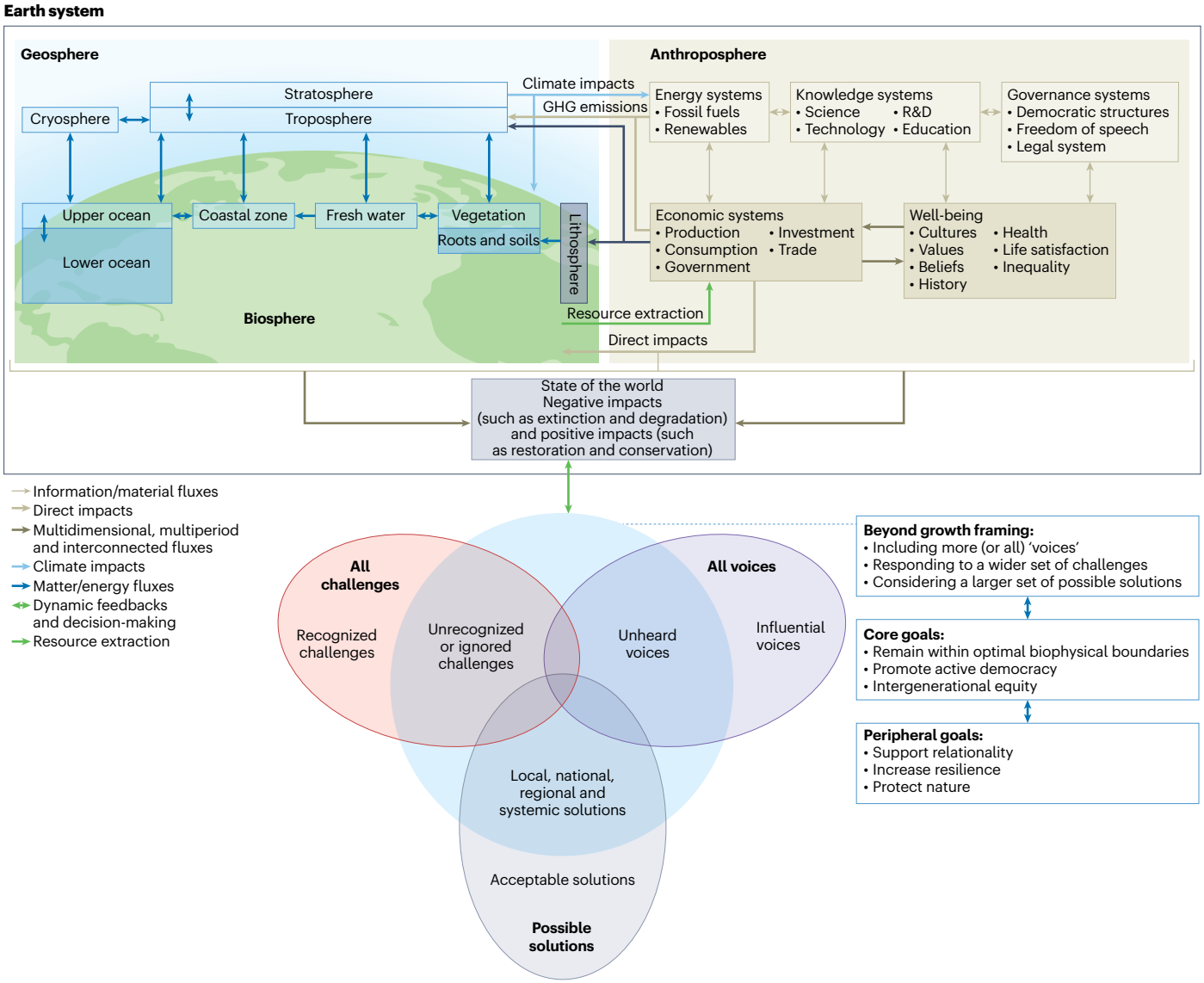

Fig. 3 | The Earth system, the state of the world and a beyond growth framing. The top part of the figure represents the Earth system, which comprises multiple interacting systems summarized as the geosphere, biosphere and anthroposphere. Collectively, these systems determine the current state of the world in terms of both positive and negative impacts. The current and future state of the world is affected by and affects the framing or worldviews of people and, especially, decisionmakers. A beyond growth framing (bottom) seeks to go beyond existing growth framings (for example, economic and green growth) to explicitly (1) include previously unrecognized or ignored challenges (for example, systemic and cascading risks across multiple systems), (2) listen to unheard voices (for example, Indigenous Elders) and (3) have nested and systemic solutions at multiple scales (for example, local to national to regional and global). Figure adapted with permission from: top, ref. 76, Springer Nature Ltd; bottom, ref. 77, IEEE.

