



Nature's Contributions to People (NCP) of rural freshwater ponds in Bangladesh: An exploration of the impacts of pondscape degradation

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Received: 2 December 2024 / Accepted: 13 June 2025 / Published online: 30 June 2025
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Abstract

Rural freshwater ponds in Bangladesh are vital socio-ecological systems that provide essential Nature's Contributions to People (NCPs), including water provisioning, flood regulation, livelihood support, and cultural sustenance. However, rapid degradation due to pollution, privatization, and mismanagement threatens these benefits, disproportionately affecting marginalized communities. This study examines the impacts of pondscape decline in Sultanpur village, Chattogram, through semi-structured surveys with 210 residents. Findings reveal a stark reduction in material NCPs, with only 26.9% of households still relying on ponds for daily water needs due to contamination and shifting preferences for privatized alternatives like tube wells. Regulating contributions, such as flood buffering and microclimate cooling, have diminished, exacerbating climate vulnerabilities. Most critically, immaterial NCPs, such as spiritual practices, community cohesion, and mental well-being, are eroding, severing cultural ties to these once-thriving commons. Women, the primary water managers, face heightened health risks and labor burdens, while elders express solastalgia over lost traditions like religious rituals and communal storytelling. Drivers include pollution from septic systems, disputes over shared ownership, and policy neglect that prioritizes engineered infrastructure over ecological stewardship. The study underscores ponds as undervalued Nature-based Solutions (NbS) and calls for integrated governance that restores biocultural heritage, prioritizes equitable access, and aligns local knowledge with national conservation strategies. Without urgent intervention, the continued degradation of pondscares risks irreversible losses to biodiversity, climate resilience, and the rural well-being in Bangladesh.

Keywords Biocultural heritage · Freshwater ponds · Nature-based Solution · Nature's Contributions to People (NCP) · Socio-cultural degradation · Water governance

Introduction

Nature-based Solutions (NbS) are increasingly being advocated as a way to tackle two of the current major crises in the world—biodiversity loss and climate change (Mendes et al. 2020; Davies et al. 2021). NbS are defined as “[a]ctions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges, such as climate change, effectively and adaptively, simultaneously providing human well-being and biodiversity benefits” (IUCN 2020). The use of NbS can support the provision of a variety of Nature's Contributions to People (NCP), or the different ways in which living nature can affect people's quality of life (Díaz et al. 2018; IPBES 2019), which includes contributions like pollution control, greenhouse gas sequestration, flood risk management, and improved mental well-being (Liquete et al. 2016; Holgersson and Raymond 2016; Vujcic

Communicated by Jacqueline Loos

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et al. 2017; Turkelboom et al. 2021). Importantly, the NCP framework places a strong focus on the fact that culture is fundamental to all human-nature relationships, acknowledging that while nature offers a variety of crucial commodities and services, such as regulating processes or tangible products, it also has a deep cultural, social, spiritual, and religious significance that must be taken into consideration when making decisions (Kadykalo et al. 2019).

There has been a noticeable positive shift in the utilization of freshwaters as prospective NbS in human-dominated ecosystems (Keesstra et al. 2018). At the landscape level, ponds are important sources of freshwater that are also home to a variety of endemic, vulnerable, or rare species (Davies et al. 2008). Ponds are defined as tiny water bodies that can range between 1 and 50,000 m² and may be created naturally or man-made, and exist permanently or seasonally (Richardson et al. 2022). However, due to their often small size, the NCPs of ponds go rather underappreciated (Oertli and Parris 2019), exacerbated by ponds' particular vulnerabilities to anthropogenic impacts such as pollution, habitat loss, and climate change (Hill et al. 2021a).

Ponds are critical freshwater ecosystems that deliver numerous crucial NCPs to enhance human well-being (Díaz et al. 2018; Hill et al. 2021b), including, but not limited to, providing food, flood control, groundwater recharge, and improving water security, biodiversity conservation, climate regulation, pollution control, and other non-tangible benefits like recreation and spaces for educational and spiritual activities (Landuyt et al. 2014; Holgerson and Raymond 2016; Kabisch et al. 2017; Pascual et al. 2017). Indeed, because of their contributions to climate regulation, biodiversity maintenance, and other important NCPs, ponds can serve as an important NbS for various contemporary challenges (Cuenca-Cambronero et al. 2023). Even though ponds have a high potential for numerous contributions, evaluations of management practices generally consider only a few, particularly fish production, leaving out other benefits, attributed to the lack of available data (Landuyt et al. 2014), as well as the generally small size of this freshwater (Oertli and Parris 2019). As a result, ponds are often neglected, which can threaten the provision of different NCPs (Hill et al. 2018). Pond losses have significantly increased during the past century, which has had severe adverse impacts on pond biodiversity (Horváth et al. 2019) and the general delivery of numerous NCPs (Gozlan et al. 2019).

