



The Potential Benefits Ponds Offer as Nature-Based Solutions in the Rural Areas of Gwadar, Baluchistan: A Call for New Policy Directions

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Abstract

The rural ponds in Gwadar district provide clean drinking water for the local inhabitants and their livestock. They also serve as small-scale water storage, helping to prevent flash floods and providing a vital water source for agriculture in drought-prone rural areas. In this context, the current research assesses the vital role ponds play as Nature-Based Solutions (NBS) in sustaining local communities, conserving biodiversity and protecting the environment in the study area. The water source for the ponds was surface run-off, with a catchment area of less than 8 km². The average depth was 1.95 m, the surface area was 10670 m² and the pond volume was 11 acre-feet. Locals were interviewed about the details of ponds. In order to assess the quality of pond water, 26 water samples from different ponds were collected and the physicochemical parameters (TDS, EC and pH) of the pond water were recorded *in situ*. The TDS values of the samples rose from 170 mg/l to 1200 mg/l within an average of 463 ppm and the EC values varied from 240 μ S/cm to 1550 μ S/cm within an average of 702 μ S/cm, whereas the average pH was 7.4 and varied from 7.1 to 8. Analytical findings indicate that the pond water is fresh. Despite the longstanding role of ponds in supporting the local community of Gwadar for over a century and their potential use as NBS, these water bodies continue to receive almost no attention in provincial and federal water policy and environmental regulations in Baluchistan, Pakistan.

Keywords: Rural ponds; Nature-based solutions; Water policy; Gwadar; Baluchistan

Introduction

Nature-Based Solutions (NBS) tackle societal concerns, including risk vulnerability and climate resilience, while offering opportunities for local adaptation. Their implementations deal with the risks of climate-related events such as floods, droughts, heat waves and rising

sea levels. A fundamental concept of Nature-Based Solutions (NBS) is that, as a localized intervention, it addresses various issues through natural processes, offering multiple solutions requiring diverse stakeholders' involvement and local adaptation for a context-specific approach. The concept of Nature-Based Solutions (NBS) was initially introduced by the World Bank in 2008 and the first research program on NBS was inaugurated in 2013.

Ponds are small, shallow water bodies with a maximum surface area of 5 hectares, a maximum depth of 5 meters and less than 30% cover of emergent vegetation. If water clarity permits, ponds will have light penetration into the sediments and can be either permanent or temporary and natural or human-made. Ponds are widespread habitats in nearly all terrestrial biomes, from Antarctica to the tropics. There are between 547 million and 3.19 billion ponds in the world; however, there is a great deal of uncertainty about the number of ponds at the national and international levels in many areas [1].

Ponds are essential for providing ecosystem services and are hotspots for biodiversity in terms of species composition and biological characteristics. They provide shelter for numerous species exclusive to their habitat and those endangered or scarce. Ponds can significantly impact biodiversity, pollution reduction, flood control and climate change mitigation with careful planning. Additionally, there is a direct link between the community and the pond's ecosystem. Ponds, like oceans, have demonstrated their significance in sequestering carbon. The annual carbon sequestration capacity of a single 500 m² pond is equivalent to the carbon produced by an automobile over the same period.

Ponds are especially well-suited to be used as NbS because of their significant contribution to biodiversity conservation, their potential role in mitigating and adapting to climate change and the vast range of Nature's Contribution to Peoples (NCPs) they provide. The International Union for the Conservation of Nature (IUCN) defines NbS as "actions to protect, sustainably manage and restore natural and modified ecosystems in ways that address societal challenges effectively and adaptively, to provide both human well-being and biodiversity benefits".

The importance of ponds to society and the environment is increasingly recognized. However, ponds are still somewhat overlooked by researchers and often overlooked in international and national nature conservation legislation. Moreover, freshwater scientific research, legislation and conservation focus disproportionately on rivers and larger lakes. Similarly, ponds in the study area are also excluded from provincial and national water policies and environmental laws despite their significant contribution to rural communities and the provision of multiple ecosystem services [2].

No study has been conducted to assess the significant impact of ponds and the ecological services they offer in the rural areas of Gwadar district. This study aims to highlight the essential role of ponds as nature-based solutions in sustaining the local community, preserving biodiversity and safeguarding the environment in the study area. Additionally, this study strongly advocates for the inclusion of ponds in both provincial and national water policies [3].

