Rethinking Responses to the World's Water Crises

Abstract

The world faces multiple water challenges; pollution, water-related ecosystems degradation, overextraction, flooding and inequitable access. Insufficient funding, ineffective implementation and, in part, a misdiagnosis of the causes have contributed to inadequate progress and prioritized some responses (e.g. water infrastructure) over others (e.g. water reallocation). We rethink the possible responses to the world's water crises with a Beyond Growth framing and compare it to mainstream thinking. Beyond Growth, systems thinking informed by justice principles and relationality, prioritizes the most disadvantaged and seeks to decouple economic growth from environmental degradation by overcoming policy capture and inertia and fostering justice-principled institutional changes.

By

R. Quentin Grafton
Safa Fanaian
James Horne
Pamela Katic
Nhat-Mai Nguyen
Claudia Ringler
Libby Robin
Julia Talbot-Jones
Sarah Ann Wheeler
Paul Robert Wyrwoll
Fabiola Avarado
Asit K. Biswas
Edoardo Borgomeo
Roy Brouwer
Peter Coombes
Robert Costanza
Robert Hope
Tom Kompas
Ida Kubiszewski
Ana Manero
Rita Martins
Rachael McDonnell
William Nikolakis
Russell Rollason
Nadeem Samnakay
Bridget R Scanlon
Jesper Svensson
Djiby Thiam
Cecilia Tortajada
Yahua Wang
John Williams

The nine co-lead authors are listed alphabetically after the first author. All other co-authors are listed alphabetically after the co-lead authors.

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Humanity is not delivering improvements in basic water services fast enough while failing to halt further increases in global water withdrawals and water-ecosystems degradation This is despite increasing water infrastructure investments, rising levels of water-use efficiency, and multiple policies to mitigate market failures. What is needed is a rethinking of the responses to the water crises of the 21st Century. We argue for a Beyond Growth framing, systems thinking informed by justice principles and relationality, to complement current effective responses, and to overcome policy capture and inertia and foster justice-principled institutional innovations to deliver a sustainable water future for all.

Water: Too Much, Little, Dirty and Stressed

The proportion of people with access to safe drinking water globally has approximately doubled over the past 50 years, but the rate of progress is insufficient to deliver Sustainable Development Goal (SDG) 6 by 2030: 'Ensure availability and sustainable management of water and sanitation for all'. Over 50% or more of people in Sub-Saharan Africa, South Asia, South-eastern Asia and Latin America and the Caribbean are predicted to not have access to safely managed drinking water services [1].

SDG 6 is unattainable unless deficiencies in water governance, including policy capture and inertia and a lack of long-term planning [2], are corrected to decouple economic growth from water withdrawals [3]. This requires: i) governments and donors to invest more in monitoring and regulating all water supply systems, especially in rural and remote areas, that are fit for purpose, people, and place [4]; ii) urgent action to prevent the degradation of rivers, aquifers and other water sources from unsustainable withdrawals and pollution; iii) water is allocated toward just and sustainable water access for the disadvantaged; iv) integrated bottom-up and top-down local and place-based management; v) water planning that accounts for the adverse impacts on supply and quality from climate change including preparing for increased frequency and intensity of floods and more frequent and longer duration droughts; and vi) policies that prioritize delivery of the targets and indicators of SDG 6.

Due to population and economic growth, global water withdrawals have increased about five-fold over the past 50 years (see Fig. 1). Water stress, defined as the ratio of total water withdrawals to available renewable freshwater supplies, is magnified at a catchment scale by poor water quality [5]. Water stress currently exceeds 80% in large parts of India, China, Middle East and North Africa, Southern Europe, Western United States, South-east Australia, and South Africa [6]. One outcome of water stress, and dams, weirs and reservoirs that disconnect river systems with 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].

[FIG 1 HERE]

With agriculture using around 70% of the world's freshwater withdrawals, demands for food, energy and water security must be carefully balanced. This is because, in key water-stressed regions, extractions for irrigation are unsustainable [8] and some business-as-usual practices are increasing both the frequency of low stream flows and ground water depletion [9]. Compounding these challenges is climate change that will exacerbate regional patterns of over-extraction [10] and increase 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].

Three Framings of the World's Water Crises

Responses to the world's water crises are influenced by worldviews or framings – a set of beliefs and values about the world that influence thoughts and actions. We consider three growth framings (Economic Growth, Green Growth and Beyond Growth) and their implied responses to four key water crises and their associated SDG 6 Targets. These crises are: i) unsafe and/or unaffordable access to safe drinking water (SDG Target 6.1) and sanitation (SDG Target 6.2); ii) water pollution (SDG Target 6.3) and environmental degradation, including of water-related ecosystems (SDG Target 6.6); iii) water overextraction from both surface and groundwater (SDG Target 6.4), and for which improvements in water use efficiency is claimed to be a key response (SDG Indicator 6.4.1); and iv) inadequate protection for water-related ecosystems (SDG 6.6) from unmitigated social-economic-ecological system vulnerabilities, including floods and droughts (SDG Target 6.6 and SDG Indicator 6.6.1).

We review these water crises based on three growth framings: i) Economic Growth that considers growth in the economy as central to economic development; ii) Green Growth that includes both economic growth and conservation of key environmental assets as necessary for economic development [12]; and iii) Beyond Growth, not yet mainstreamed, that responds to increasing global environmental degradation [13] by prioritizing sustainability and more equitable outcomes achieved through institutional and policy reform.

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

[FIG. 2 HERE]

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 socio-economic development and, until at least the 1990s, was widely held to be the only pathway towards progress and prosperity. This is despite observations by John Kenneth Galbraith in the 1950s that 'affluent societies' have unresolved social-economic-environmental problems, including wealth inequality, inadequate public services, and excessive environmental costs [14]. In the 21st century, a growing number of economists accept that the level (and growth) of GDP is a flawed measure of welfare and progress [15].

Economic Growth framing is about increasing prosperity by raising GDP per capita. It is underpinned by 'growth theory' [16] that includes three stylized facts: i) low-income economies 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; ii) sustained economic growth, in the long-run, requires technological progress which is increased by investments in research and development; and iii) 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 very large improvements in global health (e.g. reduced child mortality and morbidity), they have not yet adequately met the needs for improved water supply and sanitation, especially in rural areas. Further, the growth dilemma is that historical patterns of economic growth have contributed to large negative environmental impacts [17], including increased carbon dioxide emissions globally and the degradation of water-related ecosystems at local and regional scales.

