Rethinking Responses to the World's Water Crises

Abstract

The world will not achieve Sustainable Development Goal 6 by 2030: 'Water for All'. In most places, responses are inadequate to mitigate water pollution, riparian degradation, groundwater overextraction and water vulnerabilities. Many responses, influenced by Economic Growth and Green Growth framings, have failed to adequately diagnose causes and remedies of the world's water crises. We rethink the drivers and consequences of the water crises and propose a Beyond Growth framing that seeks to: Deliver to the most disadvantaged, prioritize the absolute decoupling of economic growth from environmental degradation, foster justice-principled innovations in institutional arrangements, and overcome policy capture and inertia.

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World's Water Crises

The proportion of people with access to safe drinking water globally has approximately doubled over the past 40 years (see Supplementary Information) but the current 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' (United Nations 2023). SDG 6 is unattainable unless: (i) drinking water monitoring becomes holistic risk- and process-based to ensure access to safe water (Charles et al. 2020); (ii) governments and utilities invest much more in decentralized urban water supply systems, especially in rural and remote areas, that are fit for purpose, people and place; iii) urgent action is taken to prevent the degradation of rivers, aquifers and other water sources from unsustainable withdrawals and pollution (Vörösmarty et al. 2010); (iv) water is reallocated to ensure more just and sustainable water access for the disadvantaged; and (v) water planning effectively accounts for the adverse impacts on water supply and quality from climate change.

The crisis in household access to water for drinking, sanitation, and hygiene (WASH) is as much about water governance (United Nations 2006, pp. 43-85) as it is about physical water scarcity and quality. Gaps in WASH are compounded by deteriorating riparian environments and increasing water pollution in many regions (Damania et al. 2019). Since 1970, the global area of wetlands has declined by about a third (Fluet-Chouinard et al. 2023). Water stress, defined as the ratio of total water withdrawals to available renewable fresh water supplies, exceeds 80% in large parts of India, China, Middle East and North Africa, Southern Europe, Western United States, South-east Australia, and South Africa (World Resources Institute 2023). While water stress and scarcity are mitigated by effective water planning, investments, and water reallocation, if measures of water *quality* are included, the number of sub-basins suffering from quantity and quality-induced water scarcity doubles (Wang et al. 2024).

Global water extractions have quadrupled over the past 50 years and are increasing such that even in the absence of climate change there would still be water crises (see Supplementary Information). Nevertheless, regional patterns of over-extraction will worsen with climate change (Zhang et al., 2023) and under moderate Greenhouse Gas (GHG) emissions projections, about one third of the world's population should experience either wetter or drier conditions by 2100 (Trancoso et al. 2024). The frequency of unprecedented regional droughts is also projected to increase substantially in South America, South-western North America, Mediterranean Europe, and North Africa (Satoh et al. 2022).

Agriculture accounts for 70% of the world's water extractions and in some water-stressed regions extractions for irrigation are unsustainable (Scanlon et al. 2023). Business as usual will increase the frequency of low stream flows and exacerbate ground water depletion (Jasechko et al. 2024) while climate change is projected to increase irrigation water extractions in key water-stressed regions (Bhattarai et al. 2023).

Past, Current and Emerging Framings of the World's Water Crises

Effective responses to the world's water crises are influenced by worldviews or framings - the ways that decision-makers and societies perceive, act, and communicate about the world. We consider three framings and their implied responses to four key water crises and their associated SDG 6 Targets. These water crises include: (1) water pollution (SDG Target 6.3) and environmental degradation, including deteriorating wetlands (SDG Target 6.6); (2) water overextraction from both rivers and aquifers (SDG Target 6.4); (3) unsafe and/or unaffordable access to safe drinking water

(SDG Target 6.1) and sanitation (SDG Target 6.2) for all; and (4) unmitigated social-economic-ecological system vulnerabilities to shocks, such as to floods and droughts (SDG Target 6.6).

We review these four water crises based on three growth framings: i) Economic Growth that dominated 20th-century thinking; ii) Green Growth, arguably the dominant policy paradigm of the 21st century (OECD 2011); and iii) Beyond Growth, an emerging but not yet mainstreamed framing that has developed as a response to increasing global environmental degradation (Widuto et al. 2023).

The three growth framings are visualized in Fig. 1 (as 'keywords' and 'key publications', see Supplementary Information) through textual analyses of United Nations publications and conference proceedings, informed by an historical and environment perspective (Warde et al. 2018). Fig. 1 is illustrative only of the relative importance of the three growth framings because there are lags between the principles espoused in UN publications and agreements and their implementation at national (Araral and Ratra 2016) and sub-national (Pandit and Biswas 2019) levels.