Materials and Methods

The research employed a hybrid method, commonly called mixed methods, integrating quantitative and qualitative research approaches. The selection of mixed methods was due to the integration of both approaches to offer a more comprehensive understanding of the roles of ponds in arid rural areas of Gwadar, Baluchistan. Interviews with rural dwellers provided qualitative data about ponds and their roles in rural settlements. We conducted numerous field visits to witness the communities' reliance on ponds and how they contribute to biodiversity, climate change adaptation, water management and other ecological services [4].

Study area

The research site is located in the coastal district of Gwadar in Southwestern Pakistan, which is known for its arid climate and sparse vegetation. The study area's ponds, naturally occurring depressions, store water. The ponds surface areas and depths have expanded to store more water in response to the growing demand for water. The study area ponds allow small-scale water storage in a $\leq 8\text{ km}^2$ catchment. Local communities living in the villages near ponds depend on ponds for multiple basic needs. We interviewed locals about ponds' origin, maintenance and roles in the studied area. Rainwater accumulates throughout 1-2.5 years in ponds. The ponds serve agricultural and drinking water purposes for the inhabitants and their livestock. The local communities are responsible for running and maintaining the ponds. Ponds serve as the oldest surface water

reservoirs in district Gwadar and among the 26 ponds in the research site, 13 have reached an age of over 100 years, surpassing the estimated lifespan of any dam. Moreover, they are a cost-effective and low-maintenance option with a more extensive estimated lifespan and importantly that does not harm the ecosystem. Ponds are also less susceptible to evaporation, a common issue in arid regions (Figure 1 and Table 1) [5].

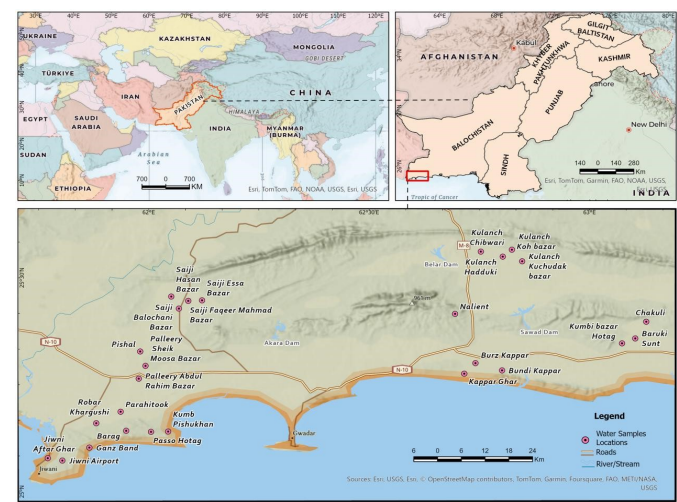


Figure 1: The location map of the study area with sampling points.

S. no	Ponds with village location names	LAT	LONG	AD	H	SA	PV	PA	Purpose
1	Kumb Pishukhan	25.14061	62.04411	1.52	21	4006	4.95	100+	Drinking
2	Passo Hotag	25.13994	62.00525	1.82	15	2720	4.02	40	Drinking and livestock
3	Ganz Band	25.10306	61.86542	1.52	27	3970	4.9	100+	Drinking and livestock
4	Barag	25.14239	61.94894	0.76	44	14650	9.05	100+	Drinking, livestock and agriculture
5	Robar Khargushi	25.16	61.88106	2.13	13	3570	6.16	80	Drinking
6	Parahitook	25.18694	61.93636	2.13	13	3482	6.02	100+	Drinking
7	Burz Kappar	25.30048	62.74125	1.82	26	1427	2.1	40	Drinking
8	Nalient	25.41575	62.695	4.57	108	1031	3.75	100+	Drinking and livestock
9	Palleery Abdul Rahim Bazar	25.26419	61.97742	1.52	17	3982	4.9	8	Livestock