economic growth[25]. Key outcomes in support of these goals, proposed at multiple scales (local, national, regional and global), include (1) reducing environmental degradation (for example, improved water quality), (2) rising human well-being (for example, longevity and higher quality of life), (3) decreasing water insecurity (for example, increased access to safe drinking water and sanitation), (4) increasing system resilience (for example, recovery supporting a more sustainable state of the world following negative shocks, such as from droughts and floods)[26] and (5) growing participatory and deliberative democracy[27] (for example, proportional representation voting, nested neighbourhood-to-regional-to-national citizen assemblies and tools for canvassing opinions or locating consensus)[28].

Figure 4 provides a timeline of the relative importance of the three growth framings as they manifest themselves in key UN publications and conference proceedings. The upper level includes key publications and events that have shaped the three framings since 1950. The middle level is the timeline. The lower level shows the percentage of the world population with access to safe drinking water. This figure highlights that economic growth and green growth have dominated thinking and that beyond growth is not yet mainstreamed.

Responses to the world's water crises

Responses to the world's water crises depend, in part, on decisionmakers' understanding of causes and consequences, as well as their goals. While there are commonalities across all three framings, the core goals of the framings are different; thus, so are the associated responses (Fig. 5). All three framings acknowledge that policies, institutions and investments should respond to market and government failures, but they differ over what is prioritized.

In the water sector, the two principal market failures are (1) externalities or side effects in both the production and consumption of water resources[29], such that the costs imposed on others (for example, from

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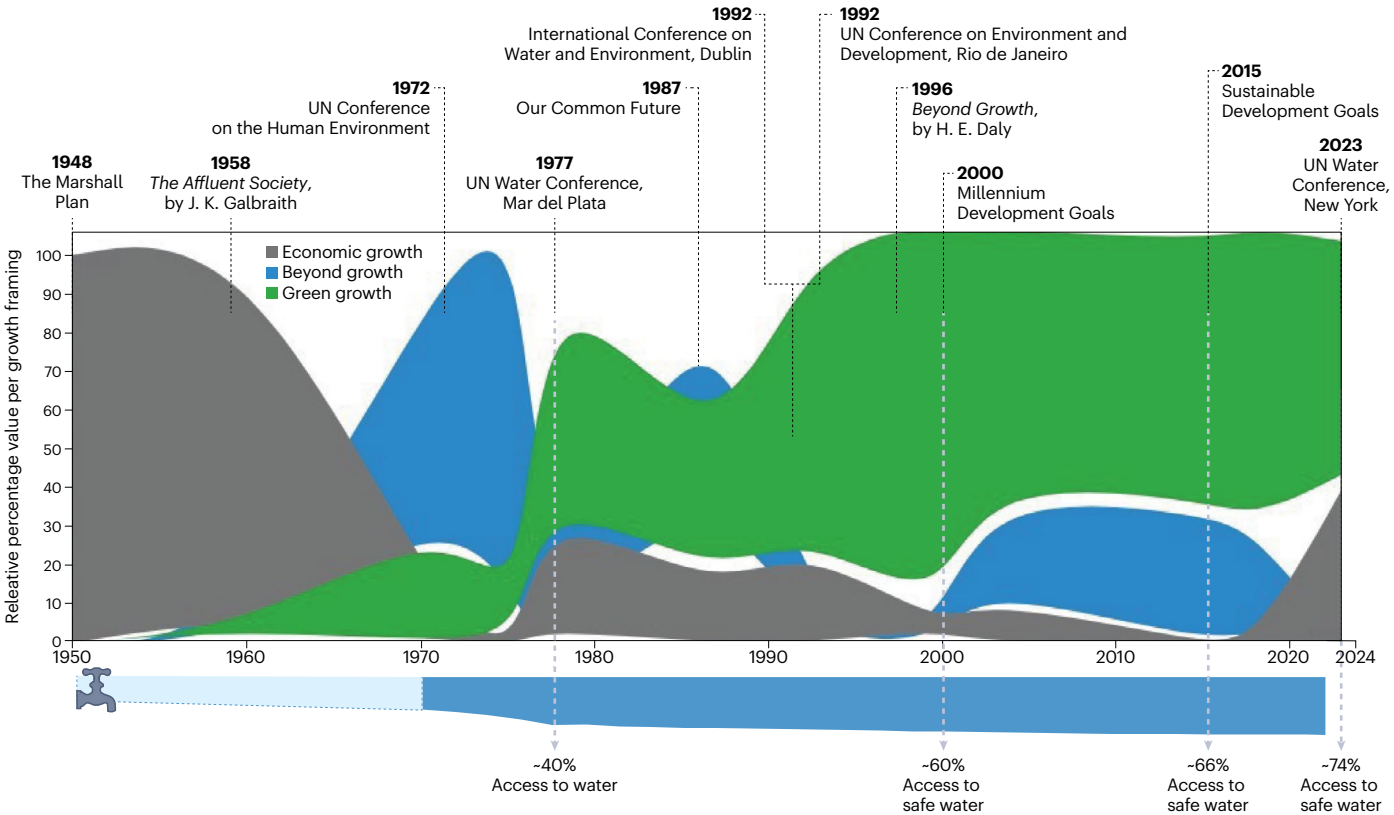