[FIG. 1 HERE]

Economic Growth Framing

Economic growth is a measure of the change in the total market value of goods and services, the Gross Domestic Product (GDP), produced in an economy over time. Economic growth was the predominant prescription for socio-economic development and, until at least the 1990s, was widely held to be the pathway towards progress and prosperity.

Economic Growth is underpinned by 'growth theory' (Solow 1969) that includes four key findings: i) low-income economies can converge to the levels of per capita income in high-income countries by increasing their produced capital (e.g. machines that make goods) per worker through private and public investments; ii) sustained economic growth, in the long-run, requires technological progress; iii) higher-income countries, typically, have much higher per capita levels of produced and human capital (Lucas Jr. 1990); and iv) technological progress can be increased by investments in research and development (Romer 1990).

While higher levels of GDP since 1950 have contributed to very large improvements in global health (e.g. reduced mortality), historical patterns of economic growth have also caused large and negative environmental consequences (Steffen et al. 2007) and contributed to increased income inequality (Milanovic 2005). As early as the 1950s, John Kenneth Galbraith observed that even for an 'affluent society' there were unresolved socio-economic-environmental problems coincident with economic growth including wealth inequality, inadequate public services, and environmental costs (Galbraith 1958). In the 21st century, economic orthodoxy accepts that the level (and growth) in GDP is a flawed welfare measure (Stiglitz et al. 2009).

Green Growth Framing

In the 21st century, and partly in response to climate change, Green Growth has challenged Economic Growth as the dominant policy framing, especially in high-income countries (e.g. European Union). Green Growth encompasses the policy goal of sustainable development, meeting the needs of the present without compromising the needs of the future (World Commission on Environment and Development 1987). The Organization for Economic Cooperation and Development (OECD) 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" (OECD 2011, p. 9). Actions in support of Green Growth include: i) pricing environmental costs and

benefits not 'internalized' in market transactions; ii) removing barriers to investments; and iii) promoting innovation and 'green' technologies that increase economic productivity and reduce environmental degradation.

Importantly, Green Growth seeks to retain per capita GDP growth as a key policy goal to stimulate efficient technologies and to improve living standards. The important difference between Green Growth and Economic Growth is that, over time with Green Growth, economies should be decoupling from resource depletion and environmental impacts. Some middle to high-income countries have had declining resource use per dollar of GDP, and a few countries have had absolute declines in some material throughputs but there has not yet been a global absolute decline in the total material footprint, global GHG emissions or total water extractions (Wiedmann et al. 2015). Given the critical need to rapidly reduce some key environmental impacts (e.g. global GHG emissions) to avoid potentially catastrophic climate risks (Tollefson 2023), there is increasing skepticism that Green Growth, as currently practiced, can deliver a sustainable future (Hickel and Kallis 2020).

Beyond Growth Framing

Beyond Growth responds to complex social-environmental systems and systems dynamics (Forrester 2001) by recognizing that economies are embedded within societies and the biosphere. That is, economies are constrained by absolute bio-physical limits (O'Neill 2020). Beyond Growth framing was first popularized by Daly (1996), but its antecedents include early global projections of the consequences of unrestrained economic growth (Meadows et al. 1972).

Beyond Growth is not negative economic growth (Widuto et al. 2023). Rather, its key policy goals are: i) rapid and absolute decoupling of economic growth from critical environmental impacts (e.g. climate change, biodiversity loss, groundwater depletion) and the global material footprint (Wiedmann et al. 2015) and ii) reduced inequalities associated with environmental degradation and economic growth (Rammelt et al. 2022).

Beyond Growth actions, at multiple scales (local, national, regional, and global), seek: i) absolute reductions in environmental degradation (e.g. rapidly declining GHG emissions rather than declining emissions intensity); ii) rising well-being (e.g. higher quality and longevity of life); iii) falling absolute inequality (e.g. declining poverty rates); iv) system resilience (e.g. a 'bounce back better' to negative shocks) (OECD 2019, p. 7); and v) active democracy (e.g. citizens assemblies) (Costanza 2024).

Fig. 2 provides a timeline of the relative importance of the three growth framings as manifest 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 for the period 1950-2023. The lower level shows the percentage of the world human population with access to safe drinking water (see Supplementary Information for further details).

[FIG. 2 HERE]

Responses to the World's Water Crises

The preferred responses to the world's water crises depend on an understanding of the causes and consequences of market failures and government failures. For the world's water crises, the two principal market failures include: i) technological externalities in both production and consumption for common-pool resources such that the costs of actions imposed on others (e.g. depletion of groundwater in a common aquifer and riparian water pollution) are not fully accounted for by those

causing the harm; and ii) inadequate provision of public goods (e.g. flood protection) because the benefits are non-rival such that while everyone benefits from its provision, some choose to 'free ride' and not pay for the costs.