Bangladesh is a country with several freshwater bodies, such as marshes, ponds, and rivers. Household freshwater ponds, which have historically served the daily needs of rural households, are one of the typical forms of freshwater ecosystems in Bangladesh. Ponds have numerous uses for rural households, including providing water for washing, bathing, and other household needs in addition to being used for fish cultivation (Dey et al. 2008). In the past, ponds

were either intentionally made as miniature freshwater ecosystems next to residences or naturally formed as borrow pits dug to supply soil for raising homesteads above flood levels during the wet monsoon (Huq 2017). Although ponds are one of the most noticeable landscape elements in rural Bangladesh (Dey et al. 2008), there is very little research on such small freshwater bodies, their usage, and their future potential in Bangladesh (Huda et al. 2010). Most that exist focus on aquaculture, primarily improving productivity, management, nutritional contributions and food security (Ahmed and Waibel 2019; Islam et al. 2020, 2021; Khan et al. 2021; Rahman et al. 2022, 2023; Sumi et al. 2023), and the public health risk concerns associated with pond water, primarily emerging from the indiscriminate use of antibiotics for aquaculture and poultry farming purposes (Neela et al. 2015; Sadique et al. 2021; Kawsar et al. 2022). However, very few attempts have been made to map the multiple NCPs of household ponds in rural lives and livelihoods, as well as threats to the ability of ponds to effectively deliver positive NCPs. Some scholars, such as Rabbani et al. (2013, 2018), demonstrated how the coastal dependence on ponds for irrigation, vegetable gardening, fish production, cooking, and drinking makes the populations highly susceptible to the impacts of hazards like cyclones, which inundate ponds with saline water. Similarly, Huq (2017) found that many households on the coast who have lost possession of ponds over the last two decades due to socio-economic issues are particularly vulnerable to the impacts of global environmental and climate changes, as they are no longer able to tap into the benefits offered by ponds. However, what continues to remain amiss is a picture of how the diminishing abilities of ponds in delivering important NCPs are affecting the more intangible dimensions of human well-being, beyond food and water security and livelihoods.

Therefore, addressing this gap, this study attempts to reveal the NCPs being delivered by ponds in a small village of Chattogram, Bangladesh, how they may have changed over the years, and how this change was perceived by the local pond users, and the primary root causes for these changes. The NCP framework, unlike the concept of ecosystem services (ES), which is more widely invoked, explicitly integrates diverse knowledge systems, including Indigenous and local perspectives, and emphasizes the dynamic, context-specific relationships between people and nature (Kadykalo et al. 2019; Díaz et al. 2018). While the ES framework often prioritizes quantifiable, utilitarian benefits such as provisioning and regulating services (Costanza et al. 2014), the NCP framework expands this perspective by foregrounding the co-production of cultural values and relational dynamics between communities and their environments, thereby recognizing that human-nature relationships are not merely transactional but deeply embedded in socio-cultural practices (Chan et al. 2012; Pascual et al. 2017). This aligns

with our focus on intangible contributions and the cultural significance of ponds in rural Bangladesh, which are often marginalized in traditional ecosystem service assessments. By adopting NCP, we aim to foreground the lived experiences of pond users and the systemic drivers of degradation that disrupt these contributions.

Methodology

The study was carried out at Sultanpur village, Raozan. Sultanpur is one of the 103 villages that make up the Raozan subdistrict of Chattogram, which is located near the coast. There are currently 25,708 people residing in Sultanpur village, which is divided into three wards—Ward 4, Ward 5, and Ward 6.¹ The entire region has a tropical monsoon climate.

A 24-item semi-structured questionnaire was developed, comprising mostly closed-ended and a few open-ended questions to reveal the state of the NCPs from the ponds. For the survey, 70 individuals were chosen evenly from each ward using a random sampling method, totaling 210 participants. To get more diverse information and perspectives, only one participant was chosen from each household to be questioned.

We categorized NCPs into three groups, material, immaterial, and regulating contributions, as proposed by Díaz et al. (2018) and Hill et al. (2021b), to systematically assess how ponds sustain both tangible livelihoods and intangible cultural practices, while also recognizing that each of these groups are fuzzy and deeply intertwined. However, while the NCP framework provides 18 generalizable categories (Díaz et al. 2018), our study adopted an inductive approach to categorize contributions based on responses from local pond users. This aligns with the NCP's context-specific perspective, which prioritizes lived experiences and avoids imposing externally defined classifications that may not resonate with local realities (Hill et al. 2021b). For example, “spiritual and religious practices” and “community building” emerged as distinct contributions in our analysis, reflecting their unique salience in the study area. Moreover, these critical immaterial NCPs intersected with material and regulating contributions. This flexible categorization mirrors the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) guidance on weaving generalizing and context-specific lenses to capture plural values (Hill et al. 2021b) and ensures our findings remain grounded in the socio-cultural context of rural Bangladesh.

The minimum age for participants was 20, with greater priority given to the older population (aged 50 or above) due

to their long history and ties with the ponds. Depending on availability, the survey covered both male and female members of the families, with women making up the majority. MS Excel software is used for overall data processing and analysis.

Ethical approval (protocol #S2022_28) for the study was sought and received from the Asian University for Women (AUW) Ethical Review Committee (ERC) on October 31, 2022. All the data collection was conducted between February and March 2023.

Results and discussion

Current status of the pond ownership and primary use

This subsection examines ownership patterns, primary uses, and management challenges of rural ponds in Sultanpur, contextualizing socio-ecological shifts over time.

In our study area, 45.2% of respondents reported owning ponds, typically shared among four to five households—a proportion consistent with earlier findings in rural Bangladesh (Huq 2017). However, only 34.7% actively maintain these ponds, signaling a decline in stewardship practices that historically sustained these water bodies. Historical accounts describe adaptive co-management strategies, such as harvesting duckweed for livestock feed or applying lime to curb algal blooms (Plummer et al. 2012), which reinforced reciprocal relationships between households. Similar practices in agrarian communities globally highlight how communal labor and shared ecological knowledge underpin sustainable resource governance (Adhikari et al. 2014). Today, however, eutrophication and plastic pollution plague most ponds, reflecting broader trends in the Global South where rapid urbanization and eroding traditional governance transform communal water bodies into waste sinks (e.g., Sugam et al. 2018; Adams et al. 2020; Roy-Basu et al. 2020).

Contrary to the dominant focus on aquaculture in Bangladeshi pond literature (see the “Introduction” section), our findings reveal that fewer than 45% of pond owners engage in fish cultivation. Nearly half retain ponds as “natural capital” for future income—a strategy aligned with neoliberal resilience narratives that prioritize financial hedging over ecological or cultural vitality (Bailey et al. 2019). This passive retention, however, risks degrading both ecological functionality and social cohesion. Natural capital frameworks often neglect the interdependence of ecological health and cultural practices (Muradian and Gómez-Baggethun 2021), a gap evident in Sultanpur: ponds held as speculative assets frequently become neglected, accelerating eutrophication and undermining their capacity to deliver critical NCPs like flood regulation or communal bonding. This

¹ According to the Raozan Union Council.

mirrors patterns observed in Sub-Saharan Africa, where land reserved for speculative use loses socio-cultural relevance, eroding place-based identities tied to ancestral landscapes (Chigbu et al. 2017).

Nature's Contributions to People provided by ponds

This section presents the findings related to the present state of the NCPs of ponds based on the three categories. Table 1 summarizes the main findings presented in this section.

Material contributions

Ponds as water supply Ponds have historically served as vital sources of water for domestic and agricultural needs in rural Bangladesh. They also serve as emergency fire buffers, with respondents emphasizing their irreplaceable role in mitigating nighttime fire risks—a stark illustration of their undervalued contributions to disaster resilience. However, only 26.9% of respondents now rely on ponds for daily household tasks, primarily due to limited access to affordable alternatives or proximity to functional ponds. The remaining 73.1% have shifted to privatized systems like tube wells or piped water, though many still turn to ponds during high-demand events (e.g., festivals, large-scale washing) or

emergencies. Even among those with alternatives, degraded water quality in nearby ponds often forces households to travel long distances to secure usable water—a burden that underscores the diminishing reliability of these once-central resources.

The privatization of water infrastructure reflects what Cornea et al. (2016) term the “infrastructural reconfiguration of power,” where access to “modern” systems (e.g., tube wells) becomes a marker of socio-economic status, giving an advantage to specific groups (e.g., affluent families with access to own water systems) while keeping others excluded. Similarly, as outlined by Zimmer et al. (2020), we have found that changing visions of nature, such as the idea that private “modern” water sources are more preferred than shared natural ones, ultimately contribute to an ongoing “uncommoning” of ponds. This transition not only weakens traditional communal heritage but also entrenches inequality. For example, while personal water infrastructure is convenient for a minority, the deterioration of ponds disproportionately impacts those who are more dependent on ponds for their daily domestic needs, particularly poor households and women.