Fig. 4 | Key reports and documents, timeline of economic growth, green growth and beyond growth, and global access to safe water. Top: a selected list of reports and documents in relation to the three growth framings. Middle: a visualization of the relative importance of the three growth framings over time. Bottom: the percentage of the global population with 'safe' drinking water. For 1977, data on drinking water access are available only as 'access to drinking water', whether the water was safe or not. From 2001 onwards, drinking water access is available as 'access to safe drinking water' with defined parameters on what constitutes 'safe'. Further details about the construction of this figure and its data sources are provided in Supplementary Section 3.

groundwater depletion or water pollution) are not fully accounted for by those causing the harm; and (2) collective action failures that result in inadequate provision of public goods (for example, flood protection) because the benefits are non-exclusive, such that while everyone benefits from their provision, some choose to 'free ride'.

Government failures in the water sector include (1) inadequate institutional, financial or technical government capacities to support effective water planning and collective action (for example, the provision and monitoring of drinking water services); (2) regulatory capture, whereby private actors redirect public funds (for example, the size and location of water infrastructure) for their own gain[30]; (3) misaligned regulations and incentives[31] that cause unintended consequences (for example, energy subsidies to farmers that incentivize excessive groundwater pumping); (4) 'crowding out' of self-organized collective actions (for example, sustainable, locally managed aquifers) by externally imposed rules[32]; and (5) failures of omission, including monitoring and enforcing of government regulations and standards concerning water, as well as a lack of accessible information (for example, flood and drought risks, sea-level rise and drinking water quality)[33].

Economic growth prioritizes efficiently allocating goods and services through markets and capital accumulation to support infrastructure-led economic development. In this framing, the water crises are primarily overcome by targeted public and private investments in water infrastructure that support the provision of water-related goods and services.

Green growth prioritizes the internalization of market failures that create environmental costs. It also recognizes the need to respond to government failures with organizational reforms (for example, operational independence of regulatory agencies, stable funding to environmental agencies, intersectoral coordination and multilevel governance, and redesigning subsidies to reduce water pollution and water withdrawals). It shares with economic growth the goal of overcoming infrastructure gaps and 'derisking' water-related investments. Green growth also seeks policies, institutions and investments that provide economic incentives for green technologies and 'nature-based solutions'. The related policy agenda of the Green New Deal highlights the need for public investments and incentives for green infrastructure and employment.

Beyond growth responds to both market and government failures with systems thinking through prioritizing the mitigation of water-related risks[34] and developing effective partnerships to achieve good-quality water access for the poorest[35]. Like green growth, it recognizes the importance of economic incentives and regulations to (re)allocate water, as well as the need for appropriate water pricing and a redesign and/or elimination of subsidies to avoid incentivizing greater water withdrawals. Repurposed subsidies could benefit existing rural beneficiaries by redirecting funding towards research and development and extension services for farmers, such as promoting climate-smart agriculture (for example, better production, better nutrition, better environment and a better life for all). Cross-subsidization can also help overcome the much higher rural water supply costs per person[36], relative to urban areas, to improve rural water service delivery to the poor, especially those not yet connected to safe water supply systems[3].