Government failures in the water sector include: i) provision of water services by governments that may have been provided at lower cost by the private sector and/or public-private partnerships (e.g. water supply infrastructure); ii) inadequate technical and/or financial government capacities to support effective water planning and collective action (e.g. the provision and monitoring of drinking water services); iii) regulatory capture whereby private actors redirect government expenditures (e.g. size and location of water infrastructure) for their personal gain; iv) misaligned incentives that result in unintended consequences (e.g. water pricing that discourages water conservation or that provides proportionately greater benefits to the well-off than the poor); v) 'Crowding Out' of self-organized collective actions (e.g. sustainable, locally managed aquifers) by externally-imposed rules (Ostrom 2000); and vi) 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 risks, sea-level rise).

Economic Growth has prioritized the efficient allocation of market goods and services with 'free' markets and capital accumulation with infrastructure-led development. In this framing, infrastructure gaps and the water crises are overcome by on-going and targeted public and private investments.

Green Growth prioritizes market failures that create environmental costs. It also recognizes both organizational and infrastructure gaps that can be mitigated by improved management of water-related financial risks and the mobilization of finance (e.g. direct expenditures by governments and alternative financing) for 'bankable' investments. In Green Growth, finance for innovation seeks changes to the composition of economic growth by 'internalizing' negative environmental impacts and by providing economic incentives for 'green' technologies.

Beyond Growth prioritizes risk mitigation (Hall and Borgomeo 2013), and a reduction in income and wealth inequalities, by responding to both market and government failures and to the insufficient attention paid to water risks by both Economic Growth and Green Growth. Both Beyond Growth and Green Growth recognize the importance of economic incentives and regulations to allocate and reallocate water (United Nations 2006) and to deliver both food and water security (Grafton et al. 2017). Beyond Growth differs to Economic Growth and Green Growth in that it is explicit about who has power and influence, and 'voice'. It highlights the need for innovations in institutional arrangements (e.g. how water is managed and used), and that may contribute to changes in the institutional environment (Saleth and Dinar 2004, p. 25), to: i) improve environmental quality; and ii) deliver intra-generational, inter-generational and inter-species justice (Gupta et al. 2023).

Table 1. summarizes 40 key responses across the three growth framings in relation to the world's water crises. The responses are 'nested' in that the responses listed for Economic Growth and Green Growth are on the 'menu' of options in Beyond Growth. That is, Beyond Growth options include all 40 responses, but how they would be implemented may be radically different to Economic Growth and Green Growth. For example, inter-catchment water transfers as a response to groundwater depletion in Economic Growth could only be considered a desirable response for Beyond Growth after full and proper engagement with all stakeholders and with full consideration of: i) system risks; ii) all economic costs and benefits (e.g. social-economic-ecological); and iii) compensation to mitigate distributional and inter-temporal impacts. Some Beyond Growth responses are compatible with Green Growth and include: i) allocation and reallocation of water as a response to degraded riparian

systems; ii) science-practitioner-community partnerships; and iii) independent regulatory oversight. A summary of the key responses under each framing is provided in Table 1.

Economic Growth Responses

Built or grey 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. A 'build and grow' approach has been successful in providing improved water quality in urban areas in most regions of the world. Investments in water storage infrastructure have also provided multiple benefits, including improved water availability and public goods (e.g. flood control). Nevertheless, large-scale built water storages have created unintended consequences (e.g. reduced stream flows, displacement of people).

To achieve SDG Targets 6.1 and 6.2, built infrastructure must be complemented by other approaches, 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 (UNESCO and UNESCO i-WSSM 2019, p. 29). In rural and remote locations, off-grid investments and 'fit for purpose, people and place' (Hall et al. 2022) communal solutions need to be prioritized, along with green infrastructure and nature-based solutions (e.g. forest conservation, riverbank repairs) (United Nations 2018).

Delivery of SDG Targets 6.3 and 6.6 must also go beyond the presumption that investments and economic growth are sufficient to deliver improved environmental outcomes such that increases in per capita GDP eventually result in a peak in environmental degradation and then a decline, a so-called Environmental Kuznets Curve (EKC). Empirical tests of EKC relationships have suffered from misspecification and misinterpretation (Stern et al. 2006) and have not yet been observed at a global scale for key pollutants (e.g. GHG emissions). Importantly, where rising GDP per capita is associated with reduced environmental degradation (e.g. river water pollution) at a local level, this has occurred because of effective water planning and active government interventions. For example, US Clean Water Grants since 1972 have provided USD 650 billion for US municipal wastewater treatment plants that have contributed to reduced riparian water pollution concentrations (Keiser and Shapiro 2019).

