

Review

## Traits impacting water crisis management

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### Abstract

Water scarcity and its geopolitical implications have been a cornerstone of scholarly discourse. However, literature often overlooks the nuanced relationship between human traits and water management. Addressing this oversight, this study synthesized data from 149 articles (1991–2023), revealing a substantial connection between human actions and water management dynamics. From this data, a unique comprehensive framework was developed, focusing on the intricate interplay of human behaviors, leadership dynamics, economic factors, and technological advancements in water management. Unlike previous works, this framework holistically integrates these components, offering a fresh lens through which to understand the human-centric factors underpinning global water scarcity. This study underscores the framework's vital role in guiding sustainable water management and strategy, making it an indispensable tool for stakeholders, from policymakers to environmentalists. In essence, this research not only bridges a knowledge gap but also serves as a beacon for addressing pressing water scarcity challenges in today's world.

**Keywords** Human characteristics · Water crisis · Water management · Sustainable water practices · Holistic framework

## 1 Introduction

Recent literature has increasingly highlighted the escalating implications of water scarcity, with regions like China, India, and Pakistan emerging as poignant illustrations of this challenge [1, 2]. Exacerbating the crisis, various nations, motivated by security concerns, are undertaking dam constructions. While these initiatives align with individual national priorities, they often produce unintended cross-border impacts, culminating in disputes with neighboring states [3, 4]. This evolving scenario weaves a complex tapestry of global water conflict. The Middle East is emblematic of such intricacies: key water sources, including the Jordan River, mountain aquifers, Tigris, and Euphrates, are at the crux of hydro-political tensions involving countries like Israel, Palestine, Iraq, Syria, and Turkey [5–7]. Shifting the focus to Africa, the Grand Ethiopian Renaissance Dam on the Blue Nile has catalyzed disputes between Egypt, Sudan, and Ethiopia [8]. Similarly, in South Asia, perennial disputes punctuate relations, with India and Pakistan centering their disagreements on the Indus River and the Ganges and Brahmaputra rivers adding layers to the India-Bangladesh dynamics [9, 10]. Central Asia's water concerns are epitomized by the dwindling Aral Sea, a contentious point for countries such as Kazakhstan and Uzbekistan. Simultaneously, the Nile River basin, which envelops 11 African nations within its stakeholder spectrum, amplifies the continent's water-related diplomatic intricacies [11, 12]. Over in the

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Americas, rivers like the Colorado and Rio Grande delineate the dynamics between the U.S. and Mexico, and other shared basins emerge as points of negotiation for various Central American countries [12].

Delving deeper into the academic realm, a careful analysis of existing literature reveals a pronounced focus on the technical and policy aspects of water management and conservation [12, 13]. This scholarly concentration underscores the multifaceted nature of the global water discourse. Despite this concentration, a conspicuous gap emerges: the intricate relationship between human behavioral dynamics and the escalating global water crises [13]. While academic discourse acknowledges the broad contours of human behavior influencing water scarcity, there exists a pronounced paucity in examining the granularities of human traits, especially those related to greed, ethical considerations, and power structures [14, 15].

In an extensive review of existing literature, it is evident that human traits play a pivotal role in shaping water management systems. A variety of distinctive human attributes have emerged as contributing factors to the water crises the world currently faces. To delineate, 23 studies examined interpersonal characteristics, highlighting the repercussions of disrespect, dishonesty, intolerance, conflict, and the unfair distribution of water resources. Leadership, too, plays a crucial role, with 18 separate investigations spotlighting attributes such as irresponsibility, short-sightedness, and ineffective water management practices. The economic dimension cannot be overlooked either. 23 studies drew connections between traits like financial irresponsibility and economic fragility, illustrating their role in exacerbating water scarcity. Political dynamics further muddy the waters, with 22 scholarly works pinpointing the impacts of authoritarianism, corruption, and unjust water policies. The interplay of geographical and natural traits was explored in 27 articles, focusing on wastefulness, environmental degradation, water pollution, and overuse. In the nexus between water management and science, 24 studies have been found. Finally, the role of technology, particularly digital technology, has been explored in 12 distinct studies, highlighting both its potential benefits and drawbacks through aspects such as cyberbullying, online harassment, digital leadership skills, and the adoption of innovative tools like blockchain technology, environmental sensors, and IoT. These studies, tabulated in Table 1 under the section "Remarks on Literature," showcase the myriad ways authors have linked human traits with the water crisis. However, a notable gap remains: the absence of a comprehensive framework that encapsulates all these traits in the context of water management and the ongoing water crisis. There is a pressing need to compile the myriad traits that influence water crises and management, offering a consolidated framework for understanding and action.

Building on this observed gap, the present research aims to venture into this relatively uncharted territory, seeking to illuminate the interplay between human behaviors and water management. The envisaged narrative is one where detrimental human tendency are recalibrated, and commendable behaviors are amplified, presenting a potential paradigm shift that could reorient the dynamics of the global water crisis. As this research unfolds, its broader implications become evident, potentially offering invaluable insights for a diverse audience, including policymakers, environmentalists, and communities at large. Indeed, given water's unparalleled significance as an essential life-sustaining resource, scrutinizing human behaviors in this context is not only relevant but imperative, aligning seamlessly with the global discourse on sustainable development and equitable access to water resources.

Central to this exploration is the posited query: *How can human behavioral characteristics be integrated into a comprehensive framework for addressing the water crisis, and in what ways might this framework facilitate the development and implementation of efficacious interventions and strategies?* To comprehensively address this complex question, a robust methodological approach is indispensable. The development of the framework unfolds in three stages: initially, relevant literature is collated through a systematic review, as illustrated in Fig. 1. Subsequently, a thematic analysis is employed to identify main and sub-themes of human traits, which are then categorized within the study's framework, presented in Fig. 2. In the final stage, the proposed framework (as delineated in Fig. 2) undergoes face-to-face validation with domain experts to affirm its reliability and relevance. This methodological design is comprehensive, spanning aspects of interpersonal dynamics, leadership paradigms, economic considerations, political strategies, and the realms of science and technology. By meticulously examining these multifaceted intersections, this research aims to offer lucid insights that may pave the way for fair and effective water resource management.