Green Growth Framing

Green Growth is challenging Economic Growth as the dominant policy framing in international fora, especially in high-income countries. It seeks sustainable development, meeting the needs of the present without compromising the needs of the future. The Organization for Economic Cooperation and Development (OECD) defines it 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: pricing environmental costs and benefits not 'internalized' in market transactions (e.g. water pollution discharges); repurposing and/or eliminating subsidies (e.g. fertilizer, energy, infrastructure) that increase water withdrawals, especially in agriculture; removing barriers to sustainability-enhancing investments (e.g. water pricing that fails to cover costs of supply)[3 18]; and promoting innovation and 'green' technologies (e.g. improved water-use efficiency) to increase economic 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 been an overall global decrease in the overall consumption of materials [19], global greenhouse gas emissions, or the total amount of water withdrawals.

Countries that have reduced their environmental footprint have, in part, achieved this by imports such as through 'virtual water'[20] in the form of food and clothing. Given the critical need to rapidly reduce key environmental impacts (e.g. global GHG emissions) to avoid potentially catastrophic climate risks [21], there is skepticism that Green Growth, as currently practiced and in the timeframe available, can deliver increased human well-being [22]. Nevertheless, a 'Green New Deal' that incorporates much of the thinking around Green Growth has become an important policy platform in some countries (e.g. United States). The key focus of Green New Deal is on public sector spending and policy reform to increase green employment, stimulate green technologies and promote low-carbon manufacturing [23].

Beyond Growth Framing

Beyond Growth framing was first presented by Daly [24] but has antecedents in earlier work, such as the primacy of 'society' over the economy, and global projections of the limits and consequences of unrestrained economic growth. Here, Beyond Growth emphasizes: i) the inter-connections between the biosphere and anthroposphere, biophysical limits, and that economies exist within complex social-ecological systems and ii) actions that are inclusive in terms of who gets listened to, what knowledge gets recognized, what challenges get considered and what solutions get selected (see Fig. 3). That is, Beyond Growth takes a 'systems thinking' view of the causes and consequences of the world water crises and is inclusive and justice-principled in its responses.

[FIG. 3 HERE]

Key policy goals of Beyond Growth include: rapid decoupling of economic growth from critical environmental impacts (e.g. climate change, biodiversity loss, groundwater depletion), including the global material footprint [19] and reduced inter-generational inequalities associated with environmental degradation and economic growth [25]. Key outcomes in support of these goals, proposed at multiple scales (local, national, regional, and global), include: i) reducing environmental

degradation (e.g. improving water quality, reduced depletion of aquifers); ii) rising human well-being (e.g. higher quality and longevity of life); iii) declining poverty rates (e.g. increasing access to safe drinking water and sanitation); iv) increasing system resilience (e.g. recovery that supports a more sustainable state of the world following negative shocks from droughts and floods) [26]; and v) growing participatory and deliberative democracy [27] (e.g. compulsory voting, proportional representation voting, nested neighborhood-to-regional-to-national citizen assembles, and tools for canvassing opinions or locating consensus) [28].

Fig. 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 human population with access to safe drinking water.

[FIG. 4 HERE]

Responses to the World's Water Crises

Responses to the world's water crises by decision-makers depend, in part, on their understanding of causes and consequences as well as their goals. While there are common goals between all three framings (e.g. reduced intra-generational inequality) the core goals are different and, thus, so are the associated responses (see Fig. 5). All three framings acknowledge that policies, institutions, and investments should respond to market and government failures but differ over what is prioritized among market and government failures.

In the water sector, the two principal *market failures* include: i) externalities or side-effects in both the production and consumption of water resources [29] such that the costs imposed on others, for example, from groundwater depletion or water pollution, are not fully accounted for by those causing the harm; and ii) collective action failures that result in inadequate provision of public goods (e.g. flood protection) because the benefits are non-exclusive such that while everyone benefits from its provision, some choose to 'free ride' and not pay.

[FIG. 5 HERE]

Government failures in the water sector include: i) inadequate institutional, financial or technical government capacities to support effective water planning and collective action (e.g. the provision and monitoring of drinking water services); ii) regulatory capture whereby private actors redirect government expenditures (e.g. size and location of water infrastructure) for their personal gain [30]; iii) misaligned regulations and incentives [31] that cause unintended consequences (e.g. energy subsidies to farmers that incentivize additional groundwater pumping); iv) 'Crowding Out' of self-organized collective actions (e.g. sustainable, locally managed aquifers) by externally-imposed rules [32]; and v) failures of omission, including monitoring and enforcing of government regulations and standards in relation to water, as well as a lack of accessible information and data (e.g. flood and drought risks, sea-level rise, drinking water quality).

Economic Growth has prioritized the efficient allocation of goods and services through markets and capital accumulation with infrastructure-led development as pathways to prosperity. In this framing, the water crises are primarily overcome by targeted public and private investments in water infrastructure and other incentives that support the provision of water-related goods and services.

Green Growth prioritizes the internalization of market failures that create environmental costs. Nevertheless, it recognizes the need to respond to government failures with organizational reforms (e.g. operational independence of regulatory agencies; stable funding to environmental agencies; intersectoral coordination and multilevel governance; repurposing 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 so-called 'nature-based-solutions'. The related policy agenda of the Green New Deal highlights public investment and incentives for private investment to create green jobs and investments.

Beyond Growth responds to both market and government failures by prioritizing mitigation of water-related risks [33] and effective partnerships to achieve good quality water access for the poorest [34]. Like Green Growth, it recognizes the importance of economic incentives and regulations to (re)allocate water and the need for appropriate water pricing and a redesign and/or elimination of subsidies to avoid incentivizing greater water withdrawals. Such subsidies could benefit existing rural beneficiaries by repurposing funding towards research and development and extension services for farmers, such as promoting climate-smart agriculture (e.g. better production, better nutrition, better environment and a better life for all). Repurposed subsidies can also help overcome the much higher rural supply costs per person [35], 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 does not get listened to by key decision-makers, and what knowledge and data has been excluded in decision-making. That is, Beyond Growth highlights the need for innovations in policy interventions and institutional arrangements [36] that 'opens up' the process of 'who gets what water and when' in terms of who participates, what problems and solutions are considered, and how do actions gets implemented justly (see Fig. 3).