[Put Table 1 here]

Green Growth Responses

An increasing recognition of the need to actively respond to market failures, especially in relation to environmental degradation, has encouraged a series of market-based approaches to achieve SDG 6. Market-based approaches include: i) charges imposed on point sources of water pollution intended to reduce discharges (e.g. China and Colombia); ii) a very limited number of 'cap-and-trade' systems that constrain overall level of water discharges but allow point sources to trade their permitted allowances; and iii) the use of payments for watershed services that have, in some cases, proved effective at improving water quality (Olmstead and Zheng 2021).

Market-based approaches require effective monitoring, compliance, and enforcement and are not a 'set and forget' response to polluted waterways. Thus, cost-effective spatial-scale measurements of water use, consumption, and water quality via remote sensing along with open access data and the use of social media are complementary actions. As with 'command-and-control' approaches that directly regulate point discharges, practices and technologies, there is also a critical need to assess the benefits of improved environmental water quality when making trade-offs. This can be facilitated

by non-market valuation of the benefits of improved water quality (Manero et al. 2024) and riparian environments (United Nations 2021).

Volumetric water pricing, when complemented by water price communication to households (Martins and Sá 2020) and effective water metering, monitoring, and compliance, incentivizes water conservation. 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 must 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). Mechanisms to assist the disadvantaged to access water include: i) a subsidised connection fee or a 'lifeline' rate; ii) a free basic water volumetric allowance; and iii) a water bill rebate. Whatever the selected subsidization approach, free or subsidized water should target those most in need (Andrés et al. 2019). This involves either higher-income water users paying more for their water to cross-subsidize the poor and/or transfers from general revenues to ensure the economic costs of water supply are fully covered.

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 proven to be valuable for irrigators when responding to droughts in Australia, and elsewhere (Wheeler 2021) but are not suitable where appropriate institutional arrangements are absent (Wheeler 2021) or if there is inadequate built infrastructure (e.g. water storages). In the MDB, formal water markets have facilitated the purchases of water rights by governments from irrigators. These government purchases of water rights have increased stream flows (Grafton et al. 2022) but have, to date, failed to resolve past injustices whereby those dispossessed of their land and water (e.g. Indigenous Australians) were not allocated water rights (O'Donnell et al. 2023).

A key goal with Green Growth is to facilitate efficient technologies through 'green finance', 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 add of water such that 'efficiency' increases can be contemporaneous with greater water stress and/or reduced water quality.

Policies (e.g. preferential allocation of water rights to higher efficiency irrigators) to promote increases in water productivity and adoption of higher technical efficiency can also exacerbate inequalities. Importantly, policy-induced increases in water-use efficiency must account for: i) the overall water consumed via evaporation and transpiration and return flows to riparian systems and aquifers (Evans and Sadler 2008) noting that farm-level water 'savings' from increases in irrigation efficiency are much less or non-existent at a catchment or basin scale (Grafton et al. 2018) and ii) 'rebound effects' whereby increases in irrigation efficiency incentivize further water use (Wheeler et al. 2020).

Beyond Growth Responses

Beyond Growth highlights the importance of responding to government failures, especially in terms of procedural justice (e.g. who gets listened to and how?) (Ruano-Chamorro et al. 2022) and epistemic justice (e.g. what knowledge gets accepted and acted on?) (Byskov 2020). This is of critical importance when responding to the world's water crises because if decision-makers ignore or do not prioritize (Matthews et al. 2023) the voices of the most disadvantaged with respect to safe water

access, and/or those without legal rights to water (O'Donnell et al. 2023), then SDG 6 will not be achieved, including in the wealthiest countries (Manero et al. 2024).

Overcoming Policy Capture and Inertia

'Active Democracy', where citizens effectively engage in positive change for their communities, is lacking in many countries, including in some representative democracies. In the USA, for example, federal lobbyists have overwhelming influence on lawmakers (Gilens and Page 2014). Consequently, decision-makers favour narrow and influential interests rather than diffuse interests such that their decisions may be contrary to national economic welfare (Hasen 2012). This is policy capture that causes: "… important biases in policy responses and hampers effective public policy making." (OECD 2021, p. 25).

In its most extreme form, policy capture involves petty and grand corruption that is illegal and/or legal corruption mediated through donations and 'sliding doors' of decision-makers between the public and private sectors. According to Transparency International's Corruption Perceptions Index (a higher score is preferred), the global average index of corruption has remained unchanged for more than a decade at less than 50 out of 100. Two-thirds of countries score below 50 while 155 out of 180 countries have made minimal progress against corruption, or corruption has become worse since 2012 (Transparency International 2023). This matters because of the negative association between increased corruption and delivery of SDG 6 (Gomez et al. 2019).