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10	Palleery Sheik Moosa Bazar	25.29412	61.99269	1.52	14	3854	4.75	50	Drinking
11	Pishal	25.32774	61.98074	0.91	21	183360	135	50	Drinking, livestock and agriculture
12	Jiwni Aftar Ghar	25.07839	61.77111	1.82	17	2995	4.4	30	Drinking
13	Jiwni Airport	25.07278	61.80417	1.82	58	2315	3.42	82	Drinking
14	Kulanch Chibwari	25.56122	62.75347	2.74	38	5550	12.3	16	Drinking
15	Kulanch Hadduki	25.54947	62.80317	3.05	31	4096	10.1	100+	Drinking
16	Kulanch Koh bazar	25.56569	62.82392	1.82	36	566	0.84	100+	Drinking and livestock
17	Kulanch Kuchudak Bazar	25.53853	62.84725	1.82	30	1881	2.76	40	Drinking
18	Kappar Ghar	25.27586	62.71586	1.82	26	4897	7.26	100+	Drinking
19	Bundi Kappar	25.28358	62.80165	1.82	14	1884	2.82	100+	Drinking
20	Kumbi Bazar Hotag	25.34677	63.07374	1.82	6	5585	8.28	5	Drinking
21	Chakuli	25.39729	63.12868	1.82	20	2550	3.78	5	Drinking
22	Baruki Sunt	25.35827	63.10381	2.13	17	5868	10.15	8	Drinking
23	Saiji Balochani Bazar	25.42806	62.06853	2.13	34	3295	6.02	100+	Drinking
24	Saiji Essa Bazar	25.44726	62.12102	1.82	39	2688	3.96	100+	Drinking and livestock
25	Saiji Faqeer Mahmad Bazar	25.44598	62.0897	2.13	36	3202	5.53	100+	Drinking
26	Saiji Hasan Bazar	25.4561	62.0512	2.13	28	4003	6.93	100+	Drinking
Note: LAT: Latitude °N, LONG: Longitude °E, AD: Average Depth (m), HT: Height (m), SA: Surface Area (m ²), PV: Pond Volume (Acre-feet), PA: Pond Age (years)									

Table 1: The location and description of the ponds in the study area.

Hydrology

The study area experiences an arid climate with less than 100 mm yearly rainfall. Vegetation is scarce and rain mainly occurs during the winter season. The area's northern hilly terrain is the source of many important ephemeral and intermittent streams and rivers, such as Dasht, Jakk, Laura, Pasao, Palleri, Saiji, Akra, Gatti, Shadad, Sur, Barambah, Karwat and Durabale Kaur, Balor, Chilari, Save and Shinzani, which eventually discharge into the Arabian Sea towards the South. The rural areas of Gwadar are vulnerable to drought and flash floods because of low precipitation, low relief and poor soil absorption capacity. The coastal terrain is mostly flat, which causes water to accumulate rapidly, while the soil hinders effective infiltration and results in quick runoff. All these factors contribute to the region's sudden occurrence of flash floods. Therefore, rainfall and the area's geology profoundly influence the hydrological behavior of the ponds. Due to the scarcity of groundwater resources, primarily caused by impervious geological formations, rural communities in the Gwadar district have relied on ponds as surface water reservoirs for over a century. Therefore, the region's ponds have been instrumental in addressing pressing environmental and social challenges [6].

Geological setting

The area under study is on the coastal margin of the Makran subduction, located in Southwestern Pakistan. The Makran subduction zone, one of the world's most enormous accretionary wedges, was formed when the Eurasian and Arabian plates converged. It has a shallow angle of subduction and an extensive sediment input of 7 km. In Pakistan and Iran, the oceanic Arabian plate passes beneath the continental Eurasian at a rate of ~4 cm/yr offshore. The accretionary prism extends for about 1000 km from approximately longitude 57°30' E in southeastern Iran to approximately 66°30' E longitude in Southern Pakistan and its topography varies from more than 3000 m below sea level to heights of 1500 m above sea level. The study region active tectonic convergence has brought thick tertiary sea sediments onto the continental plate, forming various geological formations such as Jiwani, Ormara, Chatti, Talar and Parkini.