Beyond growth differs from economic growth and green growth in that it is explicit about who has power and influence over water, who is not listened to by key decisionmakers, and what knowledge and data have been excluded in decision-making. That is, beyond growth

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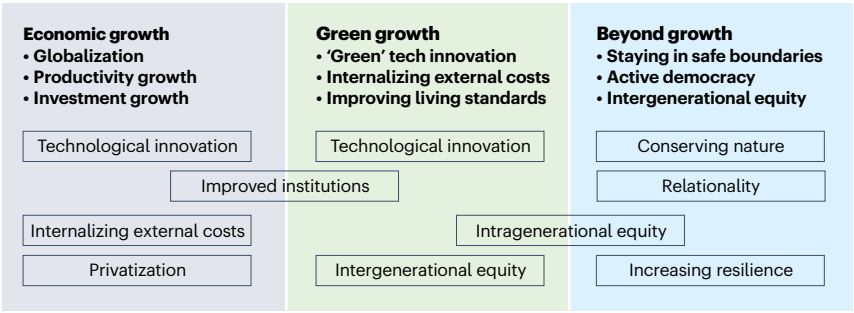

Fig. 5 | Core and peripheral goals of economic growth, green growth and beyond growth. The bulleted text indicates three selected core goals for each framing. The boxed text indicates four selected peripheral goals for each framing.

highlights the need for innovations in policy interventions and institutional arrangements[37] that open up the process of 'who gets what water and when' in terms of who participates in decision-making processes, what problems and solutions are considered, and how actions are implemented justly (Fig. 3).

Figure 6 summarizes key responses across the three growth framings in relation to the world's water crises. The responses are nested in that those listed for economic and green growth are also possible options for beyond growth. That is, beyond growth options include all responses, but how they would be implemented may differ radically from economic growth and green growth. For example, intercatchment water transfers to increase water availability elsewhere could be considered a desirable response for beyond growth only after full and proper engagement with all stakeholders, with full consideration of (1) system risks, (2) all economic costs and benefits (for example, social–economic–ecological), (3) compensation to mitigate distributional and intertemporal impacts, and (4) implementation of regulations and standards. As currently practised, nine responses in Fig. 6 are exclusive to beyond growth. Three responses are highlighted as common to beyond growth and green growth: (1) transparent and real-time water audits, (2) nature-based storage and (3) legal protections for households and ecosystems. Finally, three responses are highlighted as common to green growth and economic growth: (1) allocation of property rights and creation of formal markets to extract or pollute water, (2) managed aquifer recharge, and (3) greater access to insurance and credit for low-income and/or rural households and businesses.

Economic growth responses

Increasing the stock of built infrastructure (for example, dams, piped infrastructure, and water treatment and desalination plants) has been the primary method of economic growth to respond to inadequate access to safe water and sanitation and to mitigate water risks (such as flooding). A build-and-grow approach (Fig. 6) has been highly successful in providing improved water quality in urban areas in most regions of the world and has supported water growth opportunities (for example, irrigation). Investments in water storage infrastructure have also provided multiple benefits, including improved water availability and public goods (for example, flood control). Nevertheless, due to poor planning and execution, some built water storage systems, either unintentionally or because the estimated benefits have exceeded the perceived costs, have caused negative consequences (such as reduced stream flows, displacement of people and interruptions of fish migrations).

To achieve SDG Targets 6.1 and 6.2, economic growth that prioritizes built infrastructure should be complemented by other interventions, especially in rural areas, where the number of households without access to safe water and sanitation is five times greater than for the urban poor[38]. In rural and remote locations, safer water access is facilitated by (1) off-grid investments that are fit for purpose, people and place[4]; (2) water users who pay for operations and maintenance complemented by complete transparency about costs with full accountability of water suppliers and service providers (for example, results-based contracts)[39]; and (3) investments in green infrastructure and nature-based solutions (such as upstream watershed protection and riparian buffer zones)[40].

With an economic growth framing, delivering SDG Targets 6.3 and 6.6 related to water pollution and water-related ecosystems is promoted by investments and regulations that respond to public demands for a better-quality environment. This prioritization is, in part, justified by the environmental Kuznets curve, which posits that increases in per capita GDP eventually result in a peak in environmental degradation with rising incomes, followed by a decline. That is, for some decision-makers, a possible remedy to increasing environmental degradation is more economic growth until degradation peaks, rather than the prioritization of remedial actions. Empirical tests of environmental Kuznets curve relationships have suffered from misspecification and misinterpretation[41], and declining environmental degradation has not yet been observed at a global scale for either water withdrawals or key pollutants (such as world GHG emissions). Where rising GDP per capita is associated with reduced environmental degradation (for example, water pollution) at a local level, this has occurred because of effective water management and active government interventions, not by economic growth alone[42].