The water sector, especially in relation to large-scale water projects, is at risk of corrupt decision-making that benefits the few at the cost of the public good. Despite long-standing evidence of corrupt practices in the water sector, there is frequently a 'hear no evil, see no evil, speak no evil' response by decision-makers (Huppert 2013), including when there is theft of state water resources (Loch et al. 2020).

Effective responses to policy capture that advantages the privileged few at the expense of the many are central to Beyond Growth. Four ways to mitigate policy capture, in general, include: i) 'level the playing field' to ensure fair and equitable access to decision-makers; ii) transparency about and access to data and information; iii) accountability through the use of disclosure rules and independent audits of decision-making; and iv) clear guidelines and rules for decision-makers complemented by timely and effective monitoring, compliance and enforcement (OECD 2017, p. 54).

Fostering Innovations in Institutional Arrangements

From a Beyond Growth perspective, innovations in institutional arrangements are about promoting a sustainable social-economic-environmental trajectory at multiple geographical and institutional scales. As responses to the world's water crises, Beyond Growth innovations in institutional arrangements seek: i) 'fair equality of opportunity' (e.g. intra-generational justice) and 'just savings principle' (e.g. inter-generational and interspecies justice) (Rawls 1999 [1971]) and ii) 'good' or ethical relationships (Matthews et al. 2023) whereby all decision-makers fully consider the consequences of their actions on the environment and people. Together, justice principles and good relationships guide ways to overcome longstanding, unequal and unsustainable water allocations.

Innovations in institutional arrangements consistent with Beyond Growth need the inclusion of all relevant stakeholders, consideration of 'who gets, what water and when', a recognition of current and historical property rights arrangements (e.g. land and water), and an awareness of the barriers to water allocation and reallocation (Hellegers and Leflaive 2015). Innovations in institutional arrangements can be both 'bottom up' and 'top down', may be nested spatially and/or institutionally

and are supported by horizontal coordination given the close connections between social, economic, and environmental injustices (Brown et al. 2023). Active democracy promotes innovations in institutional arrangements by elevating the voice of the marginalized that, in turn, can be facilitated by randomly selected membership in citizen deliberation on key water decisions (Lázaro et al. 2021) and deliberative polling, among other approaches.

Innovations in institutional arrangements, consistent with Beyond Growth, are responding to a wide range of local water crises. Such innovations are, typically, informal and are especially valuable when central authorities lack authority or the capacity to act (Al Naber and Molle 2017). Examples of Beyond Growth innovations in institutional arrangements include: i) community-led sanitation approaches to reduce open defecation, proven effective in about 60 countries (Zuin et al. 2019); ii) safer drinking water for poor households in Brazil through rainwater harvesting and the effective inclusion of women in decision-making (de Moraes and Rocha 2013); iii) improved information through regular monitoring of water quality in India through the Safe Water Network (Sewak et al. 2023); iv) Indigenous and non-Indigenous partnerships in the Ambato River Basin, Ecuador that have reduced downstream water user costs (Kauffman and Martin 2014); v) devolution of powers to US tribal governments about water quality standards which has supported the inclusion of Indigenous cultural and spiritual values into decision-making (Diver et al. 2019); vi) managed aquifer recharge, i.e. the deliberate recharging of aquifers for later use (Seidl et al. 2024), that has slowed and sometimes reversed groundwater declines (Jasechko et al. 2024); vii) smartphone applications that regularly report on water services (e.g. disruptions, water quality) to Costa Rican community water management committees and households (Del Carpio et al. 2021); and viii) multiple case-studies of effective nature-based practices for river flood control (World Bank 2017) and urban flooding (Soz et al. 2016).

Fostering complementarities between top-down and bottom-up innovations in institutional arrangements can overcome information asymmetries between water users, technical capacity gaps, inadequate funding, and insufficient transparency and accountability (Tomaney 2016), weaknesses that can be more pronounced at local and informal levels of water management. An example of top-down innovation in institutional arrangements consistent with Beyond Growth is to apply the public trust doctrine whereby natural resources are held in trust and protected for common use. Specific examples of Public Trust include Common Asset Trusts (Costanza et al. 2021) such that trustees are appointed with a fiduciary duty to ensure inter-generational sustainability for common-pool resources (e.g. wetlands).

Another example of top-down innovation 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. For example, relevant and timely 'hydroinformatics' (Biswas and Tortajada 2023) assists 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 information that should be easily accessible at multiple institutional scales include: i) measures of the diverse values of nature (IPBES 2022); ii) community water-quality measures (e.g. *Escherichia coli*, salinity); and iii) real-time, spatial, and low-cost (e.g. remote sensing) estimates of water use and consumption (Allen et al. 2007).

Water data and information are also important when evaluating trade-offs, especially in the water-energy-food-environment nexus where risks are connected to the availability and quality of freshwater (Grafton et al. 2017). Timely information, at multiple institutional and spatial scales, is needed for: i) climate adaptation (Anisimov and Magnan 2023), not just mitigation; ii) risk

assessments, in collaboration with those exposed to risks (Hall and Borgomeo 2013); iii) resilience-management actions about the 'what' (e.g. catchment scale), 'for whom' (e.g. riparian communities), 'to what' (e.g. floods) responses to water shocks (e.g. heat extremes, droughts) (Grafton et al. 2019); and iv) effective policy, regulations and planning (Tortajada et al. 2017) that, in turn, can be facilitated by water accounting and auditing.

Transparency about corruption and/or implementation failures increases accountability of decision-makers and policy responsiveness when the public can affect a policy response (Kolstad and Wiig 2008). For example, on July 24th, 2017, the Australian Broadcasting Corporation (ABC) television program exposed alleged water theft by a few irrigators in the Northern MDB and highlighted the 'blind eye' approach taken by the responsible New South Wales (NSW) state regulator to monitor water extractions. Public outrage about the allegations led the Premier of NSW to announce an independent inquiry within two days of the ABC broadcast. The independent investigator found that: "…water-related compliance and enforcement arrangements in NSW have been ineffectual and require significant and urgent improvement" (Matthews 2017), and recommended changes in governance. His recommendations were rapidly implemented such that in 2022-23 in NSW there were 595 comprehensive water audits and 210 enforcement actions (Natural Resources Assess Regulator 2023, p. 11).

Conclusions

The world water crises need more effective and multi-faceted responses across multiple scales of governance and geographies. This is because, despite steady progress in delivering improved WASH to urban households, most people in rural areas in low-income countries still lack safe access to drinking water and sanitation. Further, in most countries there is widespread water pollution and on-going degradation of both rivers and wetlands while in some key food-growing areas of the world there is continued depletion by irrigators of the groundwater.

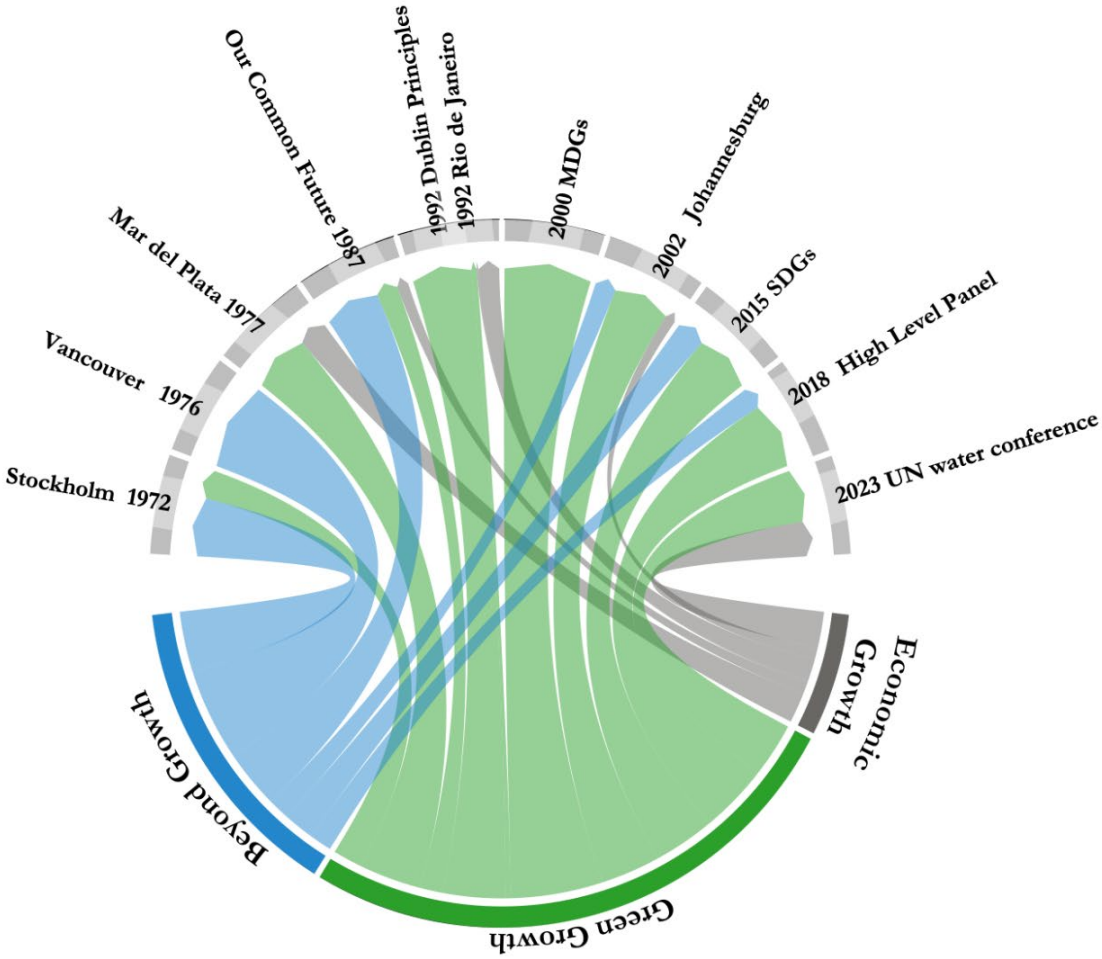
Economic Growth that dominated thinking in the 20th century recognized the importance of private and public investments to improve prosperity. Its focus on built (grey) water infrastructure provided multiple benefits but also resulted in unintended environmental consequences and contributed to rising inequality.