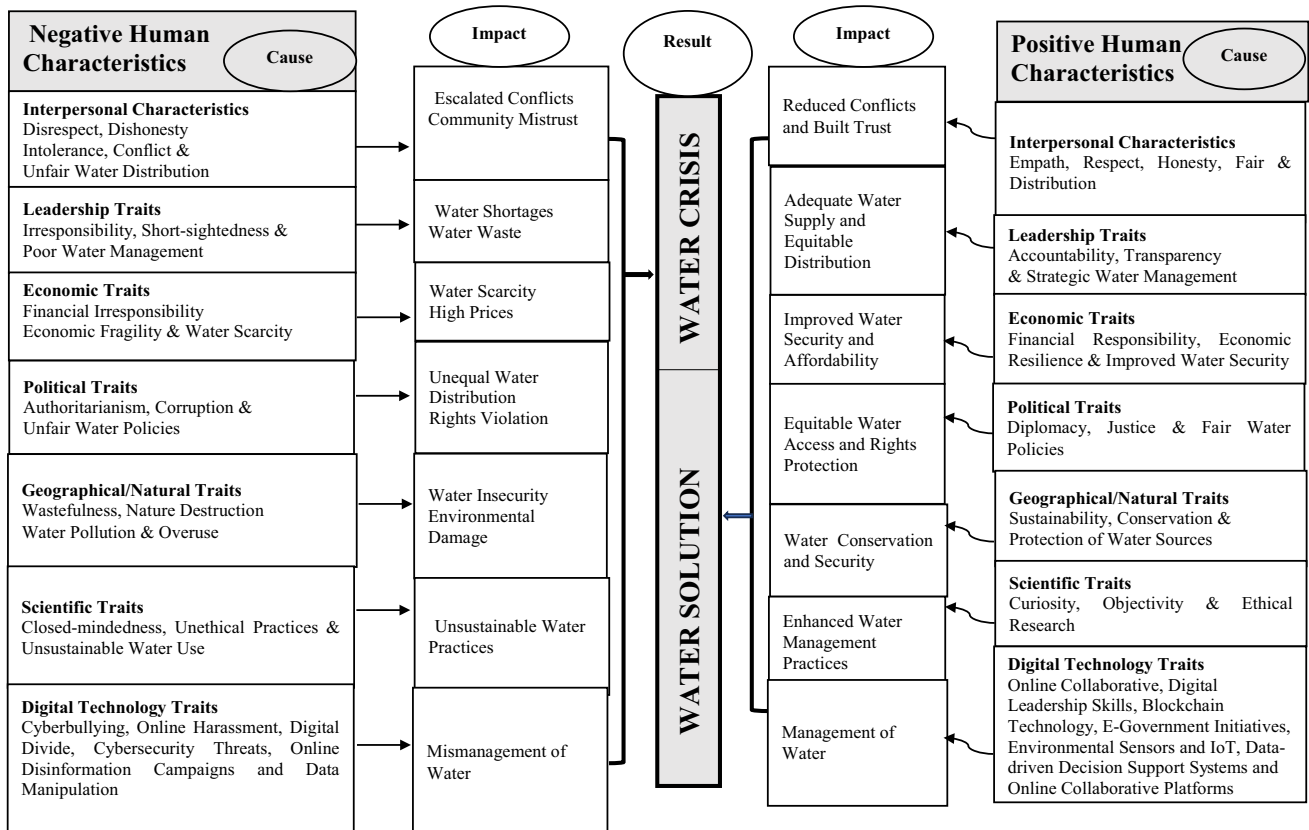
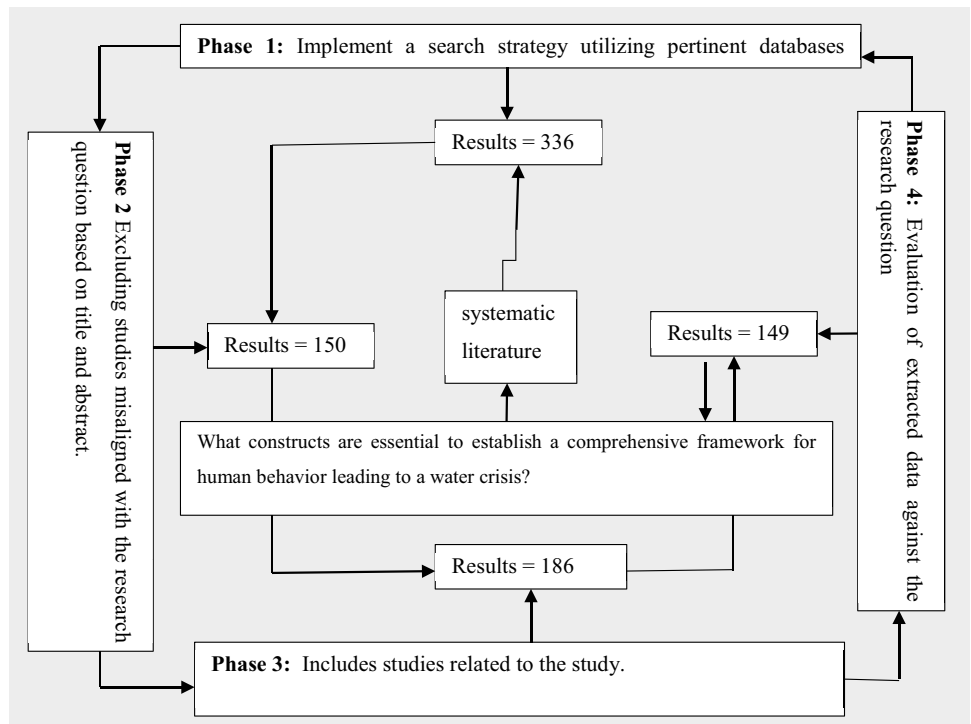
Concluding this methodological exposition is a pivotal assertion, which serves as the bedrock of this research: the notion that water, in its essence, is abundant. The perceived scarcity, it posits, emerges from the intricate tapestry of human behaviors. Grounded in seminal academic contributions, particularly [16–20], these studies seek to weave together both challenges and potentialities, offering a comprehensive perspective on the human-centric dimensions of water crises.

**Table 1** Review of analogies between human traits and water issues

Variable name	Sources	Total
Interpersonal	Allan (2002), Alva (2022), Boelens & Zwartveen (2005), Castellanos et al. (2023), Crosweiler & Tschakert (2020), Darnthamrongkul & Mazingo (2020), El Batouti, Al-Harby, & Elewa (2021), ElKaleh (2023), Garrós, Austin, & Dodek (2021), Gallego-Ayala (2013), Grey & Sadoff (2007), Heinrich (2011), Mollé, Mollinga, & Wester (2009), Ostrom (2009), Selby (2005), Sethi et al. (2023), Srinivasan et al. (2012), Swyngedouw (2009), Warner (2008), Wolf (2007), Wutich & Ragsdale (2008), Zeitoun & Mirumachi (2008), and Zeitoun & Warner (2006)	23
Leadership Ethics and its Impact	Carvalho & Mulla (2020), De Stefano et al. (2012), Edelenbos & Van Meerkerk (2015), Eigner et al. (2023), Folke et al. (2005), Gittins et al. (2021), Hasan et al. (2023), Huitema et al. (2009), Juncal et al. (2023), Koontz et al. (2015), Meinen-Dick (2007), Mollé (2008), Pahl-Wostl (2009), Rogers & Hall (2003), Saleth & Dinar (2004), Plummer et al. (2012), Wang & Gao (2023), and Zeitoun et al. (2016)	18
Economics	Allan, John Anthony (2003), Addo, Kwame Adjei (2019), Barlow, Mary (2002), Carr, James (2018), Feldman, David (2009), Grasham, Katherine (2019), Grey, David (2007), Hepworth, Noah (2013), Hoekstra, Albert Yorke (2011), Kunz, Nathaniel (2020), Lee, John Henry (2020), Madani, Kevin (2012), Madani, Kevin (2013), Marcal, Richard Scott (2021), Matthews, Robert Anthony (2022), Mishra, Anil (2021), Mollé, Francois (2009), Mutschinski, Thomas (2021), Priscoli, John Dominic (2009), Saleth, Rajeev Mohan (2005), Savenije, Hendrik Gerrit (2002), Wheeler, Katherine (2020), and Wutich, Alexandra (2023)	23
Political	Agarwal (2000), Adeel (2017), Allan (2003), Araral (2013), Boelens (2014), Conca (2008), Davis (2004), Dinar (2009), Falayi (2021), Fay (2017), Grey (2007), Imbulana (2006), Lankford (2010), Mason (2004), Nadow (2023), Pahl-Wostl (2009), Suhardiman (2015), Varis (2008), Wolf (2007), Zahar (2020), Zawahri (2009), Zeitoun (2006), and World Bank (2016)	22
Geographic	Allan (2003), Amaral (2020), Amuah (2022), Beaufort (2010), Barlow (2009), Cosgrove (2000), Dellapenna (2009), Falkenmark (2004), Hoekstra (2019), Hoffman (2010), Knorr (2023), Krishnan (2022), Kumar (2020), Lebedev (2021), Makanda (2022), Nair (2023), Oki (2006), Pahl-Wostl (2013), Postel (1999), Rees (2010), Rockström (2009), Schilling (2020), Tortajada (2013), UNEP (2016), Vörösmarty (2010), Wang (2021), and World Bank (1993)	27
Science	Ananga (2021), Barnett (2007), Doorn (2021), Edenhofer (2015), Krishnan (2022), Lankford (2013), Masood (2020), Mutschinski, Thomas (2021), Pahl-Wostl (2014), Paquin (2016), Priscoli, John Dominic (2009), Rockström (2009), Salem (2022), Serrat-Capdevila (2014), Shanono (2020), Shanono (2021), Sharma Waddington (2021), Shiva (2016), Sivapalan (2012), Staddon (2013), Steffen (2015), Trenberth (2014), Vorosmarty (2000), and Zetland (2011)	24
Technology	Abd El-Latif (2021), Ahmed (2021), Bilginoğlu (2023), Borah (2022), Chohan (2019), de Araujo (2021), Dogo (2019), Doorn (2021), Drăgulescu (2021), Michalec (2022), Obaideen (2022), and Peng (2022)	12
Total		149

Source: Author

**Fig. 1** Four Phases of Systematic Review. Source: Higgins & Green, 2011



**Fig. 2** Theoretical framework

## 2 Literature reviews

The literature review is structured into four sections. The first section delves into 'Human Behavioral Characteristics and the Water Crisis.' The second section discusses 'Comprehensive Frameworks for Addressing the Water Crisis and Solutions.' The third section focuses on 'Efficacious Strategies for the Water Crisis,' detailing various human characteristics in depth. The fourth section provides 'Remarks on the Literature Review.'