Green growth responses

Under green growth, the need to respond actively to market failures, especially relating to environmental degradation, has encouraged a series of market-based approaches to achieve SDG 6's water pollution and ecosystem health targets (Fig. 6). These approaches include (1) charges imposed on point sources of water pollution intended to reduce or eliminate polluting discharges; (2) a small number of cap-and-trade systems that constrain the overall level of water discharges but allow point sources, and in some cases non-point sources, to trade their permitted allowances[43]; and (3) the use of payments for watershed services that have, in some cases, proved effective at improving watershed cooperation, watershed integrity[44] and water quality[45].

Market-based approaches require effective monitoring, compliance and enforcement, and are not set-and-forget responses to polluted waterways. Such monitoring is facilitated by real-time measurements of water use, consumption and water quality via the 'Internet of Things', remotely sensed data and other open-access data. As with command-and-control approaches that directly regulate point-source discharges, practices and technologies, there is a critical need to assess the benefits and costs of improved water quality. This can be facilitated by non-market valuation of the aggregate benefits of improved drinking water supplies, wastewater treatments[36] and environmental improvements.

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	Economic growth	Green growth	Beyond growth
Inadequate access to safe drinking water and sanitation (SDG Targets 6.1 and 6.2)	• Privatization and public–private partnerships to improve service delivery • Increasing public investments (for example, low-interest loans and fiscal transfers) in water infrastructure (for example, dams and sewage treatment) • Incentives for centralized water infrastructure	• Reforms to reduce non-revenue water and increase cost recovery of water services • Innovation and scaling up supply technologies (such as desalination, reverse osmosis and solar-powered air moisture extraction) • Green and transition finance to increase funding base for investments in improved source water quality and supply (for example, payments for environmental services) • Independent regulatory oversight of public investments and water service outcomes	• Legislated and enforceable rights for households to have minimum service levels (such as reliability, quality and affordability of drinking water) and legal protection for key ecosystems (such as wetlands and source catchments) • Rural and remote water delivery services fit for purpose, people and place • Science–practitioner–community partnerships for justice-based adaptations to water-related risks
Poor water quality and degraded riparian systems (SDG Targets 6.3 and 6.6)	• Services-led economic growth to reduce environmental impact per dollar of GDP • Relocation of people to reduce pollution impacts (for example, urban planning and licensing of point sources of pollution) • Allocation of property rights and creation of formal markets to extract or pollute water	• Price externalities of water use (for example, pollution charges) • Multipurpose use of existing water infrastructure (for example, hydropower dam reoperation and irrigation channels to deliver environmental water) • Triple bottom line accounting • Non-market valuation studies to assess market and non-market trade-offs	• Relationality (for example, 'rights of nature', public trust doctrine and common asset trusts) • Active democracy (for example, including citizen-led decision-making and participatory approaches) • Reallocation of water to achieve environmental and justice goals including the UN Declaration of Rights of Indigenous Peoples
Surface water overextraction and groundwater depletion (SDG Target 6.4)	• Unitization of groundwater resources • Supply augmentation with intercatchment and/or inter-temporal (for example, dams) and water transfers • Agricultural extensification to reduce reliance on exisiting land and water • Managed aquifer recharge	• Pricing water (for example, water abstraction charges, volumetric water pricing and water markets) • Scaling up 'efficient' water technologies (such as drip irrigation and water recycling) • Removing or repurposing perverse subsidies (for example, capital and operating costs of water pumps) • Improving monitoring and compliance of water extractions (for example, remote sensing and use of caps and water quality standards.)	• Transparent and real-time water audits (for example, inflows, outflows, recharge, extractions and consumption) • Nature-based water storage (such as wetlands and sustainable managed aquifer recharge) • Procedural and epistemic justice-led management to include unheard voices (for example, traditional, ecological or Indigenous knowledge)
Socio-economic–environment system vulnerabilites (SDG Targets 6.5 and 6.6)	• Building infrastructure to ensure risks 'as low as reasonably practical' • Technical assistance to secure key supply chains (for example, port and food storage facilities) • Improved meteorological forecasting • Greater access to insurance and credit for low-income and/or rural households and businesses	• Climate-resilient infrastructure and climate-smart agriculture • 'Future-proof' urban planning (for example, banning new development on floodplains) • Creating a 'level playing field' for human-built (grey) and natural (green) infrastructure through regulatory reforms	• Implementing 'free, prior and informed' consent for Indigenous and locally affected communities about proposals/actions on Indigenous lands and local commons • Required use of precautionary principle for local to global planning and investments • Climate adaptation with a resilience framing that includes research and funding for local active adaptive management (for example, catchment management).

Fig. 6 | Economic growth, green growth and beyond growth: selected responses to the world's water crises. The responses are nested such that those listed for economic and green growth are possible options for beyond growth. That is, beyond growth options include all 41 responses, but how they would be implemented may be radically different from economic growth and green growth. Responses that directly overlap are noted by colour coding. For example, green highlighted responses in economic growth and beyond growth are a common priority response for green growth.

Volumetric water pricing, when complemented by effectively communicated water prices to households, along with water metering, monitoring and compliance, has been effective in conserving water for domestic water use. Full economic water cost recovery provides incentives for water utilities to maintain and/or improve water services and supply (for example, to reduce non-revenue water). Water pricing, however, must be fit-for-purpose and consider water affordability, especially in locations where the costs of treatment and distribution are high but the ability to pay is low (such as informal urban settlements and remote areas).

Policy mechanisms to help disadvantaged households access water include (1) a free basic water allowance, (2) 'social' or reduced volumetric water prices for low-income households and (3) a water bill rebate. Whatever the selected approach, cost-free or subsidized water, including for other basic needs (such as energy and housing), should not be provided to all and instead should target those most disadvantaged[46]. Pro-poor water access policies involve higher-income water users cross-subsidizing essential water use by the poor and/or transfers from general revenues, along with full transparency and accountability of the economic costs of water supply.

Concerning SDG 6.4, to reduce water overextraction, formal and informal water markets provide a way to allocate and reallocate water across users and uses. For example, formal water markets in the Murray-Darling Basin, Australia, have placed a cap on ground and surface water use. Formal water markets have proved to be valuable for irrigators when responding to droughts in Australia and elsewhere, but they are not suitable where appropriate institutional arrangements are absent[47]. In the Murray-Darling Basin, formal water markets have facilitated purchases of water rights by governments from irrigators to achieve environmental goals. These government purchases have increased stream flows but have been insufficient to meet key environmental targets. To date, these purchases have also failed to resolve past injustices whereby Indigenous Australians have been dispossessed of their land and water and restricted in their cultural practices by European colonization[48].

A key goal of green growth is to facilitate efficient technologies, which links to SDG Target 6.4: "substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity". The challenge is that increased water-use efficiency, measured as US dollars per cubic metre of water,

only accounts for the water benefits that can be monetized. Increases in efficiency may therefore be concomitant with reduced water quality and increased inequality of access. Furthermore, policies to promote greater water-use efficiency in irrigation may penalize downstream water users because of reduced return flows to streams and rivers. Thus, increases in water-use efficiency must account for (1) the overall water consumed via evaporation and transpiration, and changes in return flows from efficiency improvements; and (2) rebound effects, whereby increases in irrigation efficiency can incentivize excessive water consumption[49].

Beyond growth responses

Beyond growth highlights the importance of responding to both market and government failures[29]. Unlike economic growth or green growth, it highlights the importance of procedural justice (for example, who gets listened to, and how?) and epistemic justice (for example, whose and what knowledge gets accepted and acted on?), while highlighting the need for intragenerational, intergenerational and interspecies justice[50]. Justice is critically important when responding to the world's water crises because if decisionmakers ignore or do not prioritize the most disadvantaged in relation to safe water access, and/or those without legal rights to water, then SDG 6 cannot be achieved, including in the wealthiest countries[36].

We highlight the goals and actions for a unique 'Water Beyond Growth Agenda'. The goal is to decouple economic growth from environmental degradation while prioritizing the most disadvantaged. The prioritized actions are (1) overcome policy capture and inertia and (2) foster relationality[51], which includes place-based and ethical decision-making, and justice-principled institutional innovations at different geographies (for example, catchments) (Fig. 6).

Overcoming policy capture and inertia is a beyond growth priority because "corruption in high places frequently produces governments more oriented toward promoting the ends of a few powerful individuals than toward addressing needs for governance."[29] This policy challenge is applicable to all countries, low-, middle- and high-income, especially those with flawed or failing democracies[52] or authoritarian regimes.

Capture of public policy by narrow interests has two important implications: (1) "there is no basis for assuming that actual governments will play effective roles in addressing needs for governance"[29] and (2) government decision-making may result in "important biases in policy responses [that hamper] effective public policy making".[53] In its most extreme form, policy capture includes both petty and grand corruption that is illegal, and legal corruption that is mediated through donations and 'sliding doors' of decisionmakers between the public and private sectors.

Policy capture impedes the achievement of the SDG 6 targets and other goals, as well as the delivery of improved water services and public interest outcomes. Large-scale water projects, because of the investments' size, are at particular risk of grand corruption that benefits few at the cost of the public interest, including when state water resources are stolen[54]. Policy capture can also manifest itself through institutional assumptions and approaches that limit policy actions and can be revealed by bottom-up systems analysis[55]. Constrained policy thinking is problematic because it limits the possible actions at different institutional and geographical scales, narrows the communities of knowledge and practices that are acceptable to decisionmakers, and restrains the methods that could otherwise be applied.

Both policy capture and inertia can be mitigated through civil participation, competent public administration (for example, with accountability and transparency) and a robust legal system[56] that operates in the public interest. Transparency about corruption and/or implementation failures is especially effective if it can increase the accountability and policy responsiveness of decisionmakers. For example, in 2017, an Australian media outlet exposed alleged water theft by a few irrigators in the state of New South Wales and policy capture in relation to such infractions by the state regulator[33]. The political response—an independent inquiry—established a new and independent regulator that has greatly increased the number of water audits for monitoring, compliance and enforcement actions.

Justice-principled reforms in institutional and policy arrangements[57], informed by relationality[51], are essential and should build on past learnings in water governance wherever possible. Beyond growth responses to mitigating the world's water crises seek (1) justice principles—that is, a 'fair equality of opportunity' (for example, intragenerational justice) and a 'just savings principle' (for example, intergenerational and interspecies justice)[58]; and (2) relationality[51]—that is, ethical behaviours, respect and reciprocity to others[48], and place-based decision-making that fully considers the consequences to all (for example, people and non-humans). Relationality in Indigenous conceptualizations of water can include 'living waters'; water is a living relation such that rivers have a life force for which people are custodians with well-defined obligations and a duty of care[59]. Justice principles and relationality are not exclusively anthropocentric and give an alternative framing about how to respond to the world's water crises. Nevertheless, all responses are constrained by history, past policy priorities and investments (for example, dams constrain steam flows), and existing laws[60].

Innovations in institutional arrangements[57] consistent with beyond growth need to (1) include all relevant stakeholders; (2) focus on local (for example, catchment) and regional (for example, basin) governance, planning and operations, as well as national and transboundary considerations; (3) consider 'who gets what water and when'; (4) recognize current and historical property rights arrangements (for example, land and water); and (5) be aware of the barriers to water allocation and reallocation. Institutional changes can be both bottom-up and top-down but must be connected, be accountable to communities of interest and have a degree of flexibility to implement integrated programmes based on proper planning processes. Appropriate governance bodies in support of institutional innovations may be nested spatially and/or institutionally and can benefit from horizontal coordination given the close connections between social, economic and environmental injustices[61]. Deliberative democracy can promote institutional innovation by elevating the concerns of the affected and the disadvantaged and is facilitated by representative membership in key water decision-making bodies[62] and dialogue processes, among other approaches.

Examples of innovations in institutional arrangements and practices consistent with beyond growth occur at multiple institutional and geographical scales. They include (1) some elements of the "Singapore water story" that has delivered safe drinking water and sanitation to its residents and reduced water pollution[63]; (2) participatory processes in smallholder irrigation schemes in Tanzania, Mozambique and Zimbabwe that have empowered communities to better manage their local water resources[64]; (3) results-based contracts that support safe drinking water services in 17 countries[39]; (4) the ambition and scale of Jal Jeevan (Water for Life), the government of India's national programme to serve every rural household with functional household tap connections; (5) Indigenous and non-Indigenous partnerships in the Ambato River Basin, Ecuador, that have reduced downstream water user costs[65]; (6) smartphone applications that regularly report on water services (such as disruptions and water quality) to Costa Rican community water management committees and households[66]; and (7) multiple case studies of effective nature-based practices for flood control[67].

Fostering complementarities between top-down and bottom-up innovations in institutional arrangements can overcome information asymmetries between water users and gaps in funding and capacity—weaknesses that can be more pronounced at local and informal levels of water management. One effective institutional innovation is regional integrated catchment management, where planning and operations are effectively embedded within a top-down and bottom-up set

of institutions. Catchment management has been effective where it has been underpinned with statutory powers, an independent overview commission to set standards and review processes to report on outcomes[68]. Another institutional innovation is to apply the public trust doctrine, whereby natural resources are held in trust and are protected for common use. Specific examples of public trust include common asset trusts, whereby trustees are appointed with a fiduciary duty to ensure intergenerational sustainability of common-pool resources, such as wetlands[69].

A valuable initiative in institutional arrangements is verifiable and accessible water-related information complemented by affordable data access. Digitized information (such as maps of floodplain risks and projected sea-level rise) is non-rival and can support locally informed water management practices[70]. For example, relevant and timely analysed data can assist water managers, individuals and communities in prioritizing the size, location and timing of their actions (for example, planting crops) and investments (for example, constructing levee banks). Frequently missing but valuable data at multiple institutional scales include (1) measures of the diverse values of nature[71]; (2) water-quality measures and experiential scales, such as the Household Water Insecurity and the Individual Water Insecurity Experiences[72]; and (3) real-time and spatial (for example, remote sensing) estimates of water use and consumption that support adaptive water governance[73] and monitoring and compliance.

Timely information at multiple institutional and spatial scales is particularly needed for (1) climate adaptation of hard and green infrastructure; (2) risk assessments in collaboration with those exposed to risks[34]; (3) resilience-management actions about the 'what' (for example, catchment scale), 'for whom' (for example, riparian communities) and 'to what' (for example, floods) responses to shocks[74]; and (4) effective policy, regulations and planning that can be facilitated by, for example, water accounting and auditing, complemented by non-market valuation.

Future directions

The economic growth framing that dominated thinking in the twentieth century recognizes the importance of private and public investments to improve prosperity. Its focus on built water infrastructure has provided multiple benefits but has also resulted in negative environmental consequences. Green growth, the increasingly dominant policy paradigm, highlights the need to internalize the external costs that water polluters and users impose on others, as well as the importance of technical innovation to reduce environmental ills (for example, water pollution).

Economic growth and green growth framings have dominated the responses to the world's water crises and have contributed to steady progress in improving access to safe water and sanitation, especially in urban areas. Nevertheless, the SDG of 'Water for All' will not be delivered by 2030. Many people in rural areas still lack safe access to drinking water and sanitation, and innumerable communities suffer from widespread water pollution, depletion of groundwater or ongoing degradation of water-based ecosystems. Rather than continue with mainstream thinking, we argue for rethinking the responses to the world's water crises, across multiple scales of governance and geographies, to accelerate the delivery of the SDGs.

We contend that a beyond growth framing—systems thinking informed by justice principles and relationality—provides the foundation for necessary, effective, efficient and sustainable responses (Fig. 6) to the water crises of the twenty-first century. Its goal is to decouple both water investments and economic growth from further environmental degradation and to achieve a sustainable water future for all. Beyond growth, not yet mainstreamed, builds on the successes of economic growth (for example, delivering large-scale and public-good water infrastructure) and green growth (for example, fit-for-purpose water pricing, repurposing of subsidies and implementing 'polluter pays' charges). But beyond growth goes well beyond these mainstream framings to prioritize two key actions: (1) overcoming policy capture and inertia and (2) fostering relationality and justice-principled innovations in policy interventions and institutional governance.

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R.Q.G. is senior author. The nine co-lead authors are listed alphabetically after the first author. All other co-authors are listed alphabetically after the co-lead authors. R.Q.G., S.F., L.R. and S.A.W. conceived and designed the Perspective. R.Q.G. co-ordinated the writing process. S.F. and R.Q.G. designed Figs. 1, 2, 4 and 5. R.Q.G., P.C., N.-M.N. and S.F. designed Fig. 3. R.Q.G., S.F., P.R.W. and S.A.W. designed Fig. 6. R.Q.G., S.F., J.H., P.K., N.-M.N., C.R., L.R., J.T.-J., S.A.W., P.R.W., F.A., A.K.B., E.B., R.B., P.C., R.C., R.H., T.K., I.K., A.M., R. Martins, R. McDonnell, W.N., R.R., N.S., B.R.S., J.S., D.T., C.T., Y.W. and J.W. wrote and edited the text.

Competing interests

The authors declare no competing interests.

Additional information

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