Green Growth, arguably the dominant policy paradigm of the 21st century, has highlighted the importance of mobilizing finance for investments in infrastructure and technical innovation. It emphasizes the internalization of the external costs that water polluters and users impose on others. Green Growth, however, is neither sufficient to deliver 'Water for All' by 2030 nor adequate to respond to water-energy-food-environment risks.

Beyond Growth is an emerging framing, not yet mainstreamed, that seeks to deliver to the most disadvantaged in relation to safe water and sanitation while decoupling water investments and economic growth from further environmental degradation. It builds on the effective responses of Economic Growth (e.g. delivery of large-scale and 'public good' water infrastructure) and Green Growth (e.g. fit-for-purpose and place water pricing and 'polluter pays' charges).

Beyond Growth is critically needed to fully respond to the world's water crises. It fosters bottom up and top-down innovations in institutional arrangements to promote water justice (e.g. intra-generational, inter-generational and inter-species) and good relationships between people and their shared environment. At its core, Beyond Growth seeks to overcome policy capture and inertia that are getting in the way of delivering the Sustainable Development Goals and a sustainable water future for all.

Fig. 1: Sankey Diagram of Key Words in UN Reports and Documents from 1972 to 2023 Related to Economic Growth, Green Growth and Beyond Growth

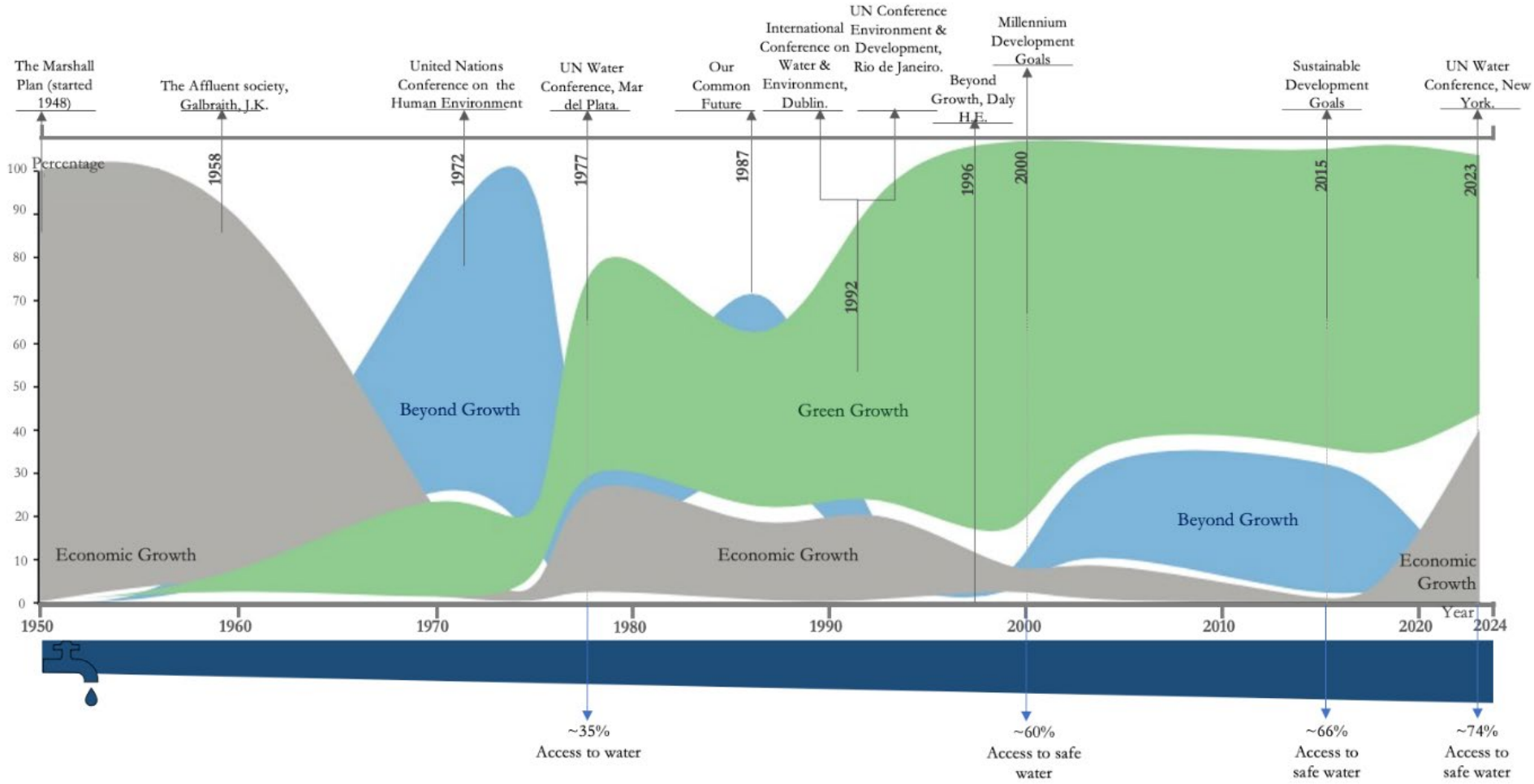


Source: The authors.

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. Further details about the construction of Fig. 1 and its data sources are available in the Supplementary Information.

Fig 2: Key Reports and Documents, Timeline of Economic Growth, Green Growth and Beyond Growth, and Global Access to Safe Water 1950-2024



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 from 1950 to 2023. See Supplementary Information for details.
3. The lower level gives the percentage of the global population with safe drinking water. In 1977, data on drinking water access is 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.

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

Growth Framings	Poor Water Quality and Degraded Riparian Systems (SDG Targets 6.3 and 6.6)	Ground Water Depletion (SDG Target 6.4)	Inadequate Access to Safe Drinking Water and Sanitation (SDG Targets 6.1 and 6.2)	Socio-Economic-Environment System Vulnerabilities (SDG Target 6.6)