### 2.1 Human behavioral characteristics and the water crisis

The relationship between human behavior and water utilization is a recurring theme in academic literature, indicating that successful management of the water crisis requires careful consideration of behavioral characteristics. The potential for integrating these characteristics into an encompassing framework is further illuminated by various studies [21]. For instance, individual and communal water consumption patterns, as highlighted by Brown and Matlock (2011), emphasize that behaviors, even those rooted in cultural or societal contexts, play a pivotal role in water usage. Recognizing and understanding these patterns is thus the first step in constructing a behavior-centric framework [22]. Such an understanding offers insights into potential points of intervention, suggesting that tailored strategies that resonate with specific behaviors can be more impactful [23].

The adoption of sustainable water practices is also heavily behavior-driven. It is outlined how the effectiveness of measures like rainwater harvesting or water-efficient appliances is largely contingent upon their acceptance by the target demographic [24]. Any comprehensive approach to the water crisis should focus on strategies that either align with current behavioral tendencies or attempt to shape them [13]. Adherence to water-related policies highlights the essential relationship between human behavior and successful water management [25]. A framework that understands the reasons for following or not following these policies will be better equipped to create strategies that promote compliance [25].

Human behaviors regarding water are shaped by several factors [26]. Societal norms are significant influencers, while economic incentives can also crucially shape consumption habits. Personal values, especially those centered on caring for the environment, can lead to water-saving behaviors [27]. For a framework to be truly effective, it should incorporate all these behavioral influences, ensuring that actions taken are comprehensive and address multiple aspects [28]. The core of managing the water crisis is closely linked to understanding human behavior. Although human behavior can be unpredictable and tends to focus on the short-term, a deep understanding of it can pave the way for tailored and efficient interventions [29]. The potential of community involvement and shared responsibility is also paramount in this context.

The balance between challenges and opportunities is also evident in specific human traits and their impact on water management. Positive traits, such as community participation, forward-thinking, and adaptability, result in sustainable actions, preemptive solutions, and beneficial community-led results [13]. On the other hand, behaviors like overconsumption, indifference, and reluctance to adapt can significantly impede efforts towards sustainable water management [30]. One significant observation is the existing gap in studies that connect the understanding of human behavior to the development of a comprehensive water crisis management framework. Current research often focuses either primarily on technical or behavioral aspects. Given the evolving challenges of the water crisis, influenced by factors like climate change and urbanization, strategies must be continuously reviewed and updated. In essence, while there's an undeniable link between human behavior and water management, the academic landscape, while rich with insights, seems to indicate an underlying need. This need, subtly hinted upon but not overtly explored, aligns with the necessity of integrating human behavioral characteristics into a holistic strategy for water crisis management. Such an approach would not only consider the challenges posed by human behavior but also leverage its potentialities, crafting a comprehensive and adaptable framework that stands resilient in the face of a dynamically evolving global water crisis.

### 2.2 Comprehensive frameworks for addressing the water crisis and solutions

The water crisis, which has widespread global implications, has led to an increase in academic discussions. Frameworks like Integrated Water Resource Management (IWRM) and the Water-Energy-Food (WEF) nexus have become notable topics of scholarly interest [31, 32]. IWRM aims to integrate water, land, and resource management for both economic and social betterment without harming ecosystems. However, its broad approach has drawn criticism, with some suggesting that its vast scope may pose challenges in practical application. On the other hand, the WEF

nexus emphasizes the interconnectedness of water, energy, and food systems [33]. This framework offers a deeper understanding of these interdependencies, promoting collaboration across sectors. Still, even with its holistic view, the integration of these sectors can introduce practical complexities. A recurring theme in these discussions is the potential oversight of adequately considering human behaviors in these strategies.

Implicit in this narrative is the idea that while these frameworks are pivotal, there's a latent need. This underlying sentiment suggests a bridge that merges the granularity of human behavioral characteristics into these frameworks, making them more holistic and impactful in addressing the water crisis. While not overtly articulated, the intertwined threads of human behaviors with water management strategies suggest the essence of the research question, spotlighting the importance of such an integration for a profound, sustainable solution.

### 2.3 Efficacious strategies for the water crisis

The connection between human behavior and sustainable water management has become a nuanced topic in academic discussions. Central to this conversation is the idea that technical and economic solutions, while crucial, aren't enough on their own [34]. A sustainable resolution to the water crisis also requires a deep understanding of human behavioral patterns [35]. For example, there's emphasis on the importance of culturally tailored public education campaigns. The idea is that when these campaigns are designed with a deep understanding of the target audience's behavioral tendencies, they are more effective. Likewise, while economic tactics like pricing policies can shift consumption patterns, their lasting impact is closely tied to understanding the varying economic behaviors within communities. This suggests that strategies, even if they make economic sense, must also be in tune with the behavioral standards of communities for enduring water conservation.

The significance of behavior in water management is further highlighted by discussions on behavioral nudges [35]. The effectiveness of these nudges, particularly in contexts like water consumption, doesn't only rely on their design. Their alignment with cultural norms is equally vital. Recent discourse indicates a shift from strategies centered primarily on technical or economic aspects to approaches that focus more on human behavior. The core message is clear: for water management strategies to make a lasting impact, they need to be designed with a comprehensive understanding of human behavior, rather than being applied in isolation.

Consequently, the subtle narrative woven through the literature culminates in a compelling argument. While the water crisis undoubtedly demands multifaceted interventions, there's an inescapable realization that without integrating human behavioral traits, these solutions might only yield transient success. In essence, policies and technical interventions might enforce compliance temporarily, but imbuing individuals with an intrinsic ethical compass promises lasting adherence [36]. This intrinsic alignment with sustainable practices, borne out of genuine understanding and appreciation, is posited to be the cornerstone of enduring solutions. The literature, therefore, gently nudges us towards the crux of the research question: the integration of human behavioral characteristics is not just beneficial, but perhaps indispensable, in devising a comprehensive framework for addressing the water crisis. Beyond the mechanics of interventions lies the human element, whose genuine commitment and voluntary participation can usher in a sustainable future. The ensuing sections of the study are poised to illuminate these crucial human traits and their profound influence on water management.

In light of the aforementioned discourse, the nexus between human characteristics and water management warrants a comprehensive examination [37]. For the purposes of this investigation, human characteristics have been divided into 'positive' and 'negative' classifications, with an exploration of their respective implications for water management [38]. A synthesis of extant literature reveals that various facets of human traits, including interpersonal, leadership, economic, political, geographical, natural, and scientific characteristics, exert influence on water-related challenges. These domains and their impacts will be elaborated upon in subsequent sections of this study.

This study formulates detailed hypotheses in line with established guidelines. Authors of review papers, aiming to consolidate extensive literature to gain a deeper understanding of a topic, often present more complex hypotheses due to the intricate nature of their work. Such comprehensive hypotheses help in providing clarity, weaving together multiple theories, and giving a richer perspective. Conversely, empirical studies, which are centered around verifying specific theories, generally opt for more concise hypotheses. This brevity is vital to maintain clear research objectives, streamline the methodology, and ensure a straightforward validation process. The depth and detail of a hypothesis should always be tailored to the context of the respective study.

## 2.4 Human factors in water management

In examining human characteristics pertinent to water issues and management, this study delves into a range of factors. These encompass personal attributes, leadership dynamics, economic considerations, and elements related to political, geographical, scientific, and technological advancements. The ensuing sections provide a detailed exploration of each of these dimensions.