Our data shows that around 73.8% of respondents were women, which reflects their key role in directly interacting

Table 1 Total NCP derived from the ponds in Sultanpur village and how they have changed

Contributions	Examples	Change (-) Degraded/no longer able to access (N/A) No change, or no longer applicable (+) Improved/greater access
Material contributions		
Water supply	Household purposes, cooking, drinking, agricultural, business, festival use, fire extinguisher	(-)
Land	Banks and nearby space provide areas for farming (vegetable and poultry), and land for burial	(N/A)
Food	Fish, naturally grown vegetables such as water spinach and water taro	(N/A)
Medicine	Medicinal plants such as Indian pennywort and bitter vine	(N/A)
Fuel	Collect fuels from the banks of the ponds such as small tree branches and leaves	(N/A)
Livelihood	Opportunities for integrated duck-fish farming, or support for duck husbandry	(-)
Regulating contributions		
Cooling effect	Cool breeze during summer	(-)
Flood regulation and support	Regulates flood and/or offers alternative water supply during flood	(-)
Immaterial contributions		
Spiritual and religious	<i>Wu'du</i> , sacrificing idols, worship, festival showers, wedding rituals, <i>Pooja</i> , discarding religious items	(-)
Community building	Group discussion, having showers together, experience and story sharing, place-based identity	(-)
Recreational	Swimming competitions, fishing, playing	(-)
Mental health	Relaxation, focus, concentration	(-)

with water resources. As Sultana (2009) refers to, women's daily interactions with water in rural Bangladesh are heavily influenced by gender norms. With most household chores and caregiving responsibilities befalling women, women are also usually tasked with collecting water for daily activities. Generally, women have to forgo more productive tasks when collecting water due to the time and effort expended. In addition, water collection is also associated with negative health consequences, such as long-term back injuries and micronutrient deficiencies due to the high caloric expenditure of the water collecting tasks (Sorenson et al. 2011). Moreover, water insecurity exposes women to gender-based violence from partners and non-partners (Kayser et al. 2019). The physical toll of water insecurity, chronic injuries, micronutrient deficiencies, and exposure to gender-based violence (Wutich et al. 2020) intersects with symbolic violence, as women's labor becomes devalued alongside the ponds they depend on.

For agriculture, ponds remain critical for 54.1% of respondents, yet declining water quality forces farmers to seek distant ponds or groundwater, exacerbating time poverty and reducing agricultural productivity. 45.9% of respondents who are basically local farmers reported being obliged to use ground water sources such as tube wells due to the lack of usable ponds. This paradox, reliance on degraded ponds due to lack of alternatives, mirrors patterns in South Asia where marginalized communities are trapped in "resource loops" of ecological decline and socio-economic precarity (Walelign et al. 2020).

To understand how the water provisioning contributions of ponds changed in the past, our respondents were asked how their dependence on ponds for resources changed over the years. Interestingly, only 36% of the respondents maintained that their dependence on ponds for water, food, and other resources has remained the same. Upon closer inspection, it was found that these respondents were residing either in cleaner ponds or were using shared ponds that were still suitable, that is, with no perceivable eutrophication and littering. However, 64% claimed that the situation was vastly different from the past. Previously, they were fully reliant on ponds for everyday purposes, agricultural uses, and so on, because ponds were the main source of water supply. Other water sources, such as tube wells, deep tube wells, and motors, were rarely used in the past. This aligns with other studies (e.g., Fischer 2018; Paerregaard et al. 2020; Hommes et al. 2022) which document how "modern" infrastructure disrupts place-based hydrosocial cycles, eroding communal resource governance. Some of the respondents also stated that they used pond water for cooking and drinking as well. Moreover, almost all of the ponds were utilized for fishing at that time, which supported many households financially. Respondents mentioned that they also did not have to actively maintain the

ponds regularly, which included removing algae or any floating waste, as the pollution level was low.

Utilization of pond banks Pond banks in the study area serve as vital multifunctional spaces, addressing both socio-cultural needs and livelihood demands amid acute land scarcity. Communities repurpose these margins as cemeteries, poultry farms, and vegetable gardens—practices particularly prevalent in densely populated rural regions. Elevated banks are commonly used for burials by both Muslim and Hindu residents, a tradition that conserves land while reinforcing cultural continuity.

These practices exemplify the concept of "multifunctional landscapes" (Fischer et al. 2015), where ecosystems simultaneously fulfill material, cultural, and spiritual needs. However, encroaching land privatization and pollution increasingly threaten these communal spaces, mirroring patterns observed across the Global South where urbanization displaces traditional land-use systems (Rademacher and Sivaramakrishna, 2013). The degradation of pond banks not only erodes ecological functionality but also disrupts the socio-cultural practices embedded in them, underscoring the interdependence of human and environmental well-being.

Food, medicine, and fuel Ponds in the study area serve as critical reservoirs of biodiversity, directly supporting local livelihoods through the provision of wild foods, medicinal plants, and fuel. Approximately 31% of respondents report harvesting organically grown food and medicinal plants, such as water taro (*Colocasia esculenta*), water spinach (*Ipomoea aquatica*), Indian Pennywort (*Centella asiatica*), and bitter vine (*Mikania micrantha*), from pond margins. These species, which grow spontaneously rather than being cultivated, contribute to dietary diversity and traditional healthcare. Additionally, ponds supply nutrient-rich fish stocks and organic fuel sources: leaves, twigs, and branches accumulating along pond banks are routinely collected for low-cost cooking fuel.

Beyond direct provisioning, ponds enable agroecological practices such as integrated duck-fish farming. Introduced in 1986 by the Bangladesh Fisheries Research Institute as a sustainable technique, this system remains underutilized compared to neighboring regions like India. Ducks forage on pond organisms (e.g., duckweed, snails), while their droppings fertilize water to enhance fish productivity (Sasmal et al. 2010). The practice requires no additional land, as duck shelters are built on pond dikes, and relies on year-round water availability. Historically, 61% of respondents collected duckweed and snails from ponds as primary feed, often using coconut leaves to attract snails. However, declining water quality has led

households to restrict ducks from polluted ponds, despite the birds' natural inclination to forage there.

The gathering of wild foods and medicinal plants reflects the enduring role of traditional ecological knowledge (TEK) in rural resilience (Turner et al. 2011). Species like water taro and Indian Pennywort represent biocultural heritage, yet their decline due to pond degradation signals losses in both biodiversity and Indigenous pharmacopeia (Cámara-Leret et al. 2019). Similarly, the abandonment of duck rearing, despite its proven agroecological benefits, highlights systemic barriers to sustainable innovation. Pond pollution disrupts synergies between aquaculture and poultry farming, a pattern consistent with global observations of how ecological degradation undermines biodiversity-dependent systems (Kremen and Merenlender 2018). These trends illustrate the fragility of TEK-driven practices in the face of environmental and institutional pressures.

Regulating contributions

Cooling effects during summer Ponds play a critical role in mitigating heat stress in rural Bangladesh, where energy poverty limits access to artificial cooling. Over 95% of respondents emphasized ponds' cooling benefits, consistent with global evidence positioning blue spaces as micro-climate regulators (Gunawardena et al. 2017). Historically, ponds functioned as communal cooling hubs during heatwaves, bolstering social cohesion—a form of “social infrastructure” vital for climate resilience (Klinenberg 2018).

However, degraded ponds now lack the vegetative buffers necessary to sustain evaporative cooling, diminishing their capacity to generate cooling breezes or provide thermal respite. This decline mirrors trends in rapidly urbanizing regions, where encroachment and pollution impair natural cooling systems (Norton et al. 2015). The loss exacerbates thermal discomfort and disrupts communal practices, contributing to solastalgia, a form of ecological grief, among elders who recall ponds as vibrant social spaces (Cunsolo and Ellis 2018).

Flood regulation and alternative water supply support Annual flooding affects nearly all 210 survey respondents (94%), exacerbating water security challenges for households dependent on groundwater, shallow tube wells, or piped water systems. Power outages during floods compound these difficulties, disrupting access for piped water users and limiting pumping capabilities for groundwater-reliant households.

Historically, communities mitigated flood-related water shortages by relying on ponds, which remained functional even during inundation. At the time, tube wells were

uncommon, making ponds the primary water source for daily needs. Today, however, only 20.5% of respondents continue to depend on ponds during floods, as most are now submerged, silted, or contaminated. This decline underscores a critical paradox: while climate change intensifies flood frequency and severity (Shahid et al. 2016), degradation of traditional water systems simultaneously erodes community resilience.

This shift reflects a global trend where engineered infrastructure, such as embankments, displaces decentralized, nature-based flood management, often heightening risks for marginalized populations (Thorne et al. 2018). Nevertheless, hybrid systems merging traditional knowledge with modern adaptations persist. For example, some households still use ponds with raised edges, demonstrating how localized practices can enhance flood resilience. Yet siltation, pollution, and inadequate maintenance increasingly undermine these systems, mirroring patterns observed across South Asia, where neglected water bodies amplify vulnerabilities (Pervin et al. 2020).

Socio-economic disparities further shape flood impacts. Lower-income households reliant on shallow tube wells or piped water face compounded crises during power outages, whereas wealthier groups mitigate risks through private infrastructure, such as deep tube wells or water storage systems. This gradient highlights how systemic inequities intersect with environmental pressures, leaving marginalized groups disproportionately exposed to flooding's consequences.

Immaterial contributions

Religious rituals using ponds Nearly half of the respondents (48%) reported that pond degradation has severely hindered their ability to perform religious rituals, underscoring a crisis of biocultural erosion. For Muslim communities, ponds are integral to spiritual practices: mosques rely on them for ablution (Wu'du) water, while weddings and festivals like Eid ul-Fitr require water from seven clean ponds for ritual showers. Torn Quran pages or papers bearing Arabic script are also traditionally disposed of in ponds, reflecting beliefs about water's sanctity.

Hindu communities similarly depend on ponds for rituals such as Bel Kumari and Gonga Pooja, which honor water bodies through offerings of milk and food. During Durga Pooja, idols are ritually submerged in ponds—a practice now fraught with shame and frustration due to polluted waters. Respondents lamented that even idol sacrifices, once acts of reverence, feel disrespectful under current conditions. The abandonment of traditions like decorating ponds with oil lamps during Diwali further signals the unraveling of sacred human-nature relationships.

This dissonance between ritual intent and ecological reality mirrors global patterns where pollution degrades both ecosystems and spiritual integrity (Verschuuren et al. 2012). For Muslims, compromised ablution water disrupts communal solidarity; for Hindus, desecrated rituals reflect a loss of cultural identity. Such tensions exemplify how environmental decline erodes rites tied to natural elements (Aswani et al. 2018), severing ties to biocultural heritage.

Social cohesion Ponds historically functioned as “third places” (Oldenburg 1999), which are neutral, inclusive hubs fostering intergenerational and interfaith bonds. Respondents unanimously affirmed their role in strengthening social ties, particularly for women and children who gathered at ghats (steps) for bathing, laundry, and recreation. Before degradation, communal activities like swimming (100%), group bathing (90%), and evening gatherings (95%) were ubiquitous. Summer nights brought cold breezes, drawing residents to pond banks for storytelling, singing, and interfaith picnics—practices that transcended class and religious divides.

Today, 67.6% of respondents report these activities have ceased, with ponds transitioning from commons to sites of exclusion. Children no longer learn to swim, leading to drownings in neglected waters—a stark human cost of lost stewardship (Adger et al. 2013). The decline of shared spaces mirrors Bangladesh’s broader erosion of pluralistic heritage, as resource degradation fractures collective identity (Berkes 2009). Privatized water infrastructure has compounded this shift, replacing communal interaction with individualistic resource use.

The loss extends beyond leisure: ponds once democratized social capital by enabling cross-community dialogue (Putnam 2000). Elders now describe a fragmented society where interfaith gatherings and collaborative stewardship are relics of the past. This decline underscores how environmental degradation reshapes not just ecosystems but the very fabric of human relationships.

Mental health impacts of ponds The concept of the “blue mind,” which is the restorative psychological effects of proximity to water (Conrad et al. 2021), manifests vividly in rural Bangladesh, where ponds historically provided sanctuary from agrarian life’s stresses. Over 90% of respondents emphasized ponds’ profound mental health benefits, describing how sitting beside these water bodies alleviated anxiety, improved concentration, and fostered peace. Many reported studying or meditating near ponds, practices corroborated by global evidence on blue spaces’ capacity to enhance cognitive function and emotional well-being (Britton et al. 2020).

Conversely, pond degradation has precipitated significant psychological distress. Sixty-one percent of respondents noted diminished aesthetic appeal and emotional attachment to ponds, eroding their sense of connection to these spaces. This loss extends beyond functionality: participants mourned the dissolution of cultural rituals and intergenerational bonds, echoing Zimmer et al.’s (2020) findings in Gujarat, where degraded water bodies fractured community identity. The collective grief over these changes exemplifies solastalgia—a form of ecological mourning for lost environments (Albrecht et al. 2007).

Altered ponds also disrupt “sense of place,” challenging individuals’ emotional ties to their surroundings (Warsini et al. 2014) and undermining feelings of belonging (McNamara and Westoby 2011). Respondents described heightened melancholy and rural identity erosion as pollution stripped ponds of their tranquility and scenic beauty, paralleling Tschakert et al.’s (2013) documentation of emotional suffering linked to environmental decline.

While marginalized groups bear disproportionate burdens, affluent households also lament lost relational non-material benefits. Wealthier interviewees highlighted the irreplaceable value of pondside gatherings, aesthetic enjoyment, and nature connection—losses that privatized alternatives cannot offset (Chan et al. 2012). This underscores the universality of blue spaces’ cultural and psychological significance, transcending socio-economic divides.

Causes for the degradation of ponds

Respondents identified multiple anthropogenic drivers degrading ponds. The most frequently cited factor is pollution from drains, septic tanks, and residential pipes, which has rendered ponds unusable for daily needs, prompting households to adopt privatized alternatives like tube wells or piped water. While this shift might appear as a neutral substitution of water sources, it masks significant socio-ecological trade-offs. First, abandoned ponds become dumping grounds for household waste due to inadequate waste management, accelerating eutrophication and further degrading water quality—a vicious cycle where pollution drives abandonment, and abandonment exacerbates pollution (Krzysztofik et al. 2015). Second, privatization reconfigures power dynamics (Cornea et al. 2016): affluent households transition seamlessly to “modern” systems, while marginalized groups, particularly women and low-income families, remain dependent on degraded ponds for washing, bathing, and rituals, amplifying inequities in access to clean water.

The shift to privatized infrastructure also disrupts communal stewardship. Shared ownership of ponds, while historically fostering collective management, now incites conflicts over responsibilities (Huq 2017), leading to over-extraction and neglect. These conflicts are compounded by

population growth, which strains finite water resources and exacerbates eutrophication, a process accelerated by nutrient runoff from densely populated areas. Furthermore, financial barriers deter maintenance: constructing flood walls or stairs to improve accessibility is often prohibitively expensive for low-income households, reinforcing cycles of disrepair.

Critically, this substitution is not merely a replacement of water sources but a net loss of NCPs. Privatized systems fail to replicate ponds' regulating contributions (e.g., flood buffering, microclimate cooling) or immaterial benefits (e.g., communal cohesion, spiritual practices). For example, abandoned ponds lose their role as social hubs, fracturing inter-generational bonds and communal identity.

Conclusion and recommendations

While ponds are among Bangladesh's most accessible and significant sources of water, a variety of human actions are presently causing them to lose most of their important aspects, such as greatly reducing the aquatic biodiversity that ponds uphold in a certain region, in addition to diminishing the important NCPs that ponds provide to human communities and the beauty of the environment. Despite being an important issue, research into ponds' NCPs is one of the most neglected concerns that has not yet made an influential mark on the general public or legislators. As a result, this study assessed the consequences of pondscape degradation on NCPs that are currently experienced by the residents of Sultanpur Village in Chittagong.

This study found that significant NCPs of ponds, such as water and livelihood provision, flood and temperature regulation, and socio-cultural contributions such as community building, recreation, mental health support, and spiritual and religious support, have dropped or even disappeared in recent years because of the pond water quality's rapid deterioration. Major causes include the community's extreme reliance on groundwater, which eventually makes pond water redundant, the rapid pace of urbanization, disputes among pond owners over responsibilities, the disposal of household waste into the water through septic tanks, drains, or connected sewage pipes, frequent flooding and extreme lack of pond management, financial support, strict policies, and awareness among local to higher authorities. Many aquatic species and surface animals that also depend heavily on the pond as their main source of food, shelter, and water are also being severely impacted. The results of the study highlighted that one of the primary roadblocks to the respondents using the pond was its polluted water.

The degradation of rural ponds in Bangladesh underscores a crisis not only of biodiversity loss but of severed human-nature relationships, as communities lose access to critical NCPs that have sustained material, cultural, and

spiritual well-being for generations. Our findings reveal that ponds, once hubs of water provisioning, flood regulation, and socio-cultural exchange, now face abandonment due to pollution, privatization, and shifting societal imaginaries that equate "modernity" with piped water and tube wells (Zimmer et al. 2020; Bryant and Bailey 1997). The substitution and/or abandonment of ponds represents a net loss of regulating and cultural NCPs, as these systems fail to replicate ponds' flood buffering, microclimate cooling, or communal cohesion. This decline disproportionately burdens marginalized groups: women navigate heightened health risks and emotional labor as polluted ponds become their only water source, while elders mourn the erosion of rituals and communal storytelling, reflecting a collective solastalgia for lost landscapes. Yet, proposed policy interventions often overlook these relational NCPs, favoring technical fixes like concrete embankments or chemical treatments that further alienate communities from their ecological heritage (Cornea et al. 2016; Escobar 1999).