Economic Growth	• 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	• 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 Urbanization	• 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 • Improved Access to Insurance & Credit for Low-income and/or Rural Households & Businesses
Green Growth	• Price Externalities of Water Use (e.g., pollution charges') • Non-Market Valuation Studies to Assess Market & Non-Market Trade-offs • Triple-Bottom Line accounting • Multi-purpose use of Existing Water Infrastructure (e.g., hydropower dam reoperation and irrigation channels to deliver environmental water)	• Price Water (e.g., water abstraction charges, volumetric water pricing, water markets) • Scale Up 'Efficient' Water Technologies (e.g., drip irrigation, water recycling) • Remove Perverse Subsidies (e.g., capital & operating costs of water pumps) • Improved Monitoring of Water Extractions through Remote Sensing	• Green & Transition Finance to Increase Funding Base for Investments in Improved Source Water Quality & Supply (e.g. payments for environmental services) • Innovate & Scale Up Supply Technologies (e.g., desalination, reverse osmosis, solar-powered air moisture extraction) • Reforms to reduce non-revenue water and increase cost recovery of water services	• 'Future-Proof' Urban Planning (e.g., banning new development on floodplains) • Create a 'Level Playing Field' for Human-built (Grey) and Natural (Green) Infrastructure through Regulatory Reforms • Climate-resilient Infrastructure & Climate Smart Agriculture
Beyond Growth	• Rights to Nature, Public Trust Doctrine & Common Asset Trusts • Implementation of UN Declaration of Rights of Indigenous Peoples • Citizen Science for Monitoring and Citizen-led Decision-making • Reallocation of water to achieve environmental and justice goals	• Transparent & Real-Time Water Audits of Inflows, Outflows, Recharge, Extractions & Consumption • Nature-based Water Storages (e.g., wetlands, sustainable managed aquifer recharge) • Monitor & Enforce Water Consumption Caps	• Legal Protection of Key Ecosystems (e.g., wetlands & source catchments) • Science-Practitioner-Community Partnerships for Water-related Risks • Independent Regulatory Oversight of Public Investments & Water Service Outcomes • Legislated and enforceable rights for households to have minimum service levels (e.g., reliability, quality, affordability of drinking water)	• Required Use of Precautionary Principle for Local to Global Planning & Investments • Research & Funding for Local Active Adaptive Management • 'Positive Feedback' Transboundary & Global Agreements (e.g., climate, biodiversity, transboundary rivers)

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