Table 1 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 be radically different from Economic Growth and Green Growth. For example, inter-catchment water transfers to increase water availability elsewhere could only be considered a desirable response for Beyond Growth after full and proper engagement with all stakeholders, and full consideration of: i) system risks; ii) all economic costs and benefits (e.g. social-economic-ecological); iii) compensation to mitigate distributional and inter-temporal impacts; and iv) implementation of regulations and standards. Nine responses are exclusive to Beyond Growth and three responses are common to Beyond Growth and Green Growth: i) transparent and real-time water audits; ii) Nature-based storages; and iii) legal protections for households and ecosystems.

Economic Growth Responses

Increasing the stock of built or gray infrastructure (e.g. dams, piped infrastructure, 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 (e.g. flooding). A 'build and grow' approach (see Table 1) has been highly successful in providing improved water quality in urban areas in most regions of the world and has supported water growth opportunities (e.g. irrigation, energy-intensive outputs). Investments in water storage infrastructure have also provided multiple benefits, including improved water availability and public goods (e.g. flood control). Nevertheless, due to poor planning and execution, large-scale built water storages have created

unintended consequences (e.g. reduced stream flows, displacement of people, interruptions of fish migrations).

To achieve SDG Targets 6.1 and 6.2, built infrastructure must 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 [37]. In rural and remote locations, safer water access is facilitated by: i) off-grid investments that are fit for purpose, people and place [4]; ii) water users who pay for operations and maintenance complemented by full transparency about costs with full accountability of water suppliers and service providers (e.g. results-based contracts) [38]; and iii) investments in green infrastructure and nature-based solutions (e.g. watershed forest conservation, riverbank repairs) [39].

With an Economic Growth framing, the delivery of SDG Targets 6.3 and 6.6 related to water pollution and water-related ecosystems is promoted by investments and regulations that complement public demands for a better-quality environment. This prioritization is reinforced by the so-called Environmental Kuznets Curve (EKC) that 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 EKC relationships, however, suffer from misspecification and misinterpretation and have not yet been observed at a global scale for water withdrawals or for key pollutants (e.g. world GHG emissions). Where rising GDP per capita is associated with reduced environmental degradation (e.g. water pollution) at a local level, this has occurred because of effective water planning and active government interventions, not by economic growth alone.

[TABLE 1 HERE]

Green Growth Responses

Under Green Growth, the need to respond actively to market failures, especially in relation to environmental degradation, has encouraged a series of market-based approaches to achieve SDG 6's water pollution and ecosystem health targets (see Table 1). These include: i) charges imposed on point sources of water pollution intended to reduce or eliminate discharges; ii) a small number of 'cap-and-trade' systems that constrain overall level of water discharges but allow point sources, and in some cases nonpoint sources, to trade their permitted allowances[40]; and iii) the use of payments for watershed services that have, in some cases, proved effective at improving watershed cooperation, watershed integrity [41] and water quality [42].

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' and remote sensing, along with open-access data. As with 'command-and-control' approaches that directly regulate source point 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 benefits of better drinking water supply and wastewater treatment [35] and environmental improvements [43].

Volumetric water pricing, when complemented by effectively communicated water prices to households along with water metering, monitoring, and compliance, assist incentivizing water conservation for domestic water use. Full economic water cost recovery provides incentives for water utilities to maintain and/or improve water services and supply (e.g. 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 (e.g. informal urban settlements, remote areas).

Policy mechanisms to assist disadvantaged households to access water include: i) a free basic water volumetric allowance; ii) 'social' or reduced volumetric water prices for low-income households; and iii) a water bill rebate. Whatever the selected approach, cost-free or subsidized water, including for other basic needs (e.g. energy, and housing), should target those most in need [44]. This involves either higher-volume 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, formal and informal water markets provide another way to allocate and reallocate water across users and uses. For example, formal water markets in the Murray-Darling Basin (MDB), Australia, have placed a 'cap' on ground and surface water use. Formal water markets have proven to be valuable for irrigators when responding to droughts in Australia, and elsewhere, but are not suitable where appropriate institutional arrangements are absent [45] or if there is inadequate built infrastructure (e.g. water storage). In the MDB, formal water markets have facilitated the purchases of water rights by governments from irrigators. These government purchases have increased stream flows but have been insufficient and, to date, have failed to resolve past injustices whereby Indigenous Australians have been dispossessed of their land and water by European colonisation [46].

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 by the United Nations as USD per cubic meter of water, only accounts for the market value-added of water. Consequently, because of how 'water-use efficiency' is measured, increases in efficiency may be concomitant with reduced water quality and increased inequality of access. Policies to promote the adoption of higher technical efficiency (ratio of the volume of water withdrawn or applied to the volume of water beneficially consumed) may also penalize downstream water users because of reduced return flows to streams and rivers. Thus, policy-induced increases in water-use efficiency must account for: i) the overall water consumed via evaporation and transpiration and changes in return flows from efficiency improvements and ii) 'rebound effects' whereby increases in irrigation efficiency incentivize further water use [47].

Beyond Growth Responses

Beyond Growth highlights the importance of responding to both market and government failures [29], especially in terms of procedural justice (e.g. who gets listened to, and how?) and epistemic justice (e.g. whose and what knowledge gets accepted and acted on?) while highlighting the need for intra-generational, inter-generational and inter-species justice [48]. Justice is critically important when responding to the world's water crises because if decision-makers 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 [49].

We highlight two important actions for a 'Water Beyond Growth Agenda' in support of the decoupling of economic growth from environmental degradation and prioritization of the most disadvantaged: i) overcoming policy capture and inertia and ii) fostering justice-principled institutional innovations at different spatial scales geographical (e.g. catchments) (see Table 1).

Overcoming policy capture and inertia is a Beyond Growth priority because of: "…unwieldy bureaucracies…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 challenge is applicable for all countries, low, middle and high-income, especially those with flawed or failing democracies [50] or authoritarian regimes.

Capture of public policy by narrow interests has two important implications: i) "…there is no basis for assuming that actual governments will play effective roles in addressing needs for governance." [29]; and ii) government decision-making may result in "… important biases in policy responses [that hamper] effective public policy making." [51]. 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 decision-makers between the public and private sectors.