Bangladesh's existing policies, such as the National Water Policy (1999), lack explicit provisions for pond conservation as NbS. While these frameworks emphasize water security and aquaculture productivity, they overlook ponds' socio-cultural and ecological roles, reflecting a broader global trend where small water bodies are excluded from environmental legislation (Hill et al. 2018). This policy gap is exacerbated by fragmented governance, where overlapping mandates between local governments, fisheries departments, and NGOs create regulatory voids, enabling pollution and encroachment (Bebés-Blázquez et al. 2016). Meanwhile, donor-driven projects prioritize visible, short-term "solutions" over communal stewardship, sidelining marginalized voices in decision-making (Ostrom 1990). To counter this, policies must re-center NCPs as multidimensional and co-produced through human-nature relationships. Co-management agreements, informed by Ostrom's principles of collective action, could empower women and landless households to govern ponds as commons, reconciling ecological restoration with cultural revitalization. Participatory mapping of NCPs, such as the role of ponds in mental health or intergenerational bonding, could further elevate context-specific values in policy design, challenging neoliberal metrics that reduce nature to economic inputs (Chan et al. 2012). Moreover, legal recognition of ponds as biocultural heritage sites, akin to protections for sacred groves or traditional water systems, would institutionalize these relational NCPs, ensuring rituals like Wu'du and Durga Pooja endure as living practices rather than relics.

Policy integration requires aligning local practices with global NbS agendas, such as the International Union for Conservation of Nature (IUCN)'s Standards, to secure funding and technical support for pond restoration. Ethnographic studies could expose how international development projects

inadvertently entrench elite capture of resources (Li 2007), while interfaith collaborations around pond festivals might model inclusive stewardship. By re-centering ponds as sites of socio-ecological justice, Bangladesh can reclaim these water bodies as linchpins of biodiversity, cultural identity, and climate resilience. Biocultural heritage frameworks (Escobar 1999) could inform legal strategies to recognize ponds as sacred sites under national biodiversity laws, ensuring rituals like Wu'du endure as living traditions rather than museum artifacts. Overall, institutional reforms must prioritize ponds in national climate adaptation strategies, ensuring they are recognized not as relics of the past but as vital NbS for sustainable futures.

The degradation of ponds in Bangladesh underscores urgent gaps in understanding the socio-political, cultural, and ecological interplay shaping the provision and erosion of NCPs. Future research must prioritize investigations into the gendered dimensions of NCP loss, particularly how privatization reconfigures women's roles from stewards of communal resources to marginalized users navigating polluted ponds. Building on Sultana's (2011) work on emotional geographies of water insecurity, studies could explore how intra-household power dynamics shift with the adoption of tube wells, and how women negotiate the dual burdens of water collection and societal blame for "backward" practices. Concurrently, relational values, such as the solastalgia elders express over lost rituals like Gonga Pooja or communal storytelling, demand deeper inquiry. Frameworks like ecological grief (Cunsolo and Ellis 2018) could quantify these immaterial losses, challenging neoliberal metrics that prioritize commodifiable services over cultural continuity. Equally critical is examining how social capital, bonding ties within kinship networks or bridging alliances with NGOs, shapes adaptive governance in contexts of institutional neglect. Drawing on Pretty's (2003) insights into the role of social capital in sustainable resource management, future studies could investigate how interfaith collaborations around pond festivals (e.g., Hindu-Muslim joint stewardship during Durga Pooja or Eid) foster collective action, or conversely, how land disputes fragment community cohesion. For instance, do interfaith collaborations around pond festivals enhance collective action, or do land disputes fragment stewardship efforts? In addition, drawing on Hill et al. (2021a), examining how pond networks mitigate climate risks (e.g., flood regulation) and enhance biodiversity in agroecological landscapes can be critical to shed light on pondscape connectivity and resilience. Political ecology lenses (Bryant and Bailey 1997) could further unravel how global discourses like "modernization" intersect with local power structures to legitimize mega-infrastructure projects while sidelining communal ponds. Such interdisciplinary inquiries would not only advance NCP scholarship but also re-center conservation as a pathway to

socio-environmental justice, bridging ecological restoration with cultural revitalization.

Acknowledgements Our sincere gratitude to Sohana Khanam, Sadia Hamid, and the AUW lab teaching assistant, Vidyashini, for assisting us with data collection, entry, and analysis. Also, we would like to extend our gratitude to Jebunnesa and the Raozan Union Council members for supporting us with important documents and information.

Funding We would like to thank the Asian University for Women (AUW) for providing financial support, without which this study would not have been possible.

Data Availability None of the data/code generated and/or analyzed during the current study is publicly available because it contains information that could compromise the privacy of research participants. This confidentiality is being maintained as stipulated by the institutional ethical review committee.

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