




# Water strategies and management: current paths to sustainable water use

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## Abstract

Freshwater is unquestionably the most crucial resource essential for the sustenance and advancement of humankind. This invaluable entity surpasses all societal, economic, and environmental domains, consequently rendering it a ubiquitous good. Globally, it has been estimated that the industrial sector employs approximately 20% of the available freshwater. The principal aim within the industrial domain is to maximize production efficiency, rather than prioritizing the enhancement of water conservation and efficiency. Research suggests that a favorable association exists between the monetary investments made in technological improvements for industrial water treatment and reuse and a profitable return on investment that is sustained over a prolonged duration. This could plausibly explain the dearth of willingness exhibited by some corporations in dedicating resources to this vital issue. The objective of this study is to explicate the notion of sustainability concerning water management that can be operationalized in the context of Pakistan, while delving into the latest advancements in the sphere of sustainable management practices. This research endeavor shall serve as an instructive source for executives, entrepreneurs, and vested parties in various industrial domains to propel their endeavors toward sustainable practices while simultaneously achieving optimization and surpassing the benchmarks set by national regulations and international establishments. This investigation has illuminated the imperative of executing an all-encompassing water management strategy that incorporates the ecological, financial, and societal dimensions as the essential constituents of viability in industrial water utilization. This work ought to possess a worldwide scope, bearing in mind the ubiquitous character of industrial practices in the epoch of globalization.

**Keywords** Water management · Economic development · Sustainability · Future challenges · Water supply demand

## Introduction

Water plays a crucial and indispensable role in the sustenance of life, facilitation of economic prosperity, assurance of ecological security, and the advancement of human civilization. Despite these fundamental roles, the exponential rise in population, rapid urbanization, intensified economic development, unprecedented technological innovations, drastic alterations in land cover, as well as the impact of climate change, have collectively culminated in a global crisis in water supply (Biswas et al. 2022). Globally, a staggering number exceeding two billion individuals are unjustly deprived of the fundamental privilege of accessing safe and potable water; while, a further four billion people are

bereft of the opportunity to avail appropriately monitored sanitation facilities. Water-borne illnesses are responsible for causing approximately 2.5 million people die (Qamar et al. 2022). The indiscriminate discharge of over 80% of wastewater originating from industrial and municipal activities into rivers or oceans without any prior treatment has resulted in deleterious consequences. This flagrant and culpable practice has culminated in an alarming 800,000 fatalities in the year 2012 alone (Sun et al. 2020), besides inflicting profound harm on fisheries, sustenance, and trophic cascades (Soomro et al. 2023a, b, c). The World Economic Forum has identified the water supply crisis as a foremost global crisis that will be confronted in the forthcoming decade (Evans et al. 2017). In light of the present predicament, the management and utilization of water resources have emerged as pivotal factors in realizing the Sustainable Development

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Goals articulated by the United Nations (Kurian & Policy 2017). Similar to numerous developing countries worldwide, Pakistan faces a variety of challenges related to the management of water resources. To tackle the worldwide water predicament, numerous techniques for managing water resources have been formulated within the previous decades, encompassing supply management, demand management, and integrated water resources management (Saravanan et al. 2009). Historically, the administration of the distribution of water has played a vital role in meeting the growing demand for water through the construction of intricate water infrastructure such as dams, reservoirs, and transfer schemes. Such undertakings facilitate the provision of water to various consumers within a specific locality. Demand management is a strategic approach that prioritizes the proficient management of water demands by employing institutional methodologies and technologies that conserve water. The strategy comprises a host of soft approaches, including water pricing, water rights and markets, conservation, and efficiency improvement, among other techniques (Ma et al. 2021). The comprehensive analysis of water supply and demand, taking into account natural and human systems, as well as the interconnectedness of upstream and downstream regions, is a widely recognized approach in the formulation and execution of water resource policies and decisions. Furthermore, the participation of stakeholders in water resource management processes is globally acknowledged. The water crisis in Pakistan was typified in the 1970s by an environmental–economic quandary. In the subsequent decade, cognizance of this exigency was engendered. From the 1990s onwards, efforts were concentrated on seeking factors that could enhance profitability and thereby address the issue (Kirby et al. 2017). The aforementioned phenomenon has endured since the advent of the industrial revolution; a period characterized by its prioritization of output optimization, or, put differently, the attainment of increased efficiency with reduced resources. The significance of water efficiency and conservation in the industrial sector is predominantly secondary, except for those particular industries wherein water acts as a primary input, as evidenced by the food and beverage industry. Furthermore, the conservation of water resources is deemed critical in areas where it is employed in critical stages of the production cycle, such as the automotive industry, where it plays a substantial role (Nawaz et al. 2022). One of the primary considerations has been the high cost associated with investing in technology and infrastructure for water treatment and reuse, particularly when aiming for the highest standard of water quality. This includes the significant expense of wastewater treatment systems utilizing reverse osmosis (Linares et al. 2016). As a result, companies often seek to meet only the minimum requirements outlined in each country's regulations. Furthermore, in addition to the exorbitant expenses incurred

in procuring the aforementioned technology, the associated expenditures for the upkeep and restoration of these units are of a substantial magnitude and are tailored to their specific requirements. The implementation of the reverse osmosis method in the industrial sector is widely observed in the beverage industry, with a specific focus on the management of treated desalinated water. The usage of desalinated seawater for the irrigation of greenhouses presents a feasible option to guarantee the endurance of aquifers, especially in situations where industrial-level agricultural production is operational. Farmers who adopt more rigorous irrigation methods by utilizing desalinated seawater significantly contribute to the maintenance of aquifer sustainability. This practice effectively circumvents potential issues that may arise from the over-exploitation of aquifers and subsequent ecological problems. Failure to implement such practices would result in significant complications for the ecosystem (Engel et al. 2008; Shi et al. 2024; Soomro et al. 2023a, b, c). The utilization of the resources and capabilities approach yields significant benefits in the context of clarifying the obstacles linked to achieving a competitive advantage while simultaneously addressing environmental management concerns. The primary objective of this study is to explicate the notion of sustainability concerning water management that can be operationalized in the context of Pakistan, while delving into the latest advancements in the sphere of sustainable management practices.

## Research route

The utilization of qualitative research serves as a pivotal component in the facilitation of achieving the objectives and goals inherent in the current study. To carry out the investigation of the subject matter under scrutiny, various sources are employed including books, journal articles, newspapers, official documents, policies, regulations, and open websites. Moreover, search sources will be consulted to conduct this research. The observed phenomenon bears significant implications for the advancement of the economy, the generation of innovative ideas, and the overall welfare of consumers, given its influence on a wide range of economic actors. The reason to choose Pakistan is that it is an underdeveloped country and has significant economic issues and water political conflicts (e.g., India). As a result, understanding their water management crisis and policy can have important implications for businesses and policymakers operating in these regions (e.g., South Asia). Implementing and enforcing competition laws and policies in both countries has been an ongoing reform and development area. The overall methodology is mentioned in below Fig. 1.

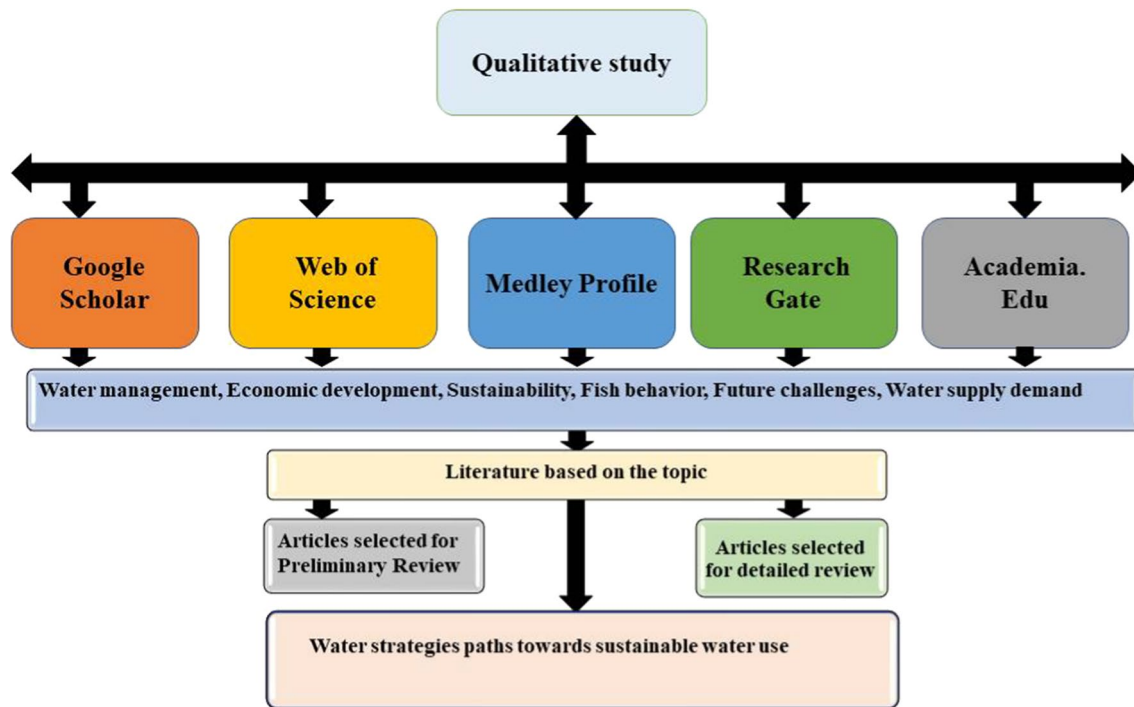


Fig. 1 Research route flow diagram

## Results

### The utilization of water resources in calamities

The occurrence of divergent interests among persons is frequently recognized as a social predicament within the scholarly literature. In the course of their routine daily activities, individuals frequently encounter scenarios in which their inclinations are at odds with the collective concerns of a broader societal organization to which they belong. Decisions that may seem logical from a personal perspective can lead to unfavorable outcomes for the general welfare of the societal or communal establishment. This quandary is brought to the forefront when individuals are presented with the prospect of obtaining and competing for shared resources. (Cogolati et al. 2018) revealed the concept of the Tragedy of the Commons, which portrayed a collection of pastoralists who were granted unbridled access to a communal grazing area for their livestock. Though it may prove beneficial for each herder to allow their animals to graze at length, the related costs are divvied up among the whole community. Despite this, if every pastoralist autonomously chooses to optimize their gain, the communal land will rapidly be exhausted, leading to detrimental consequences for all. According to previous studies (Campbell et al. 2017; Tarlock 1992), a proposition has been put forth that in instances where individuals accord priority to their self-interest and proceed to exploit communal resources, such

individuals will persist in doing so until the said resource becomes scarce or depleted. Technical solutions in isolation cannot effectively resolve this predicament, as they may simply augment the available resources without adequately addressing the fundamental driver behind individuals' proclivity for continuous exploitation.

This unfortunate circumstance arises when natural resources are readily available to everyone and are distributed among them. It is probable that a renewable resource will experience over-exploitation if utilized by a considerable number of individuals, resulting in prolonged and detrimental effects (Janssen et al. 2004). The utilization of communal resources in multiple regions of the world has resulted in the manifestation of numerous calamities. Underground aquifers are demonstrative of shared resources as, in the majority of instances; all parties possess unmediated entry to subsurface water reserves. Therefore, it can be deduced that subterranean aquifers tend to adhere to the overarching concept of the tragedy of the commons. Amid a quandary surrounding a common-pool resource, a group of individuals collectively arrive at determinations concerning the degree to which the communal resource is extracted. Additionally, the amount consumed by each individual remains inaccessible to other members of the group. The present interaction terminates abruptly once the communal resource is entirely depleted, implying that the pace at which individuals are utilizing the resource outstrips the rate at which it is being renewed within a specified timeframe (Drielsma et al. 2016).

It is noteworthy that this depiction is not an original discovery, but rather one that is deeply entrenched in pre-existing scholarly notions. Aristotle posited that any entity that is distributed among multiple individuals tends to receive the least amount of attention. Aristotle's observation posits that communal ownership of a given entity has a crucial effect on the degree of care and stewardship it receives (Drielsma et al. 2016). Consequently, said stewardship can either enhance the sustainability of resources or leave them exposed to the risks of deterioration and depletion. This particular matter of incompatibility may ensue owing to a discrepancy between an individual's immediate goals and the overarching, long-term objectives of society. Furthermore, it may also originate from discordance between the short-term goals of an individual and those of other individuals. A social predicament, essentially, refers to a situation where each individual involved is tempted to pursue an uncooperative course of action, as it offers favorable outcomes in the immediate future, solely for the individual concerned. However, should all individuals adhere to a non-collaborative demeanor, the overall circumstance will inevitably deteriorate compared to a cooperative situation (Sadoff & Grey 2002). The aforementioned circumstances present difficulties as the personal interests of individuals may prove tempting, even though collaboration could result in enduring advantages for all parties involved (Yeager & Walton 2011). Social dilemmas pertain to situations of social interdependence wherein the choice rendered by an individual bears extensive consequences not only for themselves but also for other participants entangled in the social predicament (Murphy et al. 2014). However, the outcome for each person is not solely based on their own free will, but instead is dependent on the behaviors of other individuals in the social context (Sen & Affairs 1977). The present manuscript directs its academic inquiry toward the intricate and diverse nature of societal quandaries, with particular emphasis on the predicament of communal assets, a pivotal concern in contemporary society. Common predicaments related to resources frequently involve the preservation of finite resources (Schuler & Jackson 1987). In situations where multiple individuals have unfettered access to a limited resource, and each member of the group decides the degree to which they utilize the communal asset, dilemmas regarding common resources arise (Calderón-Figueroa et al. 2022).

In situations of this nature, one is compelled to opt for either the self-serving consumption of a natural resource, such as water, which is unsustainable or instead, select a more sustainable approach that caters to societal or environmental interests, thereby reducing the utilization of resources (Grossmann et al. 2022). Common resource dilemmas are a critical concern that pertains to the survival of all living organisms inhabiting our planet. Whenever finite natural resources, such as freshwater, oil, or gas, are utilized

to enhance one's standard of living, an event transpires. Certain resources, such as grazing lands, can regenerate at a relatively fast pace, whereas other resources, specifically trees, exhibit a slower rate of regeneration. Moreover, some resources replenish at an exceedingly slow rate or not at all, for instance, oil and endangered species. When the pace of replenishment of resources is considerably lower than the rate of their extraction by humans, the likelihood of depletion of resources emerges as a critical matter of concern (Dalby 2009). The prevalence of reciprocal aid practices within Iranian society, particularly in customary rural and tribal groups, was a common occurrence in earlier periods. However, the author contends that there has been a noticeable decrease in such forms of mutual support over the past two decades. The observed decrease can be attributed to a multitude of factors, including but not limited to economic restrictions, diminished trust between the government and society, heightened class disparities, the prevalence of materialistic and economic values in personal lives, and other contributing elements (Rogers et al. 2012). A significant increase in the emphasis placed on individual interests over collective and group interests has been observed. This is demonstrated by numerous occurrences where public resources have been utilized for personal benefit, and individuals have engaged in intense competition for available opportunities within society.

Hence, the inclination to prioritize the satisfaction of personal needs and acquire instant benefits and privileges, commonly referred to as egocentrism, has become a significant characteristic of the inhabitants of Pakistan. Pakistanis exhibit a propensity toward placing a greater emphasis on their desires and safeguarding their welfare as opposed to contemplating communal, collective, and public issues. The precise occurrence in question has given rise to a plethora of quandaries and obstacles in the realm of communal resource predicaments and ecological encounters within the nation. Tourists who engage in the imprudent practice of kindling fires in forested regions in pursuit of transient enjoyment, without taking into consideration the lasting consequences of wildfires and ecological deterioration, urban residents who rely on personal vehicles for daily commute to their workplaces, with no regard for the deleterious effects on the urban environment and the potential health hazards that may arise, and farmers who exploit groundwater resources to boost crop productivity, without contemplating the repercussions of water scarcity for both current and forthcoming generations, are all instances of the intricate predicaments that confront us. The occurrence of uncontrolled conduct can be ascribed to the innate egocentrism of persons who reap the advantages of shared resources. Such individuals are inclined to give precedence to their concerns and frequently overlook the probable adverse consequences of their conduct on communal welfare.

## Environmental exposure with respect to strategic environmental assessment

The approach aforementioned is an imperative stipulation that is understood within the limits of the legal obligations set forth by Pakistan's environmental legislation policy, in conjunction with the United Nations Declaration on Environment and Development, which has been officially sanctioned and endorsed by the two nations involved (Wood 1985). The proposition and suggestion of plausible regulatory implementations represent a crucial facet in handling and curbing the conceivable consequences of any developmental endeavor on the milieu and designated ecological compartments. The principal aim is to ensure the preservation of the environment and shield the impacted atmosphere, thus ameliorating any harmful repercussions that may ensue. The implementation of the initiative was commenced in the country of Pakistan according to the Pakistan Environmental Protection Ordinance (Nadeem & Hameed 2008), the aforementioned legislative measures, which were subsequently revoked and superseded by the Pakistan Environmental Protection Act, necessitate additional examination (Saeed et al. 2012). As mandated by Section 12 of the Pakistan Environmental Protection Act (PEPA), it is incumbent upon individuals or entities to provide a detailed and all-encompassing environmental impact statement to the pertinent environmental protection agency, whether it be at the federal or provincial level, before commencing a venture that is predicted to have a significant effect on the ecosystem. Section 12 of the previously mentioned legislation comprises several provisions and clauses that are relevant to the imposition of a monetary sanction, be it in the form of a predetermined amount or a daily rate, in cases of non-adherence. Although not mandatory in Pakistan, certain facets of Strategic Environmental Assessment (SEA) have been embraced voluntarily, even with the dearth of legislative provisions. One such constituent is the integration of public engagement (Victor et al. 2014).

### Impact on ecological settings

The cooperation among the parties concerned is expected to exert a considerable impact on the present ecological settings. Furthermore, it holds the possibility of inducing substantial relocation, displacement, or transit of the indigenous inhabitants. The emergence of cultural and societal predicaments is also probable, thereby requiring their amicable settlement before the commencement of the enterprise. Pakistan, being a signatory to the United Nations Convention for Climate Change (UNFCCC), is required to conduct impact assessments to adhere to the sustainable development goals (SDG). This legal obligation necessitates the fulfillment of due assessments (Khan & Perspectives 2018). As stated by

the national representative of the International Union for Conservation of Nature (IUCN), the competencies of institutions dedicated to environmental conservation have been streamlined to enable the efficient execution of Environmental Impact Assessments (EIAs), given the increasing significance of environmental matters at the provincial level in Pakistan. However, the potential ecological ramifications of this megaproject remain ambiguous and arduous to prognosticate. Nonetheless, an Environmental Impact Assessment (EIA) must be expeditiously carried out to tackle any possible impacts and guarantee the implementation of suitable mitigation measures (Khalid et al. 2022). The collaboration between the government and relevant organizations, such as ICUN, is imperative to acquire technical proficiency. This is crucial to guarantee the ecological soundness and durability of these endeavors.

### Environmental management strategies

The dynamic alterations in the environment necessitate that the current climate change mandates that the States implement judicious policy measures to effectively attain the objectives of sustainable development. Pakistan has made notable progress in terms of relevant legislation, exemplified by the comprehensive amendment of the Environmental Protection Act in 2015 and the subsequent implementation of the Environmental Protection Tax Act in 2018 (Khan et al. 2020). In contrast, Pakistan continues to grapple with challenges related to environmental management, which have resulted in its classification as one of the nations that are most vulnerable to environmental threats across the globe (Mustafa et al. 2013). The current state of affairs mandates that Pakistan engage in the prioritization of developmental pursuits and the stringent implementation of both domestic and international environmental regulations. In this context, the assistance for achieving this goal would make a significant contribution to the improvement of regional environmental conditions. It is a matter of great regret that the current strategy being pursued may be misguided due to its failure to acknowledge the crucial advancements in capacity. This is exemplified by China's decision to restrict the use of its coal reserves and its efforts to aid Pakistan in generating energy from coal (Abbasi et al. 2022), instead of assisting in the advancement of sustainable energy, both nations must adhere to their responsibilities of restricting the usage of coal as outlined in the Paris Agreement of 2015.

### National environmental legislation and international trade law

Pakistan ought to endeavor to synchronize its domestic environmental regulations with the laws governing international trade. It is of utmost importance to establish a thorough and

all-encompassing regulatory framework at a national level about environmental concerns that are in line with the principles and standards of global trade regulations (Khan & Xu 2021). However, a disparity exists between the regulations that oversee the natural surroundings within a country's boundaries and the directives that govern global commerce. This incongruity is illustrated by the reality that the Chinese Foreign Trade Law merely briefly alludes to the actions implemented to ensure the preservation of the environment. In comparison, it is noteworthy that only a limited number of regulations about commerce are present within the realm of China's environmental legislation, which encompasses the China Environmental Protection Law as well as the Drug Administration Law (Kolk et al. 2010). Both States are advised to promptly commence the implementation of legislative measures aimed at safeguarding the environment by filling the gaps in existing laws about environmental protection domains, such as the proper handling of medical waste, appropriate disposal of blood test waste, and the elimination of ozone-depleting substances (Ferraro & Brans 2012). The subsequent steps to be implemented should encompass the expansion of the range of affiliated environmental regulations in conjunction with the enhancement of the operational efficacy of said laws using revising intricate legal doctrines. A comprehensive examination should be carried out to guarantee the harmonization of the technical regulations specified in regional or domestic ecological statutes and the ecological norms included in worldwide trade pacts.

### Natural disaster damage

Pakistan, being one of the world's most flood-prone countries, endures periodic severe floods that result in detrimental impacts on infrastructure, property, and human life. Pakistan's floods are of extreme devastation, largely due to the country's geographic location, climate, and inadequate infrastructure. Pakistan experiences yearly flood incidents that lead to loss of life, demand relocation of inhabitants, cause damage to livestock and crops, hamper communication and transportation, and propagate waterborne diseases. Pakistan undergoes significant precipitation phenomena from June to September, primarily in the northern locality (Soomro et al. 2022a, b; Soomro et al. 2021; Soomro et al. 2021). These happenings lead to devastating floods that adversely affect the existence of more than 500,000 people on an annual basis (Deen 2015). In the year 2022, a notable catastrophe occurred, whereby an overwhelming number of human lives were lost, amounting to over 1730 individuals who perished. Moreover, there was a considerable amount of damage to the infrastructure, as evidenced by the demolition of 1.7 million dwellings (Hamid et al. 2011). The aftermath of this calamity had a profound impact on the populace, with a staggering 33 million individuals being affected by the

deluge (Farah et al. 2023). A variety of aqueous diseases, including cholera and diarrhea, as well as dermatological and ophthalmic disorders, malaria, and pyrexia, have spread throughout Sindh and Baluchistan, constituting an epidemic (Sarkar 2022; Soomro et al. 2023; Soomro et al. 2023).

The deluge also resulted in the displacement of numerous individuals and had a disproportionate impact on the most economically disadvantaged segments of the Pakistani populace, thereby laying bare the acute destitution that had already been afflicting a significant proportion of the population. The initial evaluation of the destruction caused by the catastrophic event indicates that the estimated cost of damages amounted to a substantial sum of US \$30 billion (Sarkar 2022). Furthermore, an extensive network of 6700 km of roads, 269 bridges, and 1460 health facilities centers were irreversibly destroyed. Additionally, an alarming number of 18,590 schools were also severely impacted by the disaster (Otto et al. 2023). Based on the Human Impact Assessment conducted by the PDNA, it has been determined that there is a potential for a rise in the number of individuals residing below the poverty line. This increase is estimated to range from 8.4 to 9.1 million individuals, which equates to a percentage point increase of 3.7–4.0, after the occurrence of the 2022 floods.

### Shortage of dams

The Jhelum, Chenab, and Kabul Rivers, along with the upper and lower regions of the Indus River, represent substantial contributors to the inundation issues experienced in Pakistan. Such tributaries and river sections are deemed significant sources of flooding within the context of this region (Boota et al. 2023; Shah et al. 2020; Soomro et al. 2022). During the monsoon season from July to September, Indus floods are triggered by the failure of dams as well as the influx of glacial meltwater and sporadic outburst river floods (Boota et al. 2022; Guo et al. 2023; Nie et al. 2021). Due to the phenomenon of global warming, it has been observed that the Hindukush–Karakoram–Himalaya regions of Pakistan are experiencing an accelerated rate of glacier melting, leading to an increase in GLOFs (Glacial Lake Outburst Floods). These regions constitute a significant portion, that is, more than 50%, of the entire flow of the Indus River System, which is a substantial water system. The Himalayan region has observed an increase in the occurrence of glacier hazards as a result of the current condition. Glacial Lake Outburst Floods (GLOFs) can arise due to the sudden collapse of natural barriers or the lack of such barriers, thereby releasing substantial amounts of water and debris downstream that lead to extensive devastation. Glacial lake outburst floods (GLOFs) possess the capability to cause significant impacts on the inhabitants of the Himalayan vicinity, specifically those residing in the Indus River

Basin (Richardson & Reynolds 2000). The significance of the capacity of pre-existing dams in flood water storage is of paramount importance.

### Demand of water and its accessibility

The management of the increasing discrepancy between the demand for water and its accessibility represents a significant obstacle for modern society in the current era. As the availability of water resources decreases and the demand for water rises, individuals are faced with conflicting pressures. They are situated at a pivotal intersection between their interests, which may involve excessive water consumption, and the interests of society, which necessitate collaborative endeavors toward water conservation. Moreover, these individuals must negotiate the opposing desires for instant gratification and the prospective long-range ramifications of their behaviors. Addressing the social dilemma of water insecurity is a paramount concern that necessitates a thorough examination of societal navigation of this issue. Future investigations and governmental initiatives concerning water insecurity necessitate the implementation of an optimal amalgamation of singular and communal approaches in addressing this pivotal societal juncture (Emdin 2009). As water serves as a primary constituent of an abundant, boundless, and seemingly boundless communal asset, individuals oftentimes retain the conviction that this is, in fact, the veracity. Nevertheless, it is of utmost significance to acknowledge that the presence of water over a while is not exclusively controlled by the quantity of water accessible.

In fact, the pivotal aspect is the pace at which groundwater, rivers, and lakes are revitalized or refilled. Each water body, whether on the surface or underground, provides approximately half of the necessary freshwater supply worldwide. Nevertheless, the rate at which groundwater is replenished is significantly insufficient (Khair et al. 2010). In contrast, dissimilar to numerous other resources, water experiences an incessant need. To elucidate, following the assessments of the World Health Organization, a minimum of 20 L of water per diem is essential for individuals to ensure satisfactory health through consumption, culinary usage, and hygienic purposes. This requirement is similarly present in various other domains, including agriculture, industry, and metropolitan regions. The Food and Agriculture Organization (FAO) has released a report indicating that a significant proportion of the worldwide freshwater resources, equivalent to 69%, are employed for agricultural purposes, including irrigation, livestock rearing, and aquaculture (Mateo-Sagasta et al. 2017).

The issue of water scarcity has brought to the forefront the requirement for collective action toward protecting this vital resource, while also incentivizing individuals to prioritize the common good over their interests. This approach is

deemed necessary to effectively address the social dilemma surrounding water consumption (Insecurity et al. 2014). From the standpoint of a social quandary, the exhaustion of commonly held ecological assets, like water, results from the individualistic pursuit of fleeting self-interests, while neglecting the long-term consequences for both the community and the ecosystem (Laizer et al. 2018). Restricting water consumption can be deemed beneficial for the collective as a whole; however, individuals may likely exhibit a proclivity toward consuming water in excess. This scenario is of particular concern as it involves conduct that ultimately results in detrimental consequences for both the persons involved and the resources in question (Dawes 1980). For instance, let us contemplate a hypothetical situation wherein an individual is confronted with the decision of whether or not to discharge water from a reservoir as a means of mitigating forthcoming water scarcity or to facilitate surface water access. In the scenario where individuals hold the belief that the present level of consumption is subpar in comparison to the promised future value, their motivation to conserve water in the reservoir diminishes upon acquiring the awareness that fellow consumers can access the water immediately. The tragedies of the commons manifest due to the individualistic motivation that drives each entity to extract water resources before others, consequently leading to the swift exhaustion of the reserves (Van Vugt & Bulletin 2001). An additional example can be observed in instances of drought wherein proprietors of private wells undertake the excavation of deeper wells, leading to the depletion of subterranean aquifers that they possess by legal means (Abudu et al. 2019). The central focus of social dilemmas pertains to the methods through which individuals can be incentivized to participate in collaborative conduct amid social dilemma scenarios. To tackle this inquiry, we must take into account two distinct social dilemma strategies, namely, individual (behavioral) strategies and structural strategies.

Individual strategies encompass the alteration of individuals' cognitive processes and motivational factors, intending to foster cooperative conduct and responsible resource administration. The strategies presented herein endeavor to attend to antecedent factors that are associated with problematic behavior, namely behavioral commitment and education (Van Vugt et al. 1999). In the context of resource dilemmas, it is plausible that a minimum of four socio-psychological factors may be correlated with the endorsement of water conservation: to examine the level of consciousness toward water inadequacy (Parkes et al. 2010); individuals ought to possess a profound awareness of accountability concerning the overall welfare of the community (Fisher-Borne et al. 2015); belief in the efficacy of collaborative efforts undertaken by individuals is a commonly held notion in various contexts (Kerr & Park 2001), and the conviction that fellow members of a community will likewise display

cooperative conduct is an established belief in social interactions (Lampert 1985). Structural strategies endeavor to modify the motivational framework of social predicaments by synchronizing individuals' motives with collective outcomes, thus diminishing the incongruity between individual incentives and communal repercussions. The execution of a structural approach is frequently regarded as unchallenging when implemented through the most straightforward channel. Several investigations have been carried out to scrutinize the impact of altering the structural result on the behavior of the individuals involved. The outcomes of the aforementioned research commonly validate the inverse correlation between the expense of cooperation and the cooperative conduct of participants, while also affirming the direct relationship between the advantages of cooperation and the cooperative actions of participants. The restructuring of the result can be effectuated through the utilization of specific sanctions or inducements, including the imposition of penalties upon non-compliant parties and the bestowal of rewards upon those who exhibit cooperation (Murray 2005). The structural strategy pertains to measures implemented to alter the outcomes of maladaptive actions, including feedback and incentives (Kollock 1998). The resolution of social dilemmas invariably necessitates the implementation of a procedure that entails the elimination of non-cooperative behavioral patterns and the establishment of cooperative behavioral patterns.

### Environmental and social uncertainty

Water crisis impacts more than a third of the world's inhabitants (Clarke 2013). The provision of unpolluted water resources for productivity, consumption, and societal utility is increasingly posing a challenge owing to the escalating competition among various sectors, namely industry, agriculture, power generation, domestic consumption, and environmental necessities (Mattos et al. 2019). Individuals tend to utilize resources that they perceive as conspicuously rare, thereby intensifying the circumstances of the aforementioned resources. It, indicate that in situations of acute scarcity of a certain resource, resource users tend to augment their consumption. Desirable end-states, commonly known as "valuation," exhibit variations in significance (Frame et al. 2011), and function as fundamental tenets that direct the course of action for individuals and other social entities (Mayorga 2021). This particular definition comprehensively encompasses three essential facets of values. Firstly, values entail convictions regarding the favorability or unaffordability of particular ultimate conditions. Secondly, values are conceptual entities that possess a degree of abstractness, thereby transcending particular circumstances (Ingenbleek et al. 2015). Thirdly, values serve as fundamental tenets for assessing individuals, occurrences, and conduct (Cooper

et al. 2005). In the realm of decision-making, it is common practice to prioritize values based on their varying degrees of importance. In situations where competing values are simultaneously activated, choices are ultimately determined by the most prominent and essential value at play.

The concept of value orientation pertains to the significance that individuals ascribe to the well-being of both themselves and others in the context of social predicaments. Pro-self-values, encompassing both egoistic and hedonistic values, as well as self-transcendence values, which entail biosphere and altruistic values, exhibit dissimilar associations with beliefs, attitudes, norms, and environmental behaviors. The constructs under investigation exhibit a positive association with prioritizing self-interest, but conversely exhibit a negative association with prioritizing concern for others. When the emphasis is placed on biospheres and altruistic values within a particular area of focus, such as water conservation, individuals are more likely to act following these values. The formation of personal identities and the establishment of meaningful life objectives are inextricably linked to the influence of spiritual beliefs (Gall et al. 2005). In contemporary times, numerous cultural and spiritual paradigms have come to underscore the sanctity that characterizes the natural world. The venerated constituents inherent in the natural world have the potential to motivate individuals to dedicate themselves to ecological objectives (Cajete 1994), particularly in instances where religious affiliations underscore humanity's role as custodians of the planet. The process of spiritual adaptation is known to exert a considerable influence on the promotion of pro-social conduct. This is particularly evident within the Islamic sphere, where water is commonly recognized as the primary origin of existence, having been brought into being by a divine entity. Water embodies numerous symbolic representations within the spiritual faith (Hasan 2020). The function of this entity extends beyond being the mere genesis of life, as it additionally assumes the role of a means to cleanse the human organism. This purification process encompasses both the corporeal exterior and the ethereal interior, from a spiritual perspective. This deeply spiritual concept can potentially inspire individuals to engage in the preservation of water resources, ensuring that they remain unpolluted and available for the benefit of future generations. When a group experiences a decrease in its size, there is an observed inclination toward an upsurge in cooperative behavior (Chatman & Flynn 2001). The magnitude of a group is interrelated with a range of other variables, namely communication, environmental and social ambiguity, as well as group identity (Liebrand et al. 2015). These variables have a direct impact on the degree of cooperation within the group.

The phenomenon of communication is expected to be positively correlated with a reduction in the magnitude of the group size. Individuals can increase their opportunities



for selecting strategies and achieving coordination by engaging in communication with one another. The members of a group possess the ability to exercise self-governance to prevent the depletion or weakening of shared resources, ultimately resulting in a decrease in both environmental and social uncertainty (Van Dijk et al. 1999). The negative ramifications of the size of a group on cooperative behavior are predominantly attributed to accompanying changes in the system of rewards and punishments. More precisely, the advantages that arise from individual cooperation progressively decline in significance with the augmentation of group size. As a species that thrives on social interaction, humans exhibit a deep-seated sense of belongingness to social groups and display a natural inclination toward engaging in social comparisons with others in large gatherings. The degree of their social identity exerts an influence on their propensity to assist their group or community, exemplified by their involvement in water conservation. There exist numerous methodologies that can be deployed to elicit an individual's perception of self and affiliation, with the primary objective of strengthening environmentally-friendly conduct. Firstly, it is important to acknowledge that individuals are inclined to cultivate more resilient identities with their primary groups, namely friends and family (Efferin et al. 2007). Consequently, arguments that cater to the concerns of these groups (such as deliberating the prospects of their progeny) are typically more compelling. Secondly, it has been noted that upon individuals establishing a social identity with a specific group, there exists an increased likelihood of the exchange of valuable environmental information among members of the group (De Cremer & Van Vugt 1999). Thirdly, the attainment of social identity by individuals within a distinct social cohort stimulates an elevated degree of attentiveness toward their intragroup standing (Rosendaal & Practice 2009), consequently strengthening environmentally conducive conduct. It is imperative to recognize that societal identity possesses the capacity to operate as a dichotomous mechanism regarding the distribution of resources that are distributed among diverse communities. In situations of this kind, the prioritization and promotion of a communal societal identity, as demonstrated by fostering inter-community trade or highlighting a shared threat, such as crop failure, may potentially produce superior outcomes. The effectiveness of societal critique is rooted in its capacity to maintain beneficial societal norms through the utilization of social coercion and communal surveillance (Schroeder et al. 2003). Social validation and invalidation are pivotal mechanisms that effectively govern human behavior within social contexts. Informal forms of critique such as peer pressure and social ostracism have been observed to be effective mechanisms for deterring non-cooperative behavior in social transactions (Jensen 2010). Confronting the discontentment of fellow members results in an elevated

degree of collaboration. Critics ought to adopt a gradual approach, commencing with mild repercussions and progressively escalating them in response to recurring infringements. Some individuals maintain the perspective that the implementation of consecutive strategies of constraint offers greater benefits due to the tendency of consumers to perceive legal water-saving measures as ineffective. For example, the act of temporarily halting the affiliation of farmers with agricultural cooperatives and the refusal to provide services due to the unauthorized digging of deep wells or the usage of water from such wells is an illustration of social criticism that farmers encounter. These actions could initially restrict access to services and ultimately lead to their removal.

## Discussion

The proficient administration of scarce resources, for instance, water, represents an imposing hurdle in most communities. The process of determination pursued by individuals or groups concerning the governance of a shared resource such as water is susceptible to fluctuation (Weber et al. 2004). Individualism and collectivism are recognized as two distinct orientations that delineate the heart of the relationships between individuals or groups and their respective counterparts, creating a dynamic interplay of contrasting perspectives. Individualism is distinguished by a profound sense of self-sufficiency, accentuating individual autonomy, unique individuality, and prioritizing personal aspirations over collective objectives. Those who self-identify as collectivists, conversely, venerate the collective standards and synchronization, considering individual ambitions to be subordinate to the communal aims (Oyserman et al. 1998). The absence of communal inclinations amidst individuals within a society poses a significant hurdle that impedes the effective governance of environmental assets. The intricacy of the issue is exacerbated when considering the scarcity of a vital resource such as water, which is progressively inaccessible with each passing day. The unrestrained pursuit of personal interests by individuals has resulted in a collective detriment, ultimately leading to personal setbacks. Consumers dwelling in collectivist societies demonstrate a proclivity toward consumption habits that prioritize the welfare of others and evince heightened awareness of ecological issues (Halisah et al. 2021). In addition, a propensity for individualism is evidenced by a contrary correlation with disquietude concerning the effects of climate change, a dearth of disposition toward participating in ecologically sustainable pursuits, and reluctance to adopt corresponding methodologies. Those who exhibit proclivities of non-cooperation tend to prioritize their interests and display scant regard for environmental well-being, whereas adherents of collectivism

evinced a heightened sensitivity toward ecological concerns (Mol et al. 2020).

The management of water displays a multitude of intricate and distinct features that require concerted effort. Water is a fundamental necessity for the existence of life, and it also plays a pivotal role in supporting societal livelihoods. Furthermore, water facilitates economic production and consumption, thereby contributing significantly to various industries. Henceforth, it is widely recognized that water is considered a shared resource that warrants proactive and collaborative management, conservation, and utilization (Leb 2013). The significance of water resources is inherently critical and embodies a communal character that mandates circumspect and impartial governance, guaranteeing that individual interests do not supersede the greater communal well-being. Recently, the synergistic endeavors of numerous stakeholders are of utmost significance in efficaciously addressing the intricate concerns about water administration under the ambit of sustainable development. The achievement of a more sustainable, efficient, and equitable utilization of water is imperative. To actualize this objective, it is critical to foster a collective consciousness within society. Participation constitutes one of the foremost lacunae in water governance in the nation. When individuals in different positions fail to prioritize the collective interests and long-term perspectives on water consumption over their interests, it can lead to intractable water crises that adversely affect the entire society and pose a threat to desirable water management and governance.

The conservation of environmental assets is predicated not only on scientific expertise and effective governance but also on the collaborative endeavors of individuals. Individual actors who are tasked with the preservation of water resources should establish connections and engage in collaborative efforts with one another, rather than acting solely following their interests. Another method to resolving the predicament of collective calamities concerning jointly utilized resources entails the limitation of water entry and its transformation into a communal property. Water ought to be perceived as a ubiquitous resource, and the judicious utilization of water is to be perceived as a communal advantage that redounds to the benefit of all, thereby requiring a robust pledge to its equitable preservation. According to this discourse, it is imperative to accentuate that the augmentation of water security necessitates the implementation of multi-lateral regulations and institutional measures that transcend singular behavioral modifications. The deficiency of suitable institutional structures for the management of water demand could potentially add to the difficulties encountered in present-day water security (Vlek & Keren 1992). Moreover, tackling the intricacies of shared resource tragedies mandates an all-encompassing framework that deconstructs water security challenges from interconnected and intricate

standpoints, which necessitates an integrated approach toward water resource management. Merely focusing on the management of water demand may prove insufficient in terms of providing a satisfactory solution to the numerous water security predicaments that are present in actuality. Concerns regarding water resources are inherently intricate, characterized by intricate interconnections with diverse stakeholders and ecosystems, and frequently arising from ambiguous origins.

Therefore, the suggestion of a solitary resolution may conceivably demonstrate inadequacy in comprehensively addressing the contemporary and persistent predicaments encompassing water resource management. The management of natural resources embodies a multifaceted concept that surpasses the boundaries of a mere economic or environmental structure. Rather, it manifests as a socio-environmental and economic framework that necessitates a nuanced comprehension and strategy. Concerning the utilization and growth of water, a nation must undertake a comprehensive evaluation of all possible consequences of non-sustainable resource exploitation (Koutsoyiannis 2011). Inclusive water security cannot be attained solely through institutional measures at the national level aimed at adjusting consumer behavior. Instead, it necessitates the implementation of comprehensive policy-making and legislation across various levels. Despite continued efforts to manage water resources, the concept of a communal resource crisis continues to heavily influence policy formulation, resulting in limited modifications to traditional water resource management methods. Novel and innovative methodologies are imperative in addressing the alarming patterns in water usage, and ensuring that the maintenance of life, growth, and biodiversity are upheld for the posterity of humankind, through strategic and concerted reactions to these predicaments.

## Conclusion

A government possesses the ability to commence an abundance of expansive development initiatives that are concerned with the accessibility of water. It should be noted that as the duration of governmental tenures is restricted, the short-sightedness exhibited by governments may pose a more significant obstacle than individual opportunism. Furthermore, the resolution of water-related issues necessitates the active engagement of both the public and stakeholders. This crucial responsibility ought not to be solely borne by governmental bodies or institutions. In essence, the achievement of water security cannot be solely accomplished through institutional actions at the national level aimed at modifying water consumption patterns. Rather, it necessitates the establishment of comprehensive policy formulation and legal frameworks at various hierarchical

levels. Despite persistent efforts aimed at water resource management, the concept of the tragedy of the commons remains a significant influence on policy-making. This has resulted in limited modification of customary water resource management techniques. Novel and innovative strategies concerning water resources are imperative to counteract the disconcerting patterns observed in water availability and to uphold the sustenance of life, development, and biodiversity for future generations, as well as for the continuity of humankind, through astute and concerted responses to these critical situations.

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