Parkini formation is named after the Parkini Kaur, a tributary of the Hingol river. It is the oldest formation in the study area. It consists of mostly poorly bedded mudstone with minor intercalations of siltstone or finesandstone. Its age is Late Miocene. Talar formation is mostly found in the northern hilly regions. It mainly consists of fine sand, siltstone, shale, mudstone and some clayey limestone, dating back to the Late Miocene-Early Pliocene period. Chatti formation is after the locality of Chatti about 17 miles North west of Gwader. It consists of mostly mudstone which is interbedded with siltstone or fine grained sandstone and marl. The Chatti formation of Pliocene age is extensively exposed, from the Talar region in the east to Jiwani town in the West. The Ormara formation is primarily composed of sandy clay that is soft and poorly consolidated, with a small amount of conglomeratic bed present in its upper part. The youngest Jiwani formation of the Late Pleistocene is primarily made up of shelly and reefal limestone, sandstone and conglomerate. These geological formations serve as the foundation for the ponds in the study area [7].

Sampling

The research site spans a total area of 2690 km² and is located between latitudes 25.078389, 61.771111 and 25.397287, 63.128682. We collected 26 water samples from ponds used for drinking, agriculture, and livestock. We conducted primary *in situ* tests on water quality physicochemical parameters, such as pH, TDS and EC and we also acknowledge the limitations of these tests in assessing the water quality of the ponds in the study area. The sampling was done from March 20 to April 30, 2023, without experiencing any rainfall. We determined the locations of the samples using Garmin Etrex 10 GPS devices.

Analytical techniques

To assess the water quality in the pond study area, we used the EZDO 6011 pH meter, the EZDO 6031 TDS meter, and the EZDO 6021 conductivity meter to measure the electric conductivity, total dissolved solids and pH of the water samples. We calibrated each device after every 15 readings and immersed it in the sample for 1 minute and 30 seconds during the sample collection process. The electric conductivity ($\mu\text{S}/\text{cm}$) and total dissolved solids (mg/l) measuring ranges of the devices were "0 to 19990," respectively [8].

Software and statistical analysis

We use ArcGIS 10.7 for mapping and Google Earth Pro to determine the ponds surface area.

Pond depth

We determined the depth of the ponds using a weight and a foot-marked string. We lowered the weight into the water until it reached the bottom of the pond, then measured the length of the submerged line to determine the depth. To find the average pond depth, we measured it along two transects-one along the length and one along the width. We made sure to select transects that represent both the shallow and deep parts of the pond. For example, at sample collection point 2 (Kumb), which has an irregular shape, we took pond depths at six locations across the length and five across the width. We calculated the average pond depth by averaging all these measurements.

Surface area of the pond: The surface areas of the pond were measured *via* imagery from Google Earth satellites.

Determining pond volume: We calculate the volume of water in a pond in acre-feet by multiplying the pond's acreage by its average depth in feet (Figure 2).

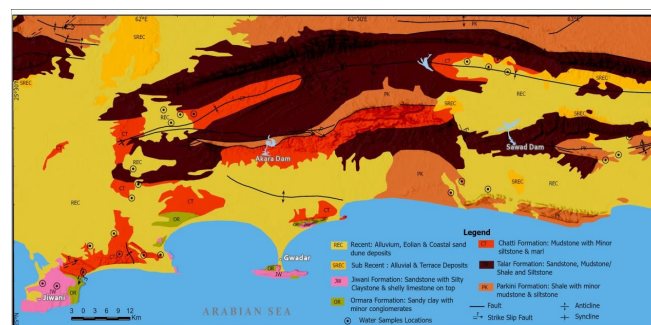


Figure 2: The geological map of the study area illustrates the geological setting and the locations of ponds on various geological formations.

Results and Discussion

Ponds in rural areas of Gwadar district provide residents with numerous benefits. They provide clean drinking water to rural dwellers and livestock. Additionally, they support agricultural activities by facilitating the growth of crops such as great millet, finger millet, fodder, musk melon, watermelon, gaur bean, green gram (mung bean) and other pulses. These ponds also act as biodiversity hotspots, store water and help address water scarcity in an area with less than 100 mm annual rainfall. Furthermore, they help mitigate flash floods and provide recreational opportunities. Ponds provide several ecological services, such as reducing flood risk, mitigating climate variability, enhancing runoff water quality, and boosting biodiversity and recreational value. Due to their variety of services, the ponds in the study area are valuable as nature-based solutions. Rural dwellers strategically located the pond to collect water from natural drainage systems, reducing the water's nutrients by settling suspended particles, absorbing phosphate and nitrogen and interacting with microbes. Ponds can remove scattered contaminants such as sediment, pesticides, phosphorