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Navigating Global Water Scarcity with Digital Technologies

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The global water crisis has become one of the most pressing challenges of the 21st century, with over two billion people lacking access to clean drinking water. This study explores how digitalisation can serve as both a solution and a risk in achieving the human right to water. The research applies a multidisciplinary methodology, combining legal analysis, policy review, and regional case studies, particularly from Latin America. The results reveal that while smart technologies can increase efficiency and transparency, they may also deepen inequality without proper regulatory safeguards. The study proposes a framework of legislative and policy recommendations to ensure water digitalisation remains a tool for equity and sustainability.

Keywords: climate change, digitalisation, right to water, sustainability, water justice

1. Introduction

Water is the foundation of life, health, and dignity. Yet in the 21st century, access to clean water remains a profound global challenge. As of 2024, more than 2.2 billion people lack access to safe drinking water, highlighting not only a humanitarian crisis but also a profound failure of governance, infrastructure, and justice (UN-Water 2021). The emergence of digital technologies has created new opportunities to address global water scarcity and enforce the human right to water (Bakker 2010). However, these same technologies raise ethical, legal, and political concerns, especially in terms of access, equity, and data control (Costa–Soares 2020). This essay explores how digitalisation can both promote and undermine the right to water in a world of increasing scarcity, with particular attention to sustainability, regulation, and the digital divide.

The relevance of the topic lies not only in the alarming statistics of water scarcity but also in the increasing complexity of governing water as a public good in an era of digital transformation. As water resources become more stressed due to climate change, urbanisation, and over-extraction, there is a pressing need to rethink traditional water governance models (Intergovernmental Panel on Climate Change 2022). The convergence of environmental policy with technological innovation presents a unique opportunity – and risk – for vulnerable communities worldwide. The central research question of this study is: How can digital technologies support the implementation of the human right to water without exacerbating social inequalities or undermining public accountability? In addressing this question, the study critically evaluates the promises and perils of digitalisation in the water sector, with specific attention to legal, institutional, and ethical dimensions (Anandhi et al. 2024).

The inclusion of Latin American case studies in this research is motivated by several factors. The region's highly diverse hydrological conditions and contrasting water governance models – ranging from market-based systems to centrally regulated frameworks and community-led approaches – offer a unique opportunity to examine the varied impacts of digitalisation. At the same time, Latin America faces some of the world's most pronounced socio-economic inequalities, where historical, economic, and infrastructural factors vividly illustrate how digital tools can either reinforce or reduce existing injustices in access to water. Analysing these experiences therefore provides insights that are not only regionally specific but also carry significant relevance for global debates on equitable and sustainable water governance.

The structure of the study is as follows. First, it outlines the legal and normative framework of the right to water and reviews international legal instruments that recognise it. Second, it examines how digital technologies – such as smart water meters, AI-based forecasting tools, blockchain, and mobile platforms – can enhance or challenge this right. Third, it presents case studies from Latin America to illustrate both successes and failures in integrating digital tools into water governance. Fourth, it offers a set of legal and policy recommendations for ensuring that digital water governance remains equitable, transparent, and sustainable.

2. The Right to Water: A Legal and Human Rights Perspective

The right to water has emerged as one of the most urgent and multidimensional human rights of the 21st century, intricately linked to public health, human dignity, and environmental sustainability. While water has always been essential to human survival, the international legal recognition of access to safe and clean drinking water as a justiciable human right is relatively recent. This development reflects a growing awareness of the global water crisis and the importance of legally ensuring access for all, especially the most vulnerable. A key milestone was the adoption of United Nations General Assembly Resolution 64/292 (2010), which explicitly recognised "the right to safe and clean drinking water and sanitation as a human right essential for the full enjoyment of life and all human rights" (UNGA 2010). This resolution called upon states and international organisations to provide financial resources, capacity-building, and technology transfer to help developing countries ensure affordable and equitable access to safe drinking water and sanitation.

Shortly thereafter, the United Nations Human Rights Council further clarified this right by linking it directly to established human rights, such as the rights to life, health, and an adequate standard of living. This interconnectedness of rights reflects the indivisible and interdependent nature of human rights and underscores that the denial of access to water can constitute a violation of other fundamental rights.

The Committee on Economic, Social and Cultural Rights, in its General Comment No. 15 (2002), articulated the core normative content of the right to water. According to the CESCR, this right includes five interrelated elements:

- Availability: The water supply for each person must be sufficient and continuous for personal and domestic uses.
- Accessibility: Water and sanitation facilities must be physically accessible and within safe reach, particularly for vulnerable and marginalised groups.

- Affordability: The cost of water must not compromise the realization of other rights, such as food, housing, or education.
- Acceptability: Water must be culturally appropriate and sensitive to gender, privacy, and life-cycle needs.
- Quality: The water must be safe, free from microorganisms and substances that pose a threat to health.

Despite these clear standards, enforcement remains deeply uneven. Many national legal systems either do not recognise the right to water or fail to provide mechanisms for its implementation (Amjad et al. 2012). In some cases, domestic laws are ambiguous, leaving water services subject to market forces and political discretion. In others, although legal guarantees exist, they are not matched by investment in infrastructure or institutional capacity.

The gap between normative recognition and practical realisation is especially stark in low- and middle-income countries, where millions lack access to even basic water services. Rural areas, Indigenous populations, and informal urban settlements are particularly vulnerable to exclusion. Even where water is available, it may be unsafe or unaffordable, creating hidden forms of inequality. Another complicating factor is the privatisation of water services, often justified as a means of increasing efficiency and attracting investment. However, privatisation has, in many cases, led to increased tariffs, service cut-offs, and decreased accountability – further challenging the human rights framework, especially where oversight and regulation are weak (Bakker 2010).

This is where digital technologies enter the picture – not merely as technical tools, but as actors that shape governance, participation, and power. From smart water meters and predictive AI models to mobile apps and blockchain systems, digitalisation offers the potential to enhance transparency, optimise resource management, and extend services to previously marginalised communities. For instance, real-time monitoring can prevent leaks and losses, mobile platforms can enable payment in underserved areas, and satellite data can improve mapping and planning.

However, technology is not neutral. Without inclusive design, robust legal regulation, and safeguards for transparency and accountability, digital tools can entrench inequality rather than alleviate it. Those without digital literacy, internet access, or the financial means to engage with digital systems may be left behind – creating a “digital divide” in access to the right to water (Gleick 1998). In conclusion, the legal recognition of the right to water marks a critical advance in global human rights. But to be meaningful, this right must be effectively implemented – through inclusive policies, adequate funding, and equitable governance. As the digital era reshapes how services are delivered and rights are claimed, it is imperative that digitalisation supports – not substitutes – the legal and ethical obligations that underpin this essential right. The next chapter explores how digital innovation is reshaping the governance of water resources and the enforcement of water-related rights.

3. Global Water Scarcity: Triple Challenges

The global water crisis is not a looming threat – it is a present-day reality, affecting billions of people and ecosystems across the globe (UNESCO 2020). At the centre of this complex crisis are three interlinked and mutually reinforcing challenges: rising demand for water, shrinking availability of freshwater resources, and the affordability of water services (World Bank 2020). These three dimensions form the so-called "triple bottom line" of modern water governance: universal access, environmental sustainability, and economic feasibility. Navigating these simultaneously is an immense challenge for policymakers, water managers, and communities, particularly in the face of deepening social inequalities and environmental uncertainty.

3.1. Rising Global Demand: Demographics, Urbanisation, and Sectoral Pressure

The most immediate and measurable driver of water stress is the explosion in demand. Global freshwater use has increased six-fold over the last century, largely due to population growth, urban expansion, industrialisation, and agricultural intensification (UNESCO 2020). As of 2024, the world population exceeds 8 billion, with much of this growth occurring in water-stressed regions of the Global South, including sub-Saharan Africa, South Asia, and Latin America.

Urbanisation is accelerating rapidly, with more than 55% of the world's population living in cities, expected to rise to 68% by 2050. Urban growth places unprecedented stress on municipal water systems (UNDESA 2019), which are often outdated and underfunded. Many cities face "day zero" scenarios, as seen in Cape Town (South Africa) and Chennai (India), where reservoirs have run dry due to overuse, mismanagement, and delayed action. Moreover, sectoral water consumption is heavily skewed. Agriculture alone consumes roughly 70% of global freshwater resources, while industry accounts for about 19%, and domestic uses for 11% (FAO 2022). The water footprint of modern consumer lifestyles – meat-heavy diets, cotton-based clothing, and electronic goods – further compounds the stress. For example, producing one kilogram of beef requires an estimated 15,000 litres of water, illustrating the hidden but massive demands embedded in global trade and consumption patterns (Hoekstra–Mekonnen 2012).

3.2. Decreasing Availability: Climate Change, Overexploitation, and Pollution

While demand is rising, the available supply of freshwater is shrinking, both in absolute and functional terms. Climate change has significantly disrupted the global hydrological cycle, leading to changes in precipitation patterns, more intense droughts, glacial melt, reduced snowpacks, and sea-level rise that contaminates coastal aquifers with saltwater (Intergovernmental Panel on Climate Change 2022).

According to UN Water, nearly one-third of the world's population already lives in water-stressed regions, and this proportion is expected to increase due to rising temperatures and erratic weather events. Countries in the Middle East, North Africa, and parts of South Asia face chronic water scarcity, where annual renewable water resources fall below 1,000 cubic meters per person – the threshold for severe stress. In addition, over-extraction of groundwater has led to the depletion of aquifers in countries like India, Iran, Mexico, and the United States. Groundwater, which accounts for nearly 40% of global irrigation, is being extracted faster than it can naturally replenish (Van Beek et al. 2012). Many regions rely on “fossil” aquifers – non-renewable reserves thousands of years old – which are being irreversibly depleted.

Pollution further exacerbates water scarcity by making existing water sources unusable (UNEP 2023). Industrial effluents, agricultural runoff (rich in nitrates, phosphates, and pesticides), untreated sewage, and plastic pollution are major contaminants. In many developing countries, over 80% of wastewater is discharged untreated into rivers and lakes, leading to ecological collapse, waterborne diseases, and loss of biodiversity.

3.3. Affordability and Inequity: Infrastructure, Investment, and the Price of Water

While access to water is officially recognised as a universal human right, the reality of water affordability is far from universal. In practice, billions of people struggle to access water at prices they can afford – or at all. This affordability crisis is rooted in the high cost of water infrastructure, persistent underinvestment, and often regressive pricing models.

Building, operating, and maintaining water systems – treatment plants, pumping stations, reservoirs, pipes, and sanitation facilities – is capital-intensive and technologically demanding. The World Bank estimates that achieving universal access to safe water and sanitation would require investments of at least $114 billion annually through 2030, a target that most low-income countries are nowhere near meeting (World Bank 2016). Where state capacity is weak, or corruption undermines public trust, private water providers may step in. Yet privatisation has often failed to deliver on equity, with price hikes, service disconnections, and reduced accountability becoming common complaints (Barlow–Tony 2002). In areas where cost recovery is prioritised over human need, the most vulnerable households end up paying the most – either through inflated tariffs or through the costs of purchasing water from informal vendors at significantly higher rates.

Rural populations, Indigenous communities, and residents of informal urban settlements are often excluded from centralised water systems altogether. In some cases, governments explicitly deny water connections to “illegal” housing areas, perpetuating spatial and social exclusion. These dynamics reveal that affordability is not just a matter of pricing but is deeply tied to political, legal, and spatial access (Langford–Russell 2017).

3.4. The Need for Systemic Transformation

Addressing water scarcity requires more than piecemeal reforms or technological upgrades. The challenge lies in achieving a balance between social equity, environmental preservation, and economic sustainability – a task that cannot be accomplished through traditional governance structures alone.
Innovative responses are urgently needed:

- Integrated Water Resources Management must be mainstreamed into planning and budgeting processes at national and local levels.
- Nature-based solutions – like wetland restoration, watershed reforestation, and groundwater recharge – offer low-cost, sustainable methods of improving water availability (UNESCO 2018).
- Water demand management, including behavioural change and efficient use technologies (e.g. low-flow fixtures, drip irrigation), must be incentivised (OECD 2020).
- Strengthening local governance, including women's participation and community-based management, is essential to ensure equity and responsiveness.
- International cooperation and cross-border water diplomacy are needed to manage shared river basins and transboundary aquifers peacefully.

Finally, digital innovation is increasingly seen as a critical enabler of smarter water management. Tools like remote sensing, geographic information systems, Internet of Things sensors, and artificial intelligence can radically improve monitoring, forecasting, and planning (Ascenção et al. 2023). Yet, these must be introduced equitably and transparently to avoid further marginalising already excluded populations.

The triple challenges of increasing water demand, decreasing availability, and affordability are not isolated phenomena – they are deeply interwoven. Each exacerbates the others in a vicious cycle that puts billions at risk of water insecurity. Solving these challenges requires more than technical expertise; it calls for a holistic transformation of water governance, rooted in human rights, environmental stewardship, and inclusive innovation. The next chapter explores how digitalization – if designed and governed ethically – can play a pivotal role in helping societies meet these challenges, and how it might redefine what it means to deliver water as a right in the digital age.

4. Digitalisation as a Tool for Water Justice

As global water scarcity intensifies, it is increasingly clear that conventional water governance models – centralised, infrastructure-heavy, and administratively rigid – are insufficient to ensure equitable and sustainable access to water. In this context, digitalisation offers transformative potential. From data-driven decision-making to decentralised service delivery, digital tools are reshaping how water is managed, monitored, and governed. When deployed thoughtfully and equitably, these technologies can act as powerful instruments for realising water justice – defined as the fair distribution of water resources, the recognition of water as a human right, and the meaningful participation of all stakeholders in water governance.

4.1. Smart Infrastructure and Real-Time Management

One of the most impactful contributions of digitalisation lies in the emergence of smart water networks. These systems use sensors, Internet of Things devices, and telemetry to monitor water flows, detect leaks, and optimise distribution in real time. For example, smart meters installed in urban water systems can measure household consumption on an hourly basis and detect anomalies – such as burst pipes or theft – within minutes (World Bank 2020). This not only reduces water losses but also lowers maintenance costs and improves reliability.

In cities with ageing or inadequate infrastructure, smart technologies can enable utilities to do more with less. Real-time data allows water managers to prioritise repairs, target investments, and extend the lifespan of existing networks. In developing countries where data is often scarce, digital tools can fill crucial information gaps and compensate for institutional weaknesses (UN-Water 2021).

AI-powered models also allow for predictive analytics. These tools can forecast demand surges, model climate-related disruptions (e.g. floods, droughts), and plan optimal water allocation in agriculture and industry. When integrated with meteorological data, hydrological models, and satellite imagery, AI systems can vastly improve resilience and efficiency in water systems (Mohanavelu–Osman 2024).

4.2. Decentralisation and Remote Service Delivery

Digitalisation also enables decentralised and remote water governance, particularly in hard-to-reach or underserved areas. In remote or rural regions, manual monitoring is often impractical or cost-prohibitive. However, solar-powered sensors and remote telemetry systems can relay water quality and quantity data back to central databases or even to community mobile apps (Birajdar–Shaikh 2024).

This is particularly relevant for groundwater monitoring – an area traditionally marked by invisibility and data scarcity. Smart boreholes equipped with flow meters and pressure sensors can continuously monitor abstraction rates, which is vital for preventing overexploitation and ensuring long-term aquifer sustainability (Birajdar–Shaikh 2024). Drones and satellite imagery are increasingly used to detect illegal water withdrawals, unauthorised infrastructure, or deforestation in water catchment areas. These technologies strengthen enforcement of water laws and provide evidence for environmental litigation or public advocacy (Arauzo et al. 2009).

Moreover, mobile platforms have made it possible to deliver basic water services to communities without access to formal banking or identification systems. Mobile payment systems, often integrated with smart meters, allow users to prepay small amounts for water – avoiding the high upfront costs that disproportionately affect poor households (Hermy et al. 2015).

4.3. Transparency, Anti-Corruption, and Accountability

Another critical area where digitalisation contributes to water justice is enhancing transparency and reducing corruption. In many parts of the world, water allocation decisions, infrastructure contracts, and tariff-setting are opaque and vulnerable to political or corporate capture. Digital technologies can bring much-needed visibility into these processes (Biswas–Tortajada 2019).

Blockchain technology – a form of distributed ledger – can make water transactions traceable, tamper-proof, and transparent. When applied to land and water rights registries, blockchain can help resolve ownership disputes, document historical usage patterns, and ensure fair distribution. In procurement, it can track funds allocated for water projects and reduce opportunities for misappropriation (UNESCO 2023).

Open data platforms that publish water quality readings, usage statistics, and budget allocations allow citizens, journalists, and civil society organisations to hold decision-makers accountable. Platforms like Water Point Data Exchange and OpenStreetMap-based tools have already enabled communities to monitor service delivery and advocate for improvements in real time (Loftus 2009).

4.4. Participation and Local Empowerment

Perhaps most importantly, digitalisation can serve as a medium for democratising water governance. Many of the world's most water-insecure communities are also those most excluded from formal planning and policy processes. Digital tools offer new channels for civic engagement, capacity building, and empowerment.

Participatory mapping platforms allow users to geolocate broken water points, report service interruptions, or propose community solutions. Mobile surveys and voice-response systems can capture user feedback in remote or low-literacy areas. Social media campaigns can amplify local grievances and connect water activism across borders.

In Peru, for example, community-led mapping initiatives using simple GPS-enabled devices have led to the recognition of Indigenous water claims and the resolution of disputes with agribusiness firms. In Kenya, mobile-based reporting systems have helped local women's groups manage communal wells and negotiate support from local authorities (UNESCO 2023). By placing data and agency in the hands of users – not just administrators – digital technologies can shift the power dynamics of water governance from top-down control to collaborative, people-centred management.

Digitalisation is not a silver bullet, but it offers a suite of tools that – if governed justly – can dramatically improve water access, equity, and sustainability. From real-time monitoring to participatory governance, these innovations can reduce waste, increase transparency, and empower communities. However, their benefits are not automatic. Without inclusive design, legal safeguards, and public oversight, digitalisation risks reinforcing the very injustices it aims to resolve (Loftus 2009). As the next chapter will explore, these risks are real and present – ranging from digital exclusion and algorithmic bias to dependency on private actors and surveillance concerns. A justice-based approach to digital water governance must therefore ask not only what technology can do, but also for whom, by whom, and under what conditions.

5. Environmental Sustainability and Smart Systems

One of the most compelling arguments for the integration of digital technologies in water management is their capacity to advance environmental sustainability. As global water resources become increasingly strained due to overuse, contamination, and climate change, the transition toward smart, data-driven systems is not only desirable but increasingly essential (UNESCO 2023). Environmental sustainability in this context refers to the responsible use, conservation, and regeneration of water resources in ways that ensure long-term ecological balance while meeting current human needs.

Digitalisation can act as a crucial enabler of sustainable water governance, supporting efforts to reduce consumption, protect natural ecosystems, anticipate climate-related shocks, and implement circular economy principles (WMO 2022). Unlike traditional water management, which often relies on periodic or reactive interventions, smart systems provide continuous, real-time monitoring and forecasting, which allows for proactive, adaptive, and resource-efficient management (OECD 2021).

5.1. Predictive Analytics for Early Warning and Climate Resilience

One of the most transformative impacts of digitalisation is its capacity to predict and model hydrological events. Using large datasets – including meteorological, hydrological, and land-use data – machine learning algorithms and AI models can simulate complex interactions within the water cycle. These predictive tools can identify the onset of droughts, extreme rainfall events, and potential flood zones days or even weeks in advance (Cohen et al. 2024).

For instance, advanced hydrological modelling tools such as DSSAT (Decision Support System for Agrotechnology Transfer) or the WEAP (Water Evaluation and Planning System) are increasingly being integrated with digital sensors and satellite data to generate region-specific forecasts. These tools enable authorities and water managers to take preventive action – such as releasing water from reservoirs, warning populations, or optimising irrigation schedules – thereby mitigating human and environmental damage (Bosman et al. 2025).

Furthermore, predictive models also inform long-term climate adaptation strategies, helping governments understand how future climate scenarios might affect regional water availability, glacier melt, aquifer recharge, and agricultural productivity.

5.2. Smart Irrigation and Agricultural Efficiency

Agriculture, as the largest global water consumer, offers enormous potential for efficiency gains through digitalisation. Traditional irrigation systems are often based on fixed schedules and outdated assumptions, resulting in significant water waste. Smart irrigation technologies use data from soil moisture sensors, weather forecasts, evapotranspiration rates, and crop health imaging to determine precisely when, where, and how much water should be applied.

Technologies such as drip irrigation systems integrated with AI-based controllers can reduce water usage by up to 40% compared to conventional flood irrigation while maintaining or even improving yields (FAO 2022). Additionally, satellite-based monitoring platforms, like CropIn or IBM’s Watson Decision Platform for Agriculture, allow for large-scale assessment of agricultural water use and suggest crop-specific interventions based on real-time data (Boote 2025). The result is a more resource-efficient and climate-resilient agricultural sector, capable of producing more food with less water while reducing run-off, erosion, and chemical pollution of waterways.

5.3. Digital Monitoring in Industrial Water Use

In industrial sectors, water efficiency is both an environmental and economic imperative. Many industries – including textiles, mining, pharmaceuticals, and food processing – are highly water-intensive and generate large volumes of wastewater. Without proper monitoring, these sectors can be major contributors to water pollution and aquifer depletion.

Digital water meters, flow sensors, and industrial Internet of Things platforms allow real-time tracking of water use across different operational stages. This enables managers to identify inefficiencies, implement leak detection protocols, and optimise cooling and cleaning processes. Moreover, the integration of water management software with enterprise resource planning systems ensures that water is managed alongside energy, emissions, and waste, contributing to a broader sustainability framework (Choudhari et al. 2021).

Some industries are also adopting zero-liquid discharge technologies, supported by real-time quality monitoring and automated process control, to ensure that all water used in production is treated and reused on-site, thereby closing the loop and significantly reducing environmental impact (Annus et al. 2024).

5.4. Automation in Water Reuse and Recycling

Water reuse and recycling are central to the circular economy approach in water governance. This approach seeks to reduce extraction from natural sources by treating and reusing wastewater, whether from households (greywater), stormwater, or industrial processes. Digital control systems play a critical role in ensuring the safety, quality, and efficiency of these recycling processes. Smart sensors continuously monitor water quality indicators – such as turbidity, microbial content, chemical composition, and temperature – while automated valves and controllers adjust treatment processes in real time. This ensures that water reused for irrigation, industrial cooling, or even potable supply meets stringent safety standards without human intervention (Kibbee–Örmeci 2020).

Technologies such as smart rainwater harvesting systems combine rooftop collection with digital filtration and storage monitoring, alerting users when maintenance is needed or tanks are full. In Singapore, the NEWater initiative uses advanced digital filtration, UV disinfection, and membrane technology to produce ultra-clean recycled water for industrial and potable use, demonstrating the viability of digital reuse at scale. Digitalisation is reshaping the environmental dimension of water governance by increasing efficiency, enhancing resilience, and enabling the circular use of water. Through real-time data collection, predictive modelling, automated control, and integrated management platforms, smart systems provide the necessary tools to operate within environmental limits while meeting human demands (Chapagain–Hoekstra 2011).

However, these benefits are not guaranteed. The success of digitalisation depends on equitable access to technology, adequate regulatory frameworks, and the alignment of digital systems with broader sustainability goals. Without these conditions, smart water systems could inadvertently reinforce disparities and undermine environmental justice. As the study continues, the next section will examine the risks, limitations, and ethical concerns that accompany the digitalisation of water governance – particularly with respect to exclusion, dependency, and data governance (PUB 2024).

6. Risks and Inequities: The Dark Side of Digitalisation

While digitalisation offers powerful tools for advancing water justice and sustainability, it is not a neutral or universally beneficial process. Technology reflects and often amplifies the social, economic, and political contexts in which it is deployed. As such, the digital transformation of water governance carries significant risks – especially for the most vulnerable populations (Fox–Peixoto 2016).

These risks include exclusion through the digital divide, commodification and privatisation of water systems, algorithmic injustice, and systemic vulnerabilities due to cybersecurity threats or technological failure (Birhane 2021). Without deliberate regulation, inclusive design, and ethical oversight, digitalisation could entrench existing inequalities or even generate new forms of injustice in access to water.

6.1. The Digital Divide and Exclusion from Services

The most immediate and visible risk is the global digital divide – the unequal access to internet connectivity, digital infrastructure, devices, and digital literacy. While digital platforms such as water monitoring apps, mobile payment systems, and automated alerts offer convenience and efficiency, they are inaccessible to those who lack smartphones, stable electricity, or affordable internet.

According to the International Telecommunication Union, nearly 2.6 billion people still lack internet access, the majority of whom live in the Global South, rural areas, and informal settlements (International Telecommunication Union 2023). Even where access exists, digital literacy is often low, particularly among older adults, low-income groups, and women. A water management app or smart meter interface, therefore, may simply not function as intended in these communities.

This form of digital exclusion contradicts the principle of universality embedded in the human right to water. If access to clean and affordable water becomes mediated by digital tools, then digital literacy and connectivity effectively become preconditions for exercising that right – a fundamentally unjust and discriminatory outcome (Heeks 2022).

6.2. Commodification and Corporate Control

Another key concern is the growing role of private corporations in developing, operating, and managing digital water infrastructure. From smart meter providers and billing platforms to cloud-based monitoring systems, much of the technological backbone of digital water governance is owned or operated by for-profit firms (Bakker 2010). This raises fundamental ethical and legal questions: Who owns water data? Who controls access to digital water services? Who benefits from the monetisation of water consumption information? Without transparent regulatory frameworks, there is a serious risk that the digitalisation of water services will lead to further commodification of a public good (Heeks 2022).

In several cases, public utilities have entered into exclusive contracts with private tech providers, effectively outsourcing core functions of water governance to companies that are not democratically accountable. These actors may prioritise cost recovery, data monetisation, or shareholder interests over affordability, access, and environmental protection. Such developments run counter to the notion of water as a human right and undermine the role of the state as the guarantor of that right (Soitiriou–Waldron 2017).

6.3. Algorithmic Injustice and Loss of Human Oversight

Automated systems – driven by algorithms or artificial intelligence – are increasingly used to manage water distribution, billing, and service enforcement. While these systems can improve efficiency, they also introduce new layers of opaque, unaccountable decision-making (Eubanks 2018).

For example, an algorithm may be programmed to cut off water service after a certain number of unpaid bills. However, it may not account for mitigating circumstances such as disability, unemployment, or billing errors. Without human oversight, such decisions may violate the principles of fairness, proportionality, and dignity (Birhane 2021). The automation of enforcement mechanisms risks turning water governance into a technocratic regime devoid of empathy or procedural justice (Anandhi et al. 2024).

Furthermore, the use of predictive analytics in planning or resource allocation – if based on biased data or flawed assumptions – can reinforce structural inequalities. Communities that have historically lacked access to water infrastructure may be deprioritised in algorithms because they show low historic usage. This phenomenon, sometimes referred to as "algorithmic redlining," can perpetuate cycles of exclusion rather than breaking them (Birhane 2021).

6.4. Cybersecurity, Fragility, and Systemic Risk

Digital water systems are also inherently vulnerable to cybersecurity threats, system failures, and external shocks. As water infrastructure becomes increasingly digitised and connected through the Internet of Things, it becomes more susceptible to cyberattacks and technical malfunctions.

In 2021, hackers attempted to poison the water supply in Oldsmar, Florida, by remotely increasing the levels of lye in the treatment process. Though the attack was thwarted, it underscored the systemic fragility of critical water infrastructure in the digital age (Kardon 2023). Similar risks exist in conflict zones or disaster areas, where power outages or damaged networks can disable digital control systems, leaving entire communities without water access. In fragile states, reliance on external tech providers can also lead to technological dependency. When proprietary systems break down or need upgrades, local governments may lack the technical capacity or resources to fix them, leading to prolonged service interruptions or escalating costs.

The promise of digital water governance must be weighed against its potential to generate exclusion, exploitation, and systemic vulnerability. If not designed and implemented with strong ethical and legal safeguards, digitalisation risks becoming a tool of dispossession rather than empowerment.

To avoid this outcome, it is essential to adopt a human rights-based approach to digital governance – one that prioritises inclusion, transparency, accountability, and resilience (Stockholm International Water Institute 2017). Regulatory bodies must ensure that digital water technologies serve public goals, protect user rights, and uphold the principle of water as a universal human right. In the final chapters, this study offers policy and legal recommendations for creating a fair and sustainable digital water future – where technology serves people, not the other way around.

7. Regional Case Studies: Latin American Examples

Latin America represents a diverse and dynamic region in terms of both hydrological conditions and governance structures. From arid zones suffering chronic water shortages to tropical rainforests abundant in freshwater, the continent is marked by dramatic disparities in water access and management capacity. The region also exhibits a wide range of institutional approaches to digitalisation in water governance, from market-driven systems to state-regulated frameworks and community-led innovations (Basani–Fery 2022).

What unites these experiences, however, is the profound tension between technological potential and socio-political realities. Digital technologies in Latin America are being deployed within historically unequal landscapes – characterized by structural poverty, fragmented public services, colonial legacies of land and water ownership, and widespread digital divides. The following case studies from Chile, Brazil, and Peru illuminate the complex outcomes of digitalisation, revealing how technology can both reinforce and resist prevailing injustices in water governance (International Telecommunication Union 2023).

7.1. Chile: Technocratic Efficiency and Social Inequality

Chile's water governance system is one of the most radically market-based in the world. Instituted during the Pinochet dictatorship through the 1981 Water Code, Chile enshrined water rights as private property that can be traded independently of land. This legal framework has turned water into an economic commodity, allocating access through the logic of supply, demand, and speculation (Höhl et al. 2021).

In recent years, Chile has incorporated digital tools into this regime through the establishment of online water rights registries, digital transaction platforms, and blockchain-based tracking systems. These innovations have enhanced transparency, traceability, and administrative efficiency in water rights management. Users can now verify ownership, track allocations, and execute transfers through digital platforms overseen by the Dirección General de Aguas (Araya et al. 2025).

However, these technologies operate within an already deeply unequal structure of water ownership. Large agribusinesses and extractive industries – particularly in northern Chile – hold the majority of water rights and are best positioned to use these digital tools to consolidate and defend their control. By contrast, smallholder farmers, Indigenous communities, and rural households often lack the internet access, digital literacy, and institutional support necessary to navigate the system. The result is a paradox: digitalisation has improved procedural efficiency while exacerbating substantive inequality. It has streamlined a system that many critics argue is fundamentally unjust, thereby giving a technocratic sheen to an exclusionary model of resource distribution. In this context, digital water governance has reinforced the dominance of market actors, rather than challenging the commodification of a human right (Milesi 2024).

7.2. Brazil: Fragmented Progress and Spatial Inequality

Brazil presents a contrasting case, where the state retains a strong regulatory role in water governance, but institutional capacity and digitalisation efforts are highly uneven across regions. The country's National Water and Sanitation Agency has embraced digital innovations in hydrological monitoring, smart metering, and automated billing, particularly in urban centres such as São Paulo and Rio de Janeiro. São Paulo's experience is especially instructive. Following the devastating 2014–2015 drought, the city implemented real-time monitoring systems, smart water meters, and AI-driven demand forecasting to improve water efficiency and crisis response. The public utility SABESP used telemetry to detect leaks, monitor reservoir levels, and alert users to impending shortages, helping avoid a repeat of the crisis (Camacho et al. 2023).

However, the benefits of these digital systems are largely restricted to wealthier, formally connected urban areas. In contrast, Brazil's vast rural regions, informal urban settlements (favelas), and Indigenous territories often remain unconnected to both water infrastructure and digital systems. In some states, basic services are still delivered through manual systems, or not at all.

Moreover, the expansion of digital tools has tended to prioritise consumer management (e.g., billing, usage monitoring) over participatory governance or environmental oversight. In some cases, private utilities have used smart meters to enforce payment more aggressively, including automated disconnections, with limited regard for the social consequences. This raises concerns about the use of digital tools for surveillance and control rather than inclusion and empowerment. Brazil's case thus illustrates the spatial fragmentation of digitalisation, where technological advancements reinforce urban–rural divides and market logics, unless consciously integrated into equity-oriented policy frameworks (Moreira et al. 2024).

7.3. Peru: Participatory Digital Mapping and Local Empowerment

In contrast to the top-down or technocratic models seen in Chile and parts of Brazil, Peru offers a compelling example of grassroots-led digital innovation aimed at empowering local communities, particularly Indigenous groups and rural populations. In response to widespread exclusion from official water planning processes, civil society organisations, in collaboration with academic institutions and international partners, have developed digital mapping and reporting tools that allow communities to document water sources, pollution events, infrastructure failures, and rights violations. These platforms often use open-source technologies, mobile apps, and GPS-enabled devices that are adapted to local languages and cultural contexts (Fischer 2025).

One such initiative enabled rural communities in the Cajamarca region – home to contentious mining operations – to map and monitor their freshwater springs. The resulting data, when presented to regional and national authorities, became instrumental in negotiating water protection measures and legal recognition of community claims. In other cases, mobile reporting tools have been used to document illegal diversions or contamination and hold extractive industries accountable.

Critically, these digital tools were implemented alongside capacity-building, gender inclusion efforts, and legal support, making them part of a holistic empowerment strategy, rather than standalone technologies. Women in particular have played central roles in data collection and advocacy, challenging patriarchal norms in water governance and gaining new forms of public recognition. Peru's experience shows how digitalisation, when grounded in participatory methodologies and human rights principles, can serve as a vehicle for democratic transformation, not just technical optimisation (Cummings et al. 2017).

These case studies from Chile, Brazil, and Peru underscore a central lesson: digital technologies do not operate in a vacuum. Their effects are shaped by existing legal frameworks, power structures, socio-economic inequalities, and levels of political inclusion. Digitalisation can enable greater efficiency, transparency, and participation – but only if it is embedded within equitable governance models and deployed with sensitivity to context.

In Chile, digital tools have reinforced a controversial market-based system that favours powerful actors. In Brazil, technological advances have improved service delivery in cities but neglected peripheral areas. In Peru, bottom-up digital strategies have opened new spaces for community-led governance and accountability.

These examples suggest that the key to just digital water governance lies not only in access to technology, but also in access to power, participation, and legal recognition. Without these, digital systems may simply reproduce old inequalities in new forms. The next chapter turns toward concrete policy and legal recommendations aimed at ensuring that digitalisation becomes a force for equity, sustainability, and human rights in the global struggle for water justice.

8. Framework of Legislative and Policy Recommendations

Building on the findings of this study, a coherent framework of legislative and policy recommendations is essential to ensure that digitalisation in water governance supports equity, sustainability, and the human right to water. First, legal recognition and protection of the right to water must be strengthened, embedding clear obligations for states to guarantee affordable, safe, and accessible water for all, including explicit provisions for digital access and literacy as enabling conditions.

Second, equitable infrastructure investment should prioritise rural, Indigenous, and marginalised communities, with targeted funding for both physical water systems and the digital tools necessary to manage them. Third, data governance frameworks must safeguard user privacy, ensure transparency in algorithmic decision-making, and mandate open access to non-sensitive water data for public oversight. Fourth, public–private partnerships in digital water services should be regulated to prevent monopolisation, ensure affordability, and preserve public accountability. Fifth, inclusive participation mechanisms – such as community-based monitoring platforms and participatory mapping – should be institutionalised, ensuring that affected populations have a decisive role in planning and oversight.

Finally, capacity-building initiatives must address the digital divide through training, localised interfaces, and gender-sensitive approaches. Taken together, these measures create a rights-based digital water governance model that balances innovation with justice, ensuring that technology serves as a tool for empowerment rather than exclusion (Council of the European Union 2013).

9. Conclusion

Water is life – essential not only for survival but also for dignity, development, and the fulfilment of a range of other human rights. In an era marked by escalating water stress, climate variability, and socio-economic inequality, the integration of digital technologies into water governance systems offers a critical window of opportunity. These technologies – ranging from smart meters and AI-based forecasting tools to blockchain registries and participatory mobile platforms – can enhance monitoring, improve service delivery, support transparency, and empower local communities (CISA 2021).

However, this study has shown that digitalisation is not a neutral or universally benevolent force. Its impacts depend on how, by whom, and for whom these tools are designed and implemented. While digital technologies have the potential to make water governance more efficient and responsive, they also pose serious risks – including exclusion of digitally marginalised populations, corporate control over essential infrastructure, algorithmic injustice, and cybersecurity vulnerabilities.

The global digital divide means that millions of people – especially in rural, low-income, or Indigenous communities – remain excluded from the very tools that could help improve their water access. When access to water becomes mediated by internet connectivity, mobile apps, or algorithmic decisions, it risks transforming a human right into a conditional service – available only to those who can navigate complex digital systems. Furthermore, the increasing involvement of private technology providers in public water services introduces a tension between profit-driven models and the normative principles of human rights. Without strong legal safeguards, democratic accountability, and data governance frameworks, digitalisation may exacerbate rather than resolve the structural injustices that underpin global water scarcity (Carter 2024).

Yet, there is also reason for optimism. Case studies from Latin America demonstrate that when digital tools are embedded in inclusive, participatory, and rights-based frameworks, they can serve as catalysts for transformation. Participatory mapping in Peru, smart monitoring in Brazil, and transparency platforms in Chile all show that technology can be repurposed as a tool for equity, not merely for efficiency. Building on these insights, the legislative and policy recommendations proposed in this study offers concrete steps to ensure that digitalisation serves equity and sustainability. These include strengthening legal recognition of the right to water, prioritising infrastructure investment in marginalised areas, establishing robust data governance safeguards, regulating public–private partnerships to protect public accountability, institutionalising participatory mechanisms, and addressing the digital divide through capacity-building and inclusive design.

The challenge for the 21st century is not simply to innovate, but to innovate justly. As digital technologies become increasingly central to the governance of water, it is vital to ensure that these tools do not reinforce existing inequalities, but rather help to overcome them. This requires placing inclusion at the heart of digital water systems – ensuring that they are accessible to people regardless of their language, gender, income, location, or level of digital literacy.

At the same time, the growing involvement of private actors in digital infrastructure demands robust public oversight. Regulatory frameworks must ensure that commercial interests do not override the principles of equity, transparency, and public accountability. Digitalisation should serve the public interest – not commodify or restrict access to an essential resource. Empowering communities must be a central aim of any digital strategy. This means not only making data available but enabling meaningful participation in how decisions are made. Digital tools should support democratic engagement, strengthen local governance and recognise the rights of communities to be active stewards of their water resources (Grievson et al. 2022).

Closing the digital divide will also require significant investment in infrastructure and capacity-building – particularly in rural and marginalised areas. Without such investment, digitalisation may deepen spatial and economic inequalities by favouring those who already have access to technology and institutional support.

Finally, ethical and legal safeguards must be put in place to protect rights in the digital space. Issues such as data privacy, algorithmic bias and system security must be addressed head-on, with clear rules that uphold user rights and build public trust. In conclusion, digital technologies are not a herbal medicine for the global water crisis, but neither are they inherently problematic (Homaei et al. 2025). Their true value depends on how they are integrated into broader systems of governance that are rooted in equity, accountability and sustainability. If developed and governed wisely, digitalisation can be a powerful ally in the realisation of the human right to water. The task ahead is not only to adopt new tools, but to reshape the structures within which they operate – so that the future of water governance is not only smart, but just.

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