### 2.4.1 Interpersonal characteristics

In the realm of sustainable water management (SWM), the influence of human behavioral traits plays a pivotal role. Among these traits, a tendency for disrespect has been identified as a significant barrier to effective SWM [39–45]. De Heinrich [46] expounds on how an attitude rooted in disrespect can lead to inequitable water distribution practices, which in turn can intensify mistrust and conflict [47–50]. Such dynamics are counterproductive to cooperative water management efforts, as emphasized by Srinivasan et al. [51]. Furthermore, it is suggested that this dismissive attitude could result in severe misuse of water resources [42, 52–54]. The trait of dishonesty is notably harmful and carries significant consequences for SWM [43, 45, 55]. Dishonesty weakens the core principles of transparency and accountability, which can further complicate decision-making [44, 47, 51]. The negative impacts of dishonest actions not only affect strategic planning but can also intensify inequalities in water distribution [49, 55]. Hence, understanding and addressing behavioral factors is essential in the realm of SWM.

Intolerance, with its roots in socio-political dynamics, can lead to exclusionary practices, thereby sidelining certain communities and magnifying disparities in water access [56]. Such an approach not only fosters inequality but also hampers the spirit of collaboration, which is indispensable for successful SWM [42]. On the other hand, there are behavioral traits that can enhance the efficacy of SWM [48]. Empathy stands out as a central driver, encouraging inclusivity and mutual understanding. Such feelings, anchored in our collective experiences, set the stage for joint initiatives in SWM [48]. Respect and honesty are also paramount. Respect champions fair practices, while honesty reinforces the crucial principles of transparency and accountability in SWM. Drawing from the intricate interplay of human behavioral traits and their consequent impacts on sustainable water management, there emerges a compelling rationale to probe deeper into this nexus [47]. The dichotomy of negative traits, such as disrespect, dishonesty, and intolerance, and their consequential challenges juxtaposed against the elevating influence of positive traits like empathy, respect, and honesty necessitates a comprehensive approach to water management strategies. Thus, culminating from the extensive literature synthesis, the following hypothesis is proposed:

*Hypothesis: Integrating an understanding of both positive and negative human behavioral characteristics into sustainable water management frameworks will significantly enhance the effectiveness, inclusiveness, and adaptability of interventions and strategies aimed at addressing the water crisis.*

This hypothesis underscores the imperative to holistically integrate behavioral insights into water management, suggesting that such an approach will not only mitigate challenges posed by detrimental behaviors but also harness the potential of positive traits to drive robust, lasting solutions.

### 2.4.2 Leadership characteristics

The management of water resources, one of the globe's most critical assets, is influenced significantly by leadership and the inherent behavioral characteristics of leaders. Irresponsibility, defined as insensitivity to the repercussions of one's actions, has the potential to cascade into detrimental decisions in the realm of Sustainable Water Management [57, 58]. For instance, a reckless disregard for the consequences can result in over-exploitation of water, underfunded infrastructure, and a lack of response to climate change. The tangible impacts of these decisions become apparent in the depletion of freshwater reservoirs, mishandling of marine resources, and a neglectful attitude towards the melting of glaciers. Decision-Making Theory" (Read and Van Leeuwen 1998), considers the dangers of emphasizing transient gains over lasting implications [54, 60, 61]. Such an approach could catalyze imprudent actions, like excessive water usage for short-term economic pursuits without acknowledging the future requisites or the broader ecological

ramifications [59, 62, 63]. This myopia in policy-making might overlook the indispensable need to safeguard glaciers or underestimate the potentialities of saltwater desalination [64, 65].

A significant leadership challenge in the realm of water management is inconsistency. Inconsistent leadership can lead to fluctuating water management strategies [66–68]. This constant shift in policies and guidelines hampers the development and execution of long-term strategies, whether they are related to water conservation or the efficient use of freshwater and marine reservoirs. Moreover, the accountability of leadership is crucial [54, 68]. A leader's willingness to be held responsible ensures that their actions are continuously monitored. In the context of sustainable water management, leadership accountability is vital to averting mistakes, promoting better conservation methods, ensuring detailed supervision of marine ecosystems, and to timely responses to changes in the cryosphere [69–71]. Transparency in leadership is also essential in fostering trust and cooperation among various stakeholders [72–74]. In water governance, transparent operations can enhance community involvement [57, 58, 60]. This active participation can further bolster water conservation efforts, wastewater processing efficiency, and raise awareness about the status of glaciers and ice caps [17, 75, 76].

Finally, the ability to think strategically is vital for visionary leadership within the domain of water management [57, 77–79]. By anticipating future needs and challenges, leaders can craft comprehensive plans that promote sustainable freshwater utilization, invest in saltwater desalination techniques, and formulate measures to counteract the implications of glacial melts [74, 78, 79]. Given the intricacies of these leadership behavioral traits and their profound influence on sustainable water management, a pivotal research question emerges: How can these human behavioral attributes be seamlessly integrated into a comprehensive blueprint to address the water crisis? More pertinently, in what capacity can this model expedite the inception and actualization of potent solutions?

*Hypothesis: Infusing a comprehensive water management framework with an understanding of leadership's behavioral traits will exponentially enhance the strategy's efficacy and adaptability, ultimately fostering the creation and deployment of transformative interventions for the global water crisis.*

### 2.4.3 Economic characteristics

Addressing the water crisis demands more than just technological and infrastructural solutions; understanding the economic characteristics influencing Sustainable Water Management is equally paramount [80]. Literature and economic theories shed light on how these characteristics impact the sustainable management of freshwater, saltwater, glaciers, and ice caps [81, 82]. Beginning with detrimental traits, financial irresponsibility emerges as a substantial concern. Drawing parallels with Hardin's "Tragedy of the Commons" (1968), financial irresponsibility results in the overutilization of shared assets, primarily water [47, 83, 84]. When entities prioritize short-term economic benefits, this invariably accelerates the depletion of shared water resources. Without judicious financial oversight, essential components of water management ranging from infrastructure maintenance to conservation initiatives—often remain inadequately funded [85–87]. This negligence precipitates the wastage of freshwater due to decaying infrastructure and leaves the untapped potential of saltwater resources, such as desalination projects, overlooked due to steep initial costs [87]. Alongside, economies marked by economic fragility face heightened vulnerability, particularly to exogenous shifts like climate-induced changes affecting glaciers and ice caps. Fragile economies, typically constricted by limited financial dexterity, grapple with adapting to these shifts. This inability to dynamically respond can exacerbate water scarcity, pushing the costs of clean water to prohibitive levels for most of the populace [86].

Conversely, positive economic traits present a silver lining. Financial responsibility, a cornerstone for sustainable development, emphasizes the prudence of resource allocation [82, 87–89]. Drawing insights from "Investment Decision Making in Finance" by Dixit and Pindyck (1994), in the realm of water management, financial responsibility translates to judicious investments in water-centric innovations, infrastructure enhancements for freshwater conservation, efficient saltwater desalination methodologies, and dedicated initiatives to monitor and counteract the alterations in glaciers and ice caps [41, 80, 81, 87]. Complementing this, economic resilience, as elucidated by Rose in "Building a Resilient Economy" (2007), epitomizes an economy's capability to weather adversities, be it environmental disruptions or demographic expansions [90]. Such resilient economies, capacitated by their adaptability, can pivot their strategies, channel investments into pioneering water sources, and upgrade water infrastructure implementing such measures, not only do we pave the way for a fortified water security framework, but we also democratize water access [86, 91]. This ensures that clean water becomes economically accessible to a wider segment of the population. Upon synthesizing the interplay of these



economic traits with sustainable water management, a pressing query emerges: How can these economic behavioral characteristics be holistically integrated into a strategic blueprint aimed at ameliorating the water crisis? Further, how can such a framework augment the inception and deployment of innovative strategies to confront this crisis effectively?

*Hypothesis: Incorporating a keen understanding of economic behavioral traits into a water management framework will markedly enhance its strategic depth, ensuring both sustainability and affordability. This integration will catalyze the formulation and execution of innovative interventions tailored to the diverse economic contexts, ultimately paving the way for a more resilient and equitable water future.*

#### 2.4.4 Political characteristics

Political characteristics wield considerable influence over sustainable water management. Their nuances, both positive and negative, not only shape policies and practices around water but also the broader narrative of equity and access. Delving into the intricacies of these characteristics provides valuable insights into how they mold the sustainable management of freshwater, saltwater, glaciers, and ice caps.

Beginning with the more daunting characteristics, authoritarianism is notably prominent. An authoritarian approach can often bias water policies, favoring the needs of a select few over the broader population. This centralized decision-making style can result in missteps such as the mishandling of freshwater sources, neglect of saltwater ecosystems, or even undermining the ecological relevance of glaciers and ice caps [92, 93]. This autocratic shadow deepens with the menace of corruption. Corruption can erode the core principles of water management [94–96]. Whether through misappropriating funds designated for essential water infrastructure or malignly manipulating water access, corruption exacerbates imbalances in water distribution, jeopardizing the basic human entitlement to water [97–100]. Moreover, the pervasive influence of unfairness can hinder just water distribution, pushing already marginalized communities further to the fringes, and increasing strain on freshwater resources, often overlooking viable alternatives like saltwater desalination [41, 101–103].

Conversely, certain positive political attributes hold the potential to promote both sustainable and equitable water management [98, 103, 104]. Diplomacy, a vital instrument for international collaboration, acts as a defense against possible water-related conflicts [105, 106]. Through promoting cooperation over shared water resources, diplomacy not only preserves these assets but also protects global treasures such as glaciers and ice caps [73, 107, 108]. The principle of justice, deeply embedded in ecological equity, ensures that water policies prioritize fairness, advocating for every individual and community. This equitable emphasis extends to both freshwater and saltwater domains [43, 109]. Supporting these commendable attributes is the adherence to the rule of law, which emphasizes the importance of sound legislation that delineates water rights, outlines clear directives for water utilization, and promotes sustainable practices [110, 111]. Such a legal foundation not only guarantees just water distribution but also optimizes the value extracted from freshwater and saltwater sources, all while staunchly defending significant global resources like glaciers and ice caps [44, 97].

Given this intricate tapestry of political characteristics and their ramifications for sustainable water management, a pivotal inquiry surfaces: How might the interplay of these human behavioral attributes be amalgamated into a cohesive framework to robustly confront the water crisis? Furthermore, how might such a construct galvanize the genesis and enactment of pioneering interventions and strategies?

*Hypothesis: A framework that interactively harnesses both the positive and mitigates the negative political characteristics holds the promise to revolutionize Sustainable Water Management. Such an approach would not only ensure water accessibility and equity but would also inspire the development and execution of innovative, holistic strategies, anchoring a future where water sustains life rather than becoming a source of strife.*

#### 2.4.5 Geographical and natural characteristics

Geographical and natural characteristics undeniably wield a substantial influence on sustainable water management, shaping our interactions with freshwater, saltwater, glaciers, and ice caps [112, 113]. These characteristics, as illustrated in various academic sources, sketch a path of either degradation or conservation, contingent upon the prevailing attitudes and actions of societies [113]. Foremost, several negative characteristics present ominous implications for our water resources [114–116]. The culture of wastefulness, for instance, does not merely reflect an excessive consumption of water but also encapsulates the broader disregard for its long-term availability and

health. Such behavior jeopardizes not only our freshwater sources but also neglects the potential of saltwater through sustainable methods like desalination [117–120]. Equally troubling is the destruction of nature, an aspect meticulously explored in “The Economics of Ecosystems and Biodiversity” (TEEB, 2010). This work throws into sharp relief the multifaceted repercussions of human interference on natural water habitats [121–123]. Without checks, this interference can manifest in the obliteration of watersheds, contamination of both freshwater and saltwater ecosystems, and an unnaturally rapid melting of glaciers and ice caps [124]. Underpinning these behaviors is unsustainability.

The renowned Brundtland Report, titled “Our Common Future” (1987), underscores the pitfalls of short-term practices that threaten both the environment and future generations [125]. Viewed from this perspective, water management risks tipping into over-extraction, intensifying environmental threats, and causing lasting ecological harm [126–128]. Central to this is the tenet of sustainability. Grounded in the pioneering “Limits to Growth” theory by Meadows et al. (1972) and later nuanced by the Brundtland Report, sustainability becomes the compass guiding our interaction with water [128–131]. This philosophy propels communities to harness freshwater judiciously, innovate in saltwater utilization sustainably, and engage in mindful endeavors that mitigate the melting of glaciers and ice caps. Complementing sustainability are the virtues of conservation and a “love for nature” [120, 132–136]. These traits drive societies to protect water habitats, engage in restoration projects, and nurture a profound respect for the intricate balance of natural water ecosystems [44, 137]. With these geographical and natural characteristics laid bare, the inquiry then shifts: How can we assimilate these human behavioral tendencies into a cohesive framework poised to address the burgeoning water crisis? Furthermore, can such an integrated approach not only illuminate the issues at hand but also catalyze the formulation and deployment of effective strategies and interventions?

*Hypothesis: By holistically integrating both the positive and counteracting the negative geographical and natural characteristics, a robust framework emerges for sustainable water management. This paradigm, grounded in respect for nature and foresight, has the potential to revolutionize our water interactions, spawning interventions that are both innovative and effective, and ensuring water remains a sustaining force for generations to come.*

#### 2.4.6 Scientific characteristics

Scientific characteristics, as evidenced by an array of literature, hold a pivotal position in the discourse on sustainable water management. These characteristics, both constructive and detrimental, intertwine with our interactions with freshwater, saltwater, glaciers, and ice caps, guiding the trajectories of our water strategies [138, 139]. The detrimental side of scientific characteristics, including closed-mindedness and unethical scientific practices, raises serious challenges [123, 140, 141]. Closed-mindedness acts as a stumbling block in water management. Such a mindset obstructs the inclusion of new scientific findings, resulting in opposition to technological progress and a clinging to obsolete methods [123, 140, 141]. This resistance has several implications, potentially stagnating the progression in water management and continuing inefficient approaches. The uprightness of scientific procedures is paramount for steering successful and sustainable water management. When research deviates from ethical standards, it jeopardizes the essence of sustainable water management [84, 142–144].

Conversely, the brighter spectrum of scientific attributes provides hope [86, 123, 145]. Traits such as curiosity, objectivity, and ethical research form the backbone of sustainable water initiatives. Curiosity fuels innovation in water management, prompting the exploration of novel solutions, from advanced conservation measures to strategies addressing glacier melt [146–150]. Objectivity is crucial, ensuring research remains free from prejudices, thereby shaping water policies rooted in factual evidence [143, 151–154]. Such a factual base makes sure water strategies are efficient, maximizing the potential of both freshwater and saltwater resources while addressing the environmental changes impacting glaciers and ice caps. Moreover, ethical research upholds the integrity of scientific pursuits, assuring their trustworthiness and ethical application [155–158].

Given this intricate weave of scientific characteristics, a pertinent question emerges: Can the constructive momentum of positive scientific traits be harnessed while simultaneously countering the detrimental aspects to shape a comprehensive framework to tackle the water crisis? How might such a fusion of human scientific behaviors enhance the design and realization of potent interventions and strategies?

*Hypothesis: Integrating positive scientific characteristics while actively mitigating the negative ones can forge a robust, adaptive, and ethical framework for sustainable water management. This framework, rooted in curiosity, objectivity, and ethical rigor, is poised to catalyze impactful interventions, ensuring that water, a life-essential resource, is managed with the diligence and innovation it merits.*

#### 2.4.7 Digital technology traits

In the extensive academic landscape, a notable surge in interest can be observed regarding digital leadership skills and their integration across diverse sectors, including management, social media, and environmental considerations [159, 160]. Yet, there remains a discernible gap in understanding the applicability of these within the sphere of water management and crises [161, 162]. Despite exhaustive literature explorations, there appears to be a dearth of relevant studies in this specific area. As digital technologies become more central to contemporary water governance, the incorporation of digital leadership skills becomes increasingly vital for efficient water resource governance [140, 160]. This evident gap emphasizes the need for more focused research and highlights the importance of these skills in ethical water management discussions.

The increasing application of blockchain technology across varied sectors, such as smart grids, societal progression, sustainability, and IoT security, is evident [163]. However, its application to water management is still nascent. Some initial investigations have hinted at the utility of blockchain in areas like “smart watering system security technologies” and blockchain-based cybersecurity [140, 162, 164]. The transformative nature of blockchain calls for a deeper dive into its unique benefits and contributions to water management and security [164, 165]. Furthermore, some studies have begun to explore the intricate relationship between online misinformation campaigns, e-government models, and water management. These works suggest the complexities introduced by misinformation in shaping water policies and propose that e-government approaches could enhance transparency and efficiency in water governance [160].

A more in-depth exploration of such studies could provide clearer insights into the interplay between digital communication, governance models, and prudent water resource management. There’s a glaring absence of discussion in literature of the intersection of environmental data misuse, environmental sensors, and IoT technology within water management’s context [166]. While various research endeavors delve into water management topics, a concentrated study on the potential misappropriation of data remains lacking [167]. The potential roles that sensors and IoT might play, either as exacerbating factors or solutions, are still largely unexplored [164, 166]. This gap underscores the urgency to study these elements’ collective effects on water management, especially given the ethical imperative to handle environmental data responsibly for sustainable outcomes. Unfortunately, harmful actions, such as data tampering or misuse of water technologies, can distort policy formulations, leading to uneven distribution of water security benefits. It’s imperative to note that both the beneficial and harmful facets of these practices exist, particularly considering the pivotal role that scientific data manipulation could play in water management frameworks.

So, the meticulous synthesis of the literature evinces the imperative to integrate these variables into a comprehensive framework for water management and addressing the water crisis. Such a framework would provide a holistic understanding, blending technological advancements with ethical considerations, to ensure sustainable and equitable water governance for the future.

*Hypothesis: Integrating positive digital technology traits like blockchain technology and E-government initiatives, while actively mitigating challenges such as cyberbullying and online disinformation campaigns, can forge a robust, adaptive, and ethical framework for sustainable water management. This framework, when applied, promises enhanced transparency, security, and efficiency in water resource governance.*

#### 2.5 Remarks on the literature review

Despite the extensive body of research on water crises, a significant gap in the literature exists: there is a dearth of comprehensive studies that systematically examine the relationship between diverse human characteristics and global water crises [160, 168]. Most of the research conducted thus far has focused on technical and policy-oriented aspects of water management and conservation [169]. While these approaches are undoubtedly important, they often overlook the considerable role that human behaviors and characteristics play in water scarcity and mismanagement [170].

Furthermore, the few studies that have delved into the impact of human behaviors have largely focused on specific characteristics like justice and equity, leaving a substantial portion of other influential traits unexplored [171, 172]. Traits

such as greed, unethical behavior, misuse of power, general unfairness, etc. have been identified as contributing to water crises [171], but have not been thoroughly investigated within a holistic framework. This lack of study leaves a significant gap in our understanding of how these traits affect water resource management on a global scale and, more importantly, how positive traits can be fostered to mitigate these [173]. There is a noticeable absence of comprehensive frameworks that compile and systematize these human characteristics to provide a holistic understanding of their effects on the global water crisis [174]. Such a framework could guide future research and policy-making, contributing substantially to our efforts to tackle water scarcity. It is noteworthy that many researchers acknowledge that water, being a fundamental requirement for all life forms on Earth, is not intrinsically scarce. Instead, it is human behaviors that are largely contributing to the creation of water crises. This perspective can be elucidated as follows:

It is possible to infer a concept of balance and equilibrium from our understanding of natural systems, including the water cycle. Water, as a resource, is indeed crucial to life and can be found throughout our planet, showing a sort of balance. Virtually all living beings, whether human, animal, or plant, need water to survive and thrive. The way that water cycles through our world, from the oceans to the atmosphere, and back down to the land, demonstrates a kind of natural balance. With around 97.5% saltwater and 2.5% freshwater, Earth's water circulation also appears to be in some form of balance. Of this 2.5%, a significant portion is locked in ice caps and glaciers, a smaller portion is groundwater, and an even smaller amount is surface water, which is readily accessible for human use. Despite these apparent abnormalities, the Earth's water system has sustained a variety of living forms for billions of years.

However, humans are disrupting this natural balance by polluting water sources and using them at unsustainable rates. Climate change, largely driven by human activities, is also altering the distribution and availability of freshwater resources. These actions underscore the importance of sustainable water management to restore and maintain the balance of water resources on Earth. For academic support, there are several articles and books discussing the concept of water balance and sustainable management, such as "Water in Crisis: A Guide to the World's Fresh Water Resources" by Peter H. Gleick (1993) and "Global Water Ethics: Towards a global ethics charter" by Rafael Ziegler and David Groenfeldt [171].

Different authors have discussed both directly and indirectly that human traits play a role in creating water issues and influencing water management. As illustrated in Table 1, some studies examine the direct relationship between leadership and water management. In explaining their findings, they justify that due to corrupt leadership, water issues remain unresolved. This study contributes by addressing these gaps, investigating a broad variety of human qualities, both positive and negative, and unfolding how they connect to the worldwide water dilemma. By compiling these characteristics and presenting them within a comprehensive framework, the study intends to shed light on previously overlooked dimensions of the water crisis and contribute to a more complete, multidimensional understanding of this global challenge.

### 3 Research methodology

To comprehend how human behavioral characteristics can be integrated into a framework to address the water crisis and its potential ramifications, three tasks were undertaken. Firstly, a systematic literature review was conducted, following a four-phase approach based on the Cochrane Handbook and Policies for Systematic Reviews of Interventions (Higgins and Green) [175], as depicted in Fig. 1. Secondly, a thematic analysis in six steps, as outlined by Braun and Clarke (2006), was employed to categorize variables for the development of the framework [176]. To create a coherent framework, one needs to systematically categorize the variables involved. One effective approach for categorization and understanding patterns is thematic analysis. This method involves identifying, analyzing, and reporting patterns (themes) within the data. Due to its structured nature and ability to capture intricacies within large data sets, thematic analysis has gained popularity in various research contexts. When applied correctly, it can provide invaluable insights, making the process of framework development more grounded and comprehensive [177–179]. Lastly, the framework was presented to two experts to validate its credibility. Validating a conceptual framework in social sciences and humanities is essential for maintaining research integrity and robustness [180]. As the foundation of a study, the framework details key theories and concepts. Expert review introduces diverse perspectives, ensuring a comprehensive and objective approach. These experts also enhance framework clarity, confirm its relevance to contemporary literature, and ensure alignment with research goals. This validation process, therefore, bolsters research quality and adheres to ethical standards [180].

In the first phase of the systematic review, the literature review encompassed publications from 1991 to 2023. Data were sourced from a comprehensive collection of peer-reviewed articles, books, and other academic materials, focusing on works published within the specified timeframe. Prominent databases such as Scopus, Web of Science, Google Scholar,

and JSTOR were exhaustively searched to retrieve pertinent documents. In phase two, a stringent filtering mechanism was employed to maintain focus and omit unrelated content, ensuring the review's pertinence to the association between human characteristics and water-related challenges. The search strategy was further sharpened using key terms, including "human behaviors in water conservation" and "psychological determinants of water consumption, etc."

Phase three entailed the synthesis of the accumulated data, prioritizing materials that underscored human behavioral patterns in the context of water management and conservation. Of the initial set of 336 academic contributions, 150 were ruled out based on quality standards and duplication, and 2 more were found to be irrelevant to the primary research focus, leaving a concentrated group of 184 articles suitable for in-depth review. After excluding unrelated studies, the total number of studies analyzed was 149, as shown in Fig. 1.

## 4 Results and discussion

The analysis, referencing data from Table 2, specifically identifies and dissects the varied human behaviors that impact water management. It moves beyond general discussions of interpersonal dynamics to delve into how specific traits such as dishonesty and intolerance lead to conflicts and mistrust, disrupting equitable water distribution. This detailed exploration aligns with theories like Homer-Dixon's "Environmental Scarcities and Violent Conflict" and Ostrom's "Common Pool Resources," which illustrate the consequences of such behaviors on water management. Distinct attention is given to the influence of leadership styles on water policies. Instead of broadly categorizing leadership, the analysis delves into how specific leadership styles, such as participative versus autocratic, impact water management differently. This includes an exploration of case studies like Brazil's approach to managing the Amazon Basin, demonstrating the varied effects of leadership decisions on water regulation (Table 3).

The economic dimension is addressed by examining specific economic policies and their direct impacts on water management. This segment moves away from general economic models to focus on policies, like the influence of agricultural subsidies on water conservation. This approach offers a more concrete understanding of how economic decisions affect water resources. Political ideologies and policies are explored in the context of their direct influence on water resource

**Table 2** Thematic analysis of the water crisis to develop a comprehensive framework

Step of thematic analysis	Description
Step 1 Familiarization with the Data	Immersed in the data by reviewing the tables outlining both negative and positive traits affecting the water crisis and solutions
Step 2 Generating Initial Codes	Identified initial codes related to interpersonal characteristics (e.g., respect, dishonesty, empathy, conflict, and fair distribution), leadership traits (e.g., accountability, irresponsibility, transparency, and strategy), economic factors (e.g., financial responsibility/irresponsibility, economic resilience, and scarcity), political factors (e.g., diplomacy, authoritarianism, fair policies, and corruption), geographical/natural factors (e.g., sustainability, wastefulness, conservation, and pollution), and scientific factors (e.g., curiosity, closed-mindedness, ethical research, and unsustainable use)
Step 3 Searching for Themes	Grouped the initial codes into six themes: interpersonal dynamics, leadership & governance, economic influences, political landscape, environmental impacts, and scientific engagement
Step 4 Reviewing Themes	Analyzed the overlap between the themes and refined them. For example, distinguished between internal organizational behaviors in leadership & governance vs. broader political strategies in the political landscape
Step 5 Defining and Naming Themes	Defined and named the six themes as follows: <ul style="list-style-type: none"> <li>* Interpersonal dynamics: Individual and group behavior related to water issues</li> <li>* Leadership &amp; governance: How organizations impact water management</li> <li>* Economic influences: The monetary aspects influencing water issues</li> <li>* Political landscape: The societal structures related to water distribution and access</li> <li>* Environmental impacts: The human effects on nature and water</li> <li>* Scientific engagement: The dual role of science in water crises</li> </ul>
Step 6 Developing Framework	Concluded that the water crisis can be understood through six core themes which encompass both negative and positive human behaviors. These themes elucidate human influence on water from personal interactions to societal structures. By recognizing these patterns, the root causes of the crisis become apparent, guiding potential solutions. However, based on themes the framework of the study is developed

Source: Author

**Table 3** Thematic analysis framework for human behavioral characteristics in addressing the water crisis

Code	Characteristic type	Main theme	Negative sub-theme	Positive sub-theme
Compassion, Regard Integrity, Equity	Interpersonal	Interpersonal Characteristics	Disrespect, Dishonesty Intolerance, Conflict & Unfair Water Distribution	Empath, Respect, Honesty & Fair Distribution
Accountability, Clarity Strategy, Governance	Leadership	Leadership Traits	Irresponsibility, Short-sightedness & Poor Water Management	Accountability, Transparency & Strategic Water Management
Financial Ethics, Resilience, Economic Security, Stability	Economic	Economic Traits	Financial Irresponsibility, Economic Fragility & Water Scarcity	Financial Responsibility, Economic Resilience & Improved Water Security
Diplomacy, Just Governance, Fairness, policy alignment	Political	Political Traits	Authoritarianism, Corruption & Unfair Water Policies	Diplomacy, Justice & Fair Water Policies
Environmental Ethics, Preservation, Clean Water, resource protection	Geographical/Natural	Geographical/Natural Traits	Wastefulness, Nature Destruction Water Pollution & Overuse	Sustainability, Conservation & Protection of Water Sources
Inquisitiveness, ethical science, Research Integrity, Sustainable Practice	Scientific	Scientific Traits	Closed-mindedness, Unethical Practices & Unsustainable Water Use	Curiosity, Objectivity & Ethical Research
Digital Blockchain Technology, E-Government, Cybersecurity Threats, Online Disinformation Campaigns, Environmental Data Misuse	Digital Technology	Digital Technology Traits	Cyberbullying, Online Harassment, Digital Divide, Cybersecurity Threats, Online Disinformation Campaigns and Data Manipulation	Online Collaborative, Digital Leadership Skills, Blockchain Technology, E-Government Initiatives, Environmental Sensors and IoT, Data-driven Decision Support Systems and Online Collaborative Platforms

Source: Author

management. The analysis looks at specific political decisions and regulations, using the management of the Nile River as a case study to demonstrate the real-world impact of these policies. Environmental and scientific factors are considered, with a particular emphasis on the implications of climate change for water availability in specific regions. This section moves beyond general discussions of environmental impact to focus on concrete examples, such as the effects of climate change on water resources in Sub-Saharan Africa and the role of scientific innovations in addressing these challenges.

Finally, the role of technology in water management is examined through the lens of specific tools and their ethical implications. The analysis covers the utilization of digital tools like IoT for water usage monitoring and the ethical considerations surrounding large-scale desalination technologies [95]. Further reinforcing the importance of fostering positive behaviors, “Cialdini’s Social Norms Theory” and Schlosberg’s “Environmental Justice Theory” accentuate the criticality of traits like honesty and empathy for achieving sustainable and equitable water management. This sentiment is echoed in the “Stakeholder Theory” by Freeman and communication-centric theories, such as the two-way symmetric model by Grunig and Grunig. They collectively underscore the necessity of an open, candid, and respectful stakeholder engagement process for optimizing water management [159].

Second, the influence of leadership characteristics on water management, both positive and negative, is undeniably significant. On one hand, traits such as accountability, transparency, and strategic thinking are vital for instituting effective water management practices. These characteristics not only ensure an adequate supply of water but also guarantee its equitable distribution. Conversely, poor leadership, manifested through traits like irresponsibility, short-sightedness, and inconsistency, can sow seeds of discord and mistrust within communities. The consequences of such leadership shortcomings are grim: mismanagement, unequal water distribution, and escalated water conservation challenges that may culminate in a water crisis. The study closely examines the role of leadership in water management by applying the “Transformational Leadership” theory (Bass) [159]. It highlights how positive leadership traits like accountability and strategic thinking contribute to effective water management. In contrast, the analysis also considers negative leadership aspects, referencing the “Myopic Decision-Making Theory” (Read and Van Leeuwen, 1998) and “Leadership and the Psychology of Power” (Magee and Galinsky) [160]. These theories help explain how traits like short-sightedness and irresponsibility in leadership can lead to water mismanagement and crisis.

Furthermore, the “Public Value Management” framework (Moore, 1995) serves as a poignant reminder of the indispensability of leadership traits like transparency, accountability, and strategic thinking in public service [162]. Particularly for sectors as crucial as water supply and distribution, the role of effective leadership cannot be overstated. Cumulatively, these theories fortify the argument that leadership characteristics are monumental in dictating the trajectory of sustainable water management—positive traits propel the sustainability agenda, while negative ones jeopardize it.

Third, the intricate relationship between economic characteristics and water management is a pivotal insight from this study. Notably, negative economic traits such as financial irresponsibility and economic fragility can lead to suboptimal utilization of resources, potentially exacerbating water scarcity and resulting in increased prices for potable water. On the flip side, positive economic attributes like financial responsibility and economic resilience can promote efficient resource allocation, ensuring enhanced water security and making water more affordable for consumers. The economic dimension is explored by linking specific economic policies to their impact on water management. This is contextualized within the “Resource Allocation Theory” [181] and the concept of the “Tragedy of the Commons”, illustrating how financial decisions influence water conservation and scarcity. Similarly, the concept of the “Tragedy of the Commons” provides a lens to understand how unregulated use of shared resources can lead to their rapid depletion, echoing our findings of water scarcity and heightened prices due to economic mismanagement.

Adding more depth, the Keynesian economic theory offers insights into how economic resilience—often underpinned by strategic government interventions—can act as a catalyst for efficient resource management, further augmenting water security [41]. Reinforcing this perspective, the concept of fiscal responsibility posits that judicious financial stewardship, particularly by governing authorities, can substantially optimize water resource allocations. Such economic prudence directly translates to improved water security and its sustained affordability.

Fourth, the complex interrelation between political characteristics and water management has emerged as a pivotal point in our study. It has been identified that negative political attributes, specifically authoritarianism, corruption, and unfairness, are instrumental in crafting water policies that unduly favor certain groups. This partiality culminates in an unequal distribution of water resources, invariably leading to the blatant violation of water rights [41]. Conversely, our findings indicate that positive political traits such as diplomacy, fairness, and an unwavering commitment to the rule of law can act as pillars for the formulation of water laws. These laws not only ensure the sanctity of universal water rights but also facilitate equitable access to this vital resource [101].

To situate our observations within the broader academic landscape, a reflection on existing political and legal theories is necessary. Theories of political corruption aptly delineate the potential detrimental effects of corruption on resource allocation. The study delves into political characteristics, applying theories of political corruption and democratic peace theory [119] to examine how different political traits affect water management. The focus is on the repercussions of authoritarianism, corruption, and unfairness on water distribution and accessibility.

Fifth, the role of geographical and natural characteristics in the realm of sustainable water management is of paramount importance. Our study has unveiled that detrimental geographical and natural behaviors, such as wasteful consumption patterns, accelerate the depletion of water resources at a pace that surpasses their natural replenishment rate, inevitably ushering in water scarcity. Compounded by actions that devastate natural habitats—deforestation, wetland drainage, and the obliteration of other critical water sources—the water cycle is disrupted [119]. This not only diminishes the inherent ability of nature to purify water but also accentuates soil erosion. Such erosion deposits sediments in water bodies, augmenting water pollution. Equally alarming is the lack of environmental prudence in various practices. Unrestrained industrial growth, coupled with injudicious utilization of fertilizers and pesticides in agriculture, becomes a conduit for introducing noxious substances into water ecosystems, intensifying water pollution.

Contrastingly, our findings also shed light on the myriad benefits of water conservation and responsible ecological behaviors. A conscious effort to minimize water wastage, bolstered by strategies to shield water sources through the retention of natural ecosystems and the enforcement of pollution control norms, can significantly enhance both the quality and quantity of water. Furthermore, initiatives like treating industrial wastewater and championing organic farming practices can substantially mitigate water contamination [119]. At the crux of this discussion is water security, which requires a harmonious amalgamation of the measures, synergized with astute policy strategies that guarantee every individual has equitable access to uncontaminated water. Thus, staving off potential water crises.

To embed our observations within a broader academic tapestry, we draw parallels with established environmental theories. The “Theory of Island Biogeography” emphasizes the essence of conservation practices [182]. These practices, encompassing water conservation and pollution mitigation, are crucial for the protection of water resources. On the other hand, neglect and ecological degradation can lead to water resource depletion, pollution, and hence, water insecurity. The biophilia hypothesis highlights the deep bond humans have with nature. This inherent connection can be leveraged to promote responsible care of water sources, driving efforts around water conservation, pollution control, and holistic water security [182]. As noted by the United Nations, a staggering 80% of worldwide wastewater is released without treatment [183]. Agriculture stands out as a major polluter, underlining the urgent need for wise practices. The extent and severity of water pollution differ regionally, with areas characterized by heavy industrialization or farming facing heightened pollution levels [184].

Sixth, the intricate relationship between scientific attributes and water management has been the focal point of this study. Our findings illuminate that certain pivotal scientific traits bear a pronounced influence on sustainable water management practices. Detrimental attitudes, primarily characterized by closed-mindedness and unethical scientific practices, can result in the wholesale disregard of valuable scientific counsel on water management. Such an attitude also creates fertile ground for the misuse of technology, culminating in environmentally detrimental water practices. In stark contrast, the infusion of positive scientific attributes, namely curiosity, objectivity, and ethical research orientation, cultivates a methodical and science-backed approach to water conservation [140]. Embracing these virtues facilitates the judicious implementation of scientific recommendations on water management. Moreover, it propels technological innovation, leading to water utilization in a manner that is both efficient and sustainable [86].

By juxtaposing our findings with established academic theories, deeper insights emerge. The theory of scientific development accentuates the indispensable role of qualities like openness and curiosity in scientific progression. Applying this to our domain, these traits can substantially enhance the methodologies employed in water management [86]. Furthermore, the principles of ethical research highlight the paramount importance of objectivity and unwavering integrity in scientific endeavors. When applied to water management, it becomes clear that the ethical application of technology is crucial [84]. Delving further, our study’s observations about the consequences of ignoring scientific advice and the potential pitfalls of technological misuse resonate with the norms of science. Any deviation from these established scientific norms equates to malpractice. In the context of our study, such deviations can lead to environmentally detrimental water practices. Seventh, the study delves into how the advent of digital technologies reshapes water management strategies. It highlights the critical role of accurate data collection, analysis, and real-time reporting facilitated by these technologies. Online collaborative platforms emerge as key tools, fostering dialogue among a wide range of stakeholders and enabling integrative decision-making for adaptive water management strategies [162]. Digital leaders, adept at utilizing digital tools, are increasingly pivotal in shaping sustainable water management practices. Their expertise in



digital data synthesis and promotion of sustainable digital initiatives is crucial for effective water conservation [160]. The introduction of blockchain technology in water management is a game-changer, offering unprecedented transparent and accountability in water transactions and rights [163]. E-government initiatives complement this by digitizing water-related public services, thus improving public engagement and the efficiency of water resource allocation [167]. Additionally, environmental sensors and the Internet of Things (IoT) are transforming water monitoring practices. They provide real-time data on water quality and consumption, aiding in timely interventions to ensure water sustainability. Data-driven decision support systems further utilize this plethora of information, offering actionable intelligence for water management and predicting potential scarcities and inefficiencies [167].

However, the study also cautions against the challenges posed by the digital landscape. It discusses how misalignment of digital traits with water management standards can lead to suboptimal decision-making. Issues like cyberbullying and online harassment can affect stakeholder participation in water management discussions, potentially impeding effective communication and strategy development [140]. The digital divide poses another significant challenge, potentially excluding certain communities from essential water management conversations [166]. Cybersecurity vulnerabilities and the risk of data manipulation further complicate the landscape, as they can lead to misguided water management strategies [160].

Moreover, the threat of online disinformation campaigns is highlighted, which can mislead both the public and policy-makers with incorrect information about water resources, leading to poor decision-making [166]. The study underscores the importance of addressing these digital challenges to ensure the effective and sustainable management of water resources. This balanced perspective is supported by existing literature [163], reinforcing the need for cautious navigation of the digital age in water management.

## 5 Conclusion

The escalating implications of water scarcity are increasingly evident in regions like the Middle East, Africa, South Asia, Central Asia, and the Americas. This situation, marked by a complex tapestry of global water conflict, has been the focus of many scholarly investigations, predominantly in the technical and policy domains of water management. Despite acknowledging the influence of interpersonal, leadership, economic, political, and technological factors on water management, no study has yet integrated these diverse human traits into a comprehensive framework for sustainable water solutions. This gap underscores the need for a more holistic approach that encompasses these varied dimensions. This study addresses the question: "How can diverse human behavioral characteristics be synthesized into a comprehensive framework to offer sustainable solutions for the global water crisis?" A systematic review of literature was conducted to gather relevant information on human traits affecting water management. This was followed by a thematic analysis to categorize main and sub-themes within the water crisis context. Face-to-face consultations with domain experts ensured the reliability and relevance of the proposed framework. The study concludes that water scarcity is less about physical scarcity and more about the complex interplay of human behaviors affecting its availability and distribution.

## 6 The implication of the research

This research broadens the scope of water dispute inquiries beyond technical and policy aspects to include human behavioral dynamics. It challenges conventional perceptions of water scarcity as a purely physical issue, positioning it within a broader socio-behavioral context. The study identifies a gap in existing literature: the absence of an integrated framework that combines various human dimensions influencing water management. By proposing such a framework, the study promotes a unified understanding of water-related challenges. Methodologically, the study's comprehensive approach sets a standard for future research. However, there are inherent limitations in its scope and potential biases in systematic reviews and expert consultations. Future research should delve deeper into human attributes and their connection to sustainable water practices, using both secondary and primary data. The study's alignment with global sustainable development goals opens avenues for practical application of its findings. Future studies should explore how to operationalize the framework in creating sustainable strategies that resonate with human intricacies.

## 7 Limitation and future research guide

The study's integrated framework, while groundbreaking, has limitations in the breadth and depth of exploration within each facet. Methodological biases and constraints in accessing a wider range of primary data might influence the insights. Future research should aim for a more detailed exploration, utilizing both secondary and primary data sources. Understanding the human-centric perspective on water scarcity offers a new paradigm for investigation. Future studies should focus on developing strategies and interventions that consider human behavior's multifaceted implications. The call for interdisciplinary collaboration should guide future research, fostering holistic and innovative solutions for the global water crisis.

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### Declarations

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