Policy capture results impedes achievement of SDG 6 Targets, and other goals, and the delivery of improved water services and public interest outcomes. Large-scale water projects, because of the size of the investments, are at particular risk of grand corruption that benefits few at the cost of the public interest, including when there is theft of state water resources [52]. Policy capture can also manifest itself through institutional assumptions and approaches that limit policy actions. Such constraints on 'thinking' limit the methods that could otherwise be used but which can be revealed by bottom-up systems analysis and other approaches [53]. In turn, this restrains the set of policy actions at different institutional and geographical scales while narrowing the communities of knowledge and practices that are acceptable to decision-makers.

Policy inertia and capture can both be mitigated through civil participation, competent public administration (e.g. accountability and transparency), and a robust legal system [54] that operates in the public interest. Transparency about corruption and/or implementation failures are especially important if they increase the accountability and policy responsiveness of decision-makers. For example, in 2017, an Australian media outlet exposed alleged water theft by a few irrigators in the state of New South Wales, and a 'blind eye' to these infractions by the state regulator [55]. The political response - an independent inquiry - established a new and independent regulator, a much greater use of water audits for monitoring and compliance, and enforcement actions.

Justice-principled reforms in institutional and policy arrangements [56] are essential and, wherever possible, should build on past learnings in water governance. As responses to the world's water crises, Beyond Growth innovations in institutional arrangements seek: i) justice principles, that is, a 'fair equality of opportunity' (e.g. intra-generational justice) and a 'just savings principle' (e.g. inter-generational and interspecies justice) [57]; and ii) relationality [58], that is, ethical behaviors, respect, and reciprocity to others [46] and place-based decision-making that fully considers the consequences to all (e.g. people and non-humans). Relationality in Indigenous conceptualizations of water 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 (e.g. dams constrain steam flows), and existing laws [60].

Innovations in institutional arrangements [56] consistent with Beyond Growth need: i) the inclusion of all relevant stakeholders, ii) be focussed on local (e.g. catchment) and regional (e.g. basin) governance, planning and operations, iii) consider 'who gets what water and when', iv) recognize current and historical property rights arrangements (e.g. land and water), and v) be aware of the barriers to water allocation and reallocation. Innovations in institutional arrangements can be both

'bottom-up' and 'top-down', but must be connected, accountable to communities of interest, and have a degree of flexibility to implement integrated programmes based on proper planning processes. These governance bodies may be nested spatially and/or institutionally, and benefit from horizontal coordination given the close connections between social, economic, and environmental injustices [61].

Innovations in institutional arrangements may be nested spatially and/or institutionally, and benefit from horizontal coordination given the close connections between social, economic, and environmental injustices [61].Deliberative democracy promotes institutional innovation by elevating the concerns of the affected and marginalized and is facilitated by representative membership in citizen deliberation on key water decisions [62] and deliberative polling, among other approaches.

Examples of innovations in institutional arrangements and practices consistent with Beyond Growth occur at multiple institutional and geographical scales and include: i) some elements of the 'Singapore water story' that have delivered safe drinking water and sanitation to its residents and reduced water pollution[63]; ii) participatory processes in smallholder irrigation schemes in Tanzania, Mozambique, and Zimbabwe that have empowered communities to better manage their local water resources [64]; iii) results-based contracts that support safe drinking water services in 17 countries [38]; iv) improved information through regular monitoring of water quality in India through the Safe Water Network [65]; v) the Jal Jeevan (Water for Life) Mission goal (not yet delivered) to serve every Indian rural household with piped water while supporting decentralized and community-managed water services; vi) Indigenous and non-Indigenous partnerships in the Ambato River Basin, Ecuador, that have reduced downstream water user costs [66]; vii) smartphone applications that regularly report on water services (e.g. disruptions, water quality) to Costa Rican community water management committees and households [67]; and viii) multiple case-studies of effective nature-based practices for flood control [68].

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 [69]. 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 inter-generational sustainability of common-pool resources, such as wetlands [70].

A valuable initiative in institutional arrangements is the centralized provision of water-related information complemented by affordable data access. Digitized information (e.g. maps of flood plain risks and projected sea-level rise) is non-rival and can support locally informed water management practices [71]. For example, relevant and timely analyzed data can assist water managers, individuals, and communities to prioritize the size, location, and timing of their actions (e.g. planting of crops) and investments (e.g. construction of levee banks). Frequently missing but valuable data at multiple institutional scales include: i) measures of the diverse values of nature [72]; ii) water-quality measures and experiential scales, such as the Household Water Insecurity (HWISE) and the individual Water Insecurity Experiences (IWISE) [73]; and iii) real-time and spatial (e.g. remote sensing) estimates of water use and consumption that support adaptive water governance [74].

Timely information, at multiple institutional and spatial scales, is needed for: i) climate adaptation of gray and green water infrastructure; ii) risk assessments, in collaboration with those exposed to risks [33]; iii) resilience-management actions about the 'what' (e.g. catchment scale), 'for whom' (e.g. riparian communities), and 'to what' (e.g. floods) responses to shocks[75]; and iv) effective policy, regulations and planning that, in turn, can be facilitated, for example, by water accounting and auditing, complemented by non-market valuation.

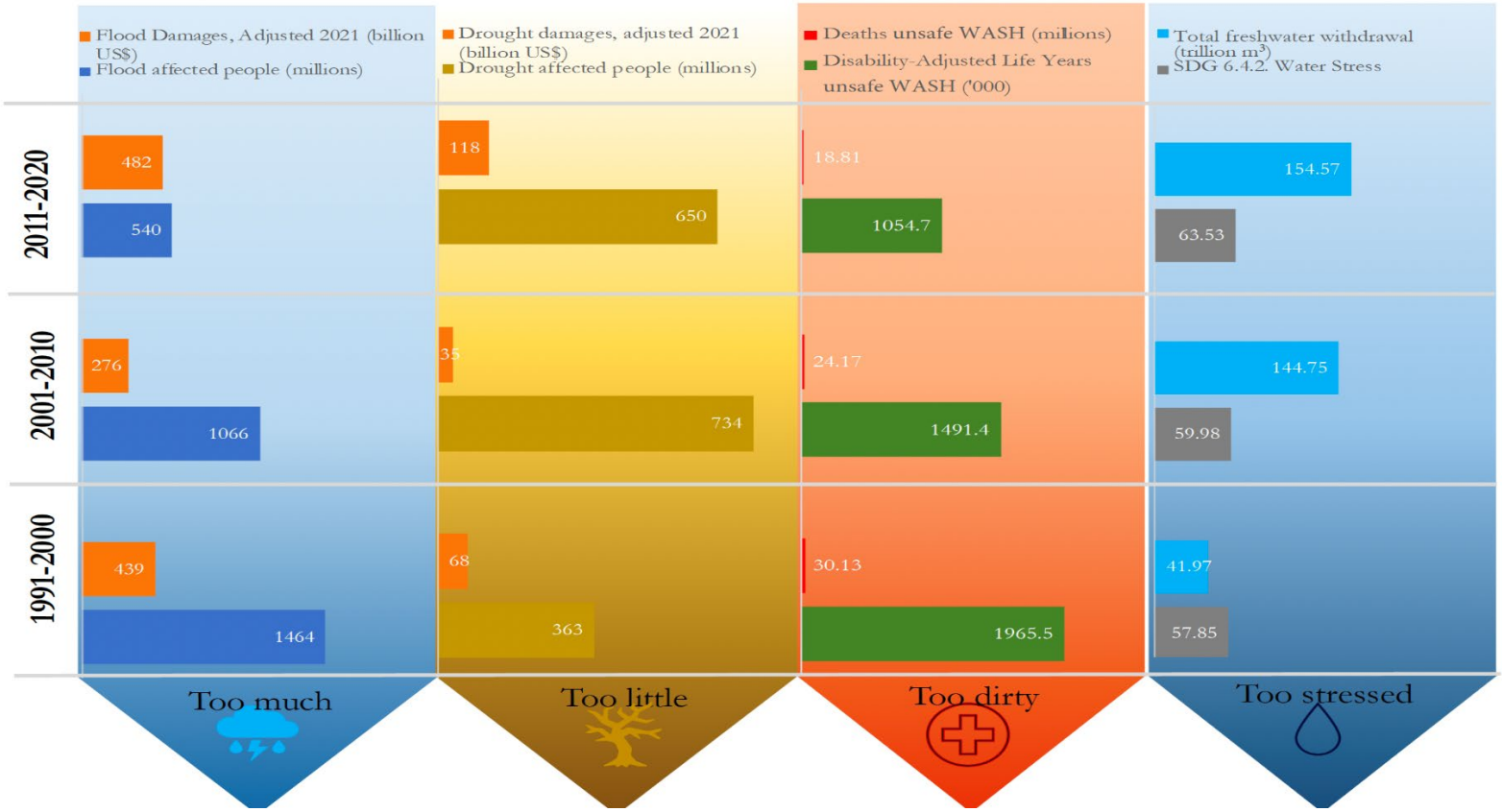
Conclusions

The Economic Growth framing that dominated thinking in the 20th century recognizes the importance of private and public investments to improve prosperity. Its focus on built (gray) water infrastructure has provided multiple benefits but has also resulted in unintended 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, and the importance of technical innovation to reduce environmental 'bads' (e.g. water pollution).

Despite Economic Growth and Green Growth framings dominating the responses to the world's water crises since the 1950s, and steady progress in improving access to safe water and sanitation, the Sustainable Development Goal 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, in most countries, there is widespread water pollution, depletion of groundwater, and ongoing degradation of water-based ecosystems. Rather than continue with mainstream thinking, we argue for a rethinking about the responses, across multiple scales of governance and geographies, to the world's water crises to accelerate 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 (see Table 1) to the water crises of the 21st 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 (e.g. delivery of large-scale and 'public good' water infrastructure) and Green Growth (e.g. fit-for-purpose water pricing, repurposing of subsidies, implementing 'polluter pays' charges). But it goes well beyond these two mainstream framings to prioritize two key actions; overcome policy capture and inertia and foster justice-principled innovations in policy interventions and institutional governance.

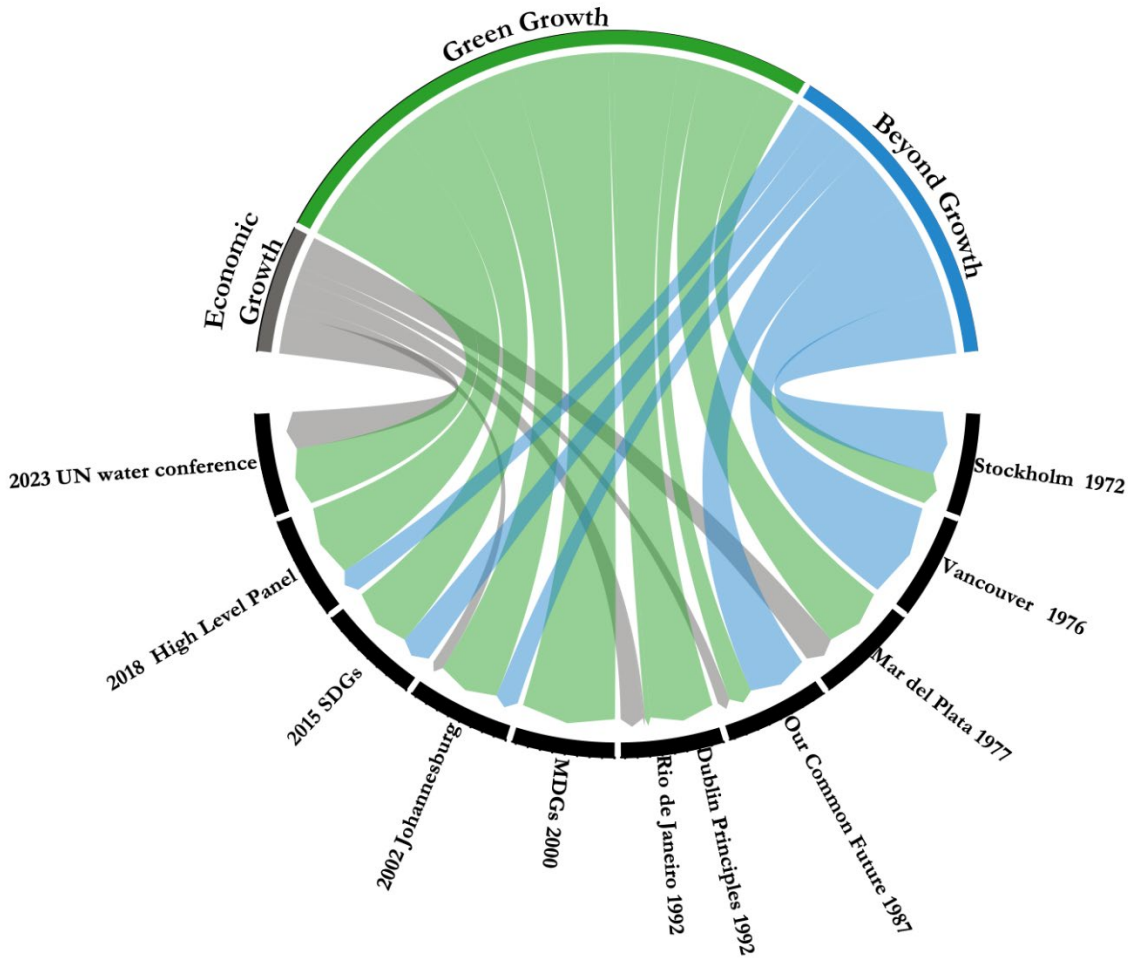
Fig. 1: Too Much, Too Little, Too Dirty and Too Stressed, decadal measures from 1991 to 2020



Source: The authors.

Notes: Too much, too little too, dirty, too stressed. Data time-period is from 1991-2020. Floods (economic losses and affected people) droughts (economic losses and affected people) Source: EM-DAT: The OFDA/CRED International Disaster Database. Too dirty is depicted via deaths and disability due to unsafe water sanitation and hygiene, source. Global Burden of Disease Collaborative Network. Global Burden of Disease Study 2021 (GBD 2021). Too stressed via total water withdrawals (trillion m3) and SDG 64.2 water stress, source: AQUASTAT - FAO's Global Information System on Water and Agriculture (https://data.apps.fao.org/aquastat/).

Fig. 2: Sankey Diagram of Keywords in UN Reports and Documents from 1972 to 2023 Related to Economic Growth, Green Growth and Beyond Growth

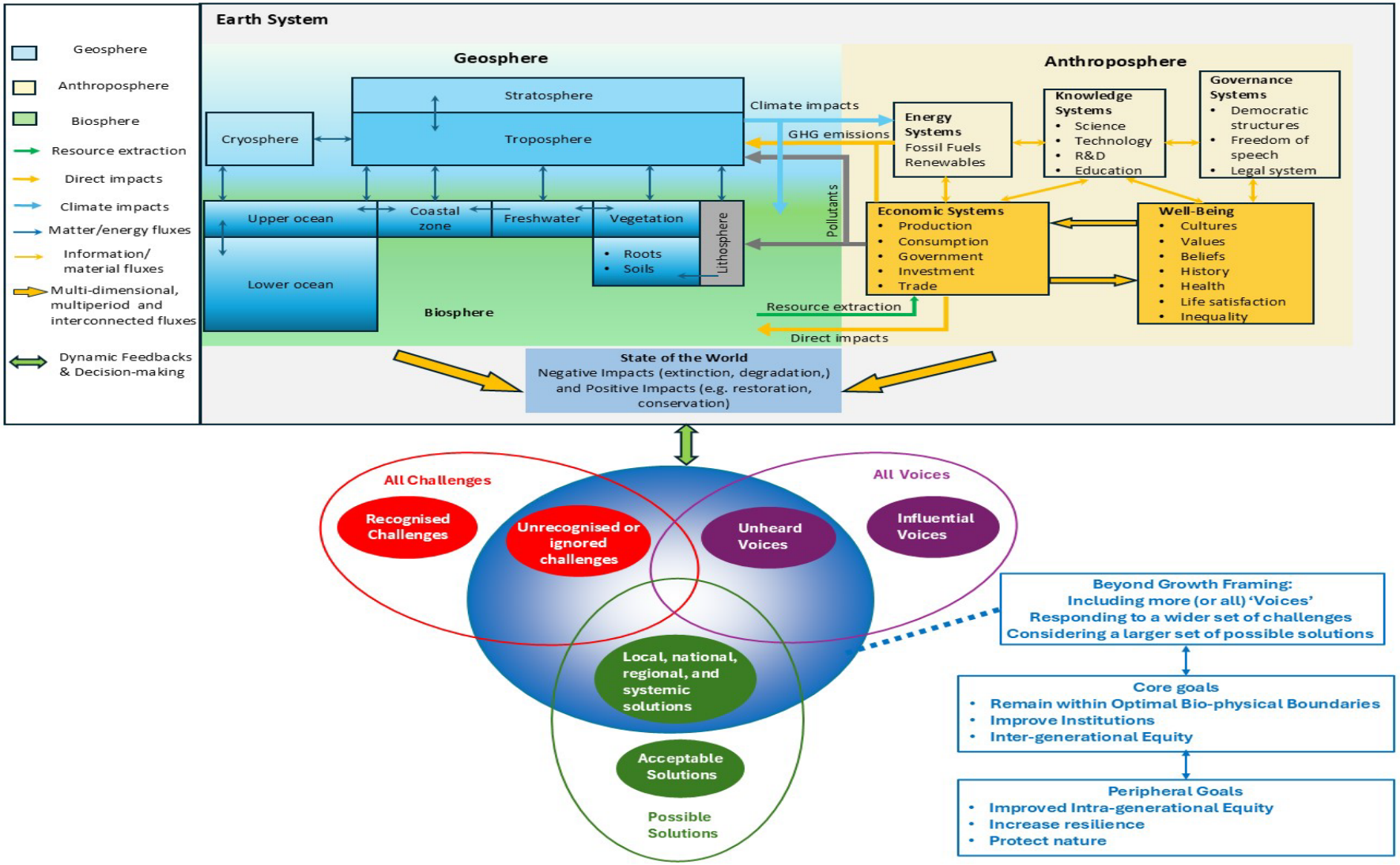


Source: The authors.

Notes:

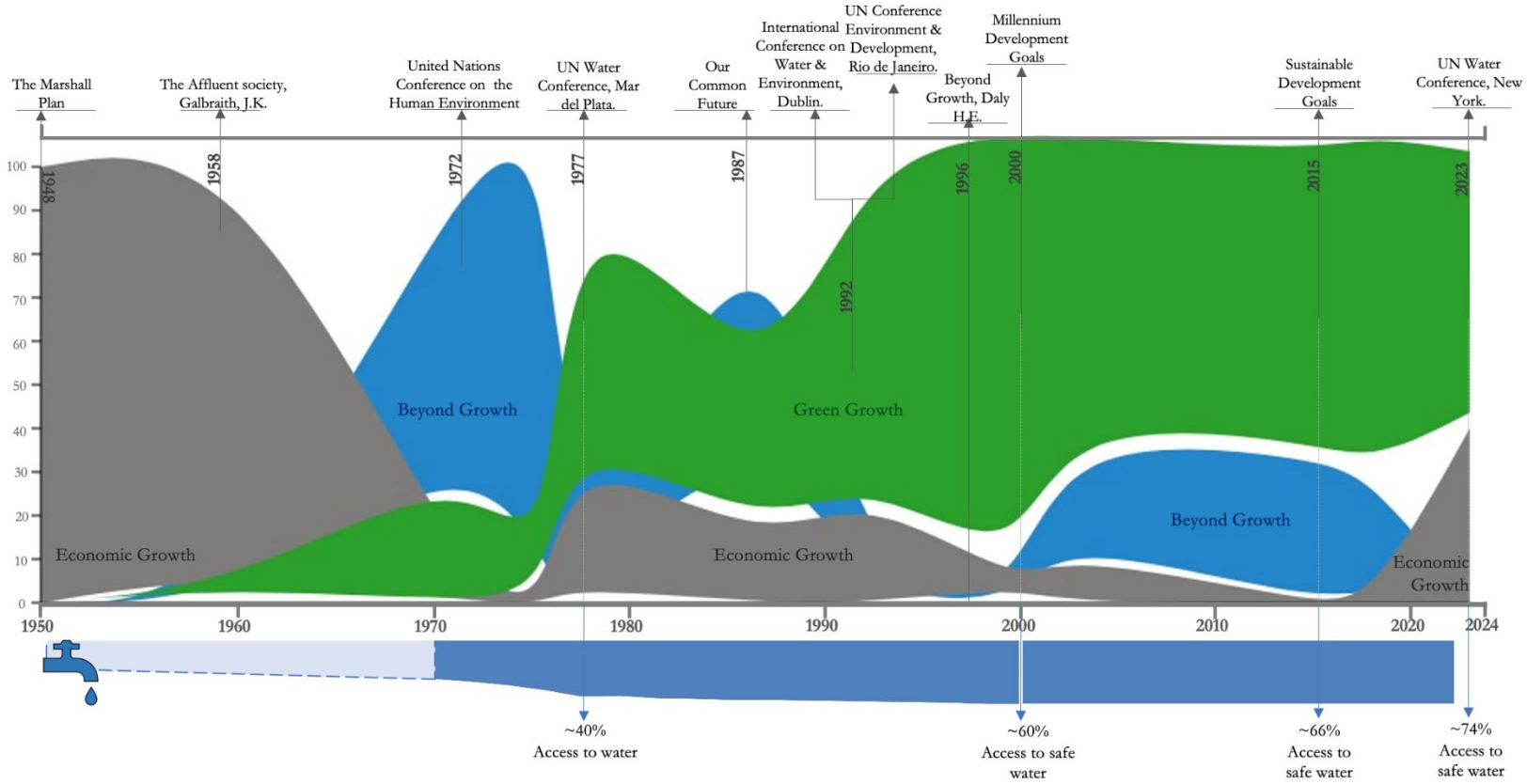
1. The UN conferences-based documents were scanned for concepts linked to: i) value; ii) pricing (price and pricing); iii) markets; and iv) justice (includes just). References to value and markets in the context of the subject meaning were coded manually (e.g. simple references such as just money, or market sales of crops, were not considered if not linked to water/environment). All references to the four concepts were coded in the respective documents in the qualitative coding software MAXQDA.
2. The size of the arrows represents the percentage of the four keywords within each document (further details are in the Supplementary Information S2).
3. Further details about the construction of Fig. 1 and its data sources are available in the Supplementary Information S2.

Fig. 3: Earth System, State of the World and a Beyond Growth Framing



Source: Adapted from Bretherton, FP Earth System Science and Remote Sensing. Proceedings of the IEEE. 1985; 73(6):1118-1127 and the authors.

Fig. 4: Key Reports and Documents, Timeline of Economic Growth, Green Growth and Beyond Growth, and Global Access to Safe Water

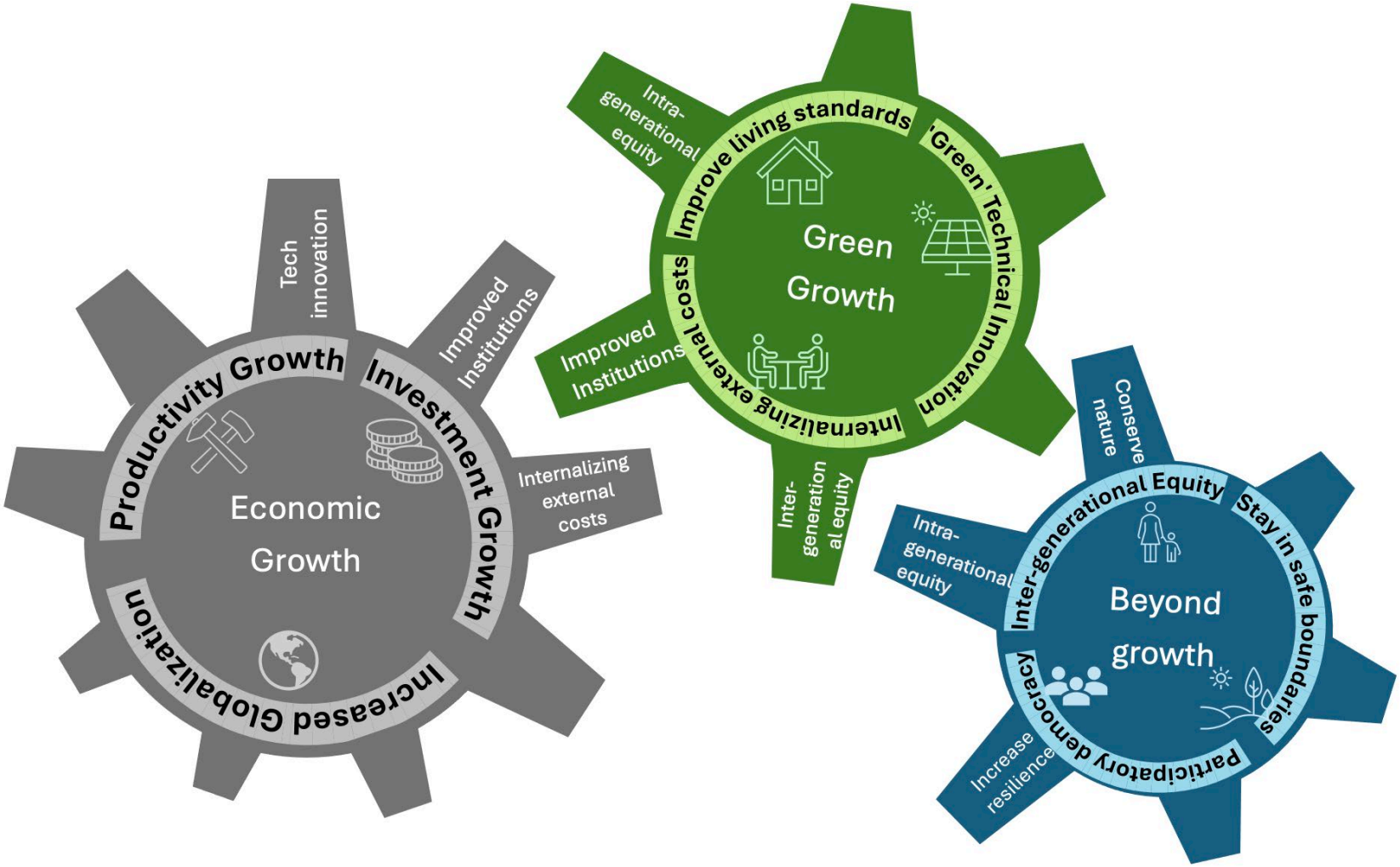


Source: The authors.

Notes:

1. The Upper-Level provides a selected list of reports and documents in relation to the three growth framings.
2. The Middle-Level is a visualization of the relative importance of the three growth framings over time.
3. The Lower-level is the percentage of the global population with 'safe' drinking water. For 1977, data on drinking water access are only available 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'.
4. Further details about the construction of Fig. 2 and its data sources are available in the Supplementary Information S3.

Fig. 5: Core and Peripheral Goals of Economic Growth, Green Growth and Beyond Growth



Source: The authors.

515 **Table 1: Economic Growth, Green Growth and Beyond Growth Responses to the World's Water Crises**

Growth Framings	Inadequate Access to Safe Drinking Water and Sanitation (SDG Targets 6.1 and 6.2)	Poor Water Quality and Degraded Riparian Systems (SDG Targets 6.3 and 6.6)	Surface water Overextraction and Groundwater Depletion (SDG Target 6.4)	Socio-Economic-Environment System Vulnerabilities (SDG Targets 6.5 and 6.6)
Economic Growth	• Privatization & public-private partnerships to improve service delivery • Increase public investments (e.g. low-interest loans and fiscal transfers) in water infrastructure (e.g. dams, sewage treatment) • Incentives for centralized water infrastructure	• Services-led economic growth to reduce environmental impact per $ GDP • Relocation of people to reduce pollution impacts (e.g. urban planning, licensing of point sources of pollution) • Allocation of property rights and creation of formal markets to extract or pollute water	• Unitization of groundwater resources • Supply augmentation with inter-catchment and/or inter-temporal (e.g. dams) water transfers • Agricultural extensification to reduce reliance on existing land & water	• Build infrastructure to ensure risks 'As Low as Reasonably Practical' (ALARP) • Technical assistance to secure key supply chains (e.g. port and food storage facilities) • Improved meteorological forecasting • Greater access to insurance & credit for low-income and/or rural households & businesses
Green Growth	• Reforms to reduce non-revenue water and increase cost recovery of water services • Innovate & scale up supply technologies (e.g. desalination, reverse osmosis, solar-powered air moisture extraction) • Green & transition finance to increase funding base for investments in improved source water quality & supply (e.g. payments for environmental services) • Independent regulatory oversight of Public Investments & Water Service Outcomes	• Price externalities of water use (e.g. pollution charges) • Multi-purpose use of existing water infrastructure (e.g. hydropower dam reoperation and irrigation channels to deliver environmental water) • Triple-bottom line accounting • Non-market valuation studies to assess market & non-market trade-offs	• Price water (e.g. water abstraction charges, volumetric water pricing, water markets) • Scale up 'efficient' water technologies (e.g. drip irrigation, water recycling) • Remove or repurpose perverse subsidies (e.g. capital & operating costs of water pumps) • Improve monitoring and compliance of water extractions (e.g. remote sensing, use of caps and water quality standards.)	• Climate-resilient infrastructure & climate-smart agriculture ' • Future-Proof' urban planning (e.g. banning new development on floodplains) • Create a 'level playing field' for human-built (gray) and natural (green) infrastructure through regulatory reforms
Beyond Growth	• Legislated and enforceable rights for households to have minimum service levels (e.g. reliability, quality, affordability of drinking water) and legal protection key ecosystem (e.g. wetlands & 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	• Relationality (e.g. 'Rights of Nature', public trust doctrine & common asset trusts) • Deliberative democracy (e.g. 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	• Transparent & real-time water audits (e.g. inflows, outflows, recharge, extractions & consumption) • Nature-based water storages (e.g. wetlands, sustainable managed aquifer recharge) • Procedural and epistemic justice led management to include unheard voices (e.g. traditional, ecological or Indigenous Knowledge)	• `Implement '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 & investments • Climate adaptation with a resilience framing that includes research & funding for local active adaptive management (e.g. catchment management).

516

517 Notes:

518 1. 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
519 all 40 responses, but how they would be implemented may be radically different to Economic Growth and Green Growth.
520 2. Responses that directly overlap are noted by color coding such that green highlighted responses in Economic Growth and Beyond Growth are also a shared priority
521 response for Green Growth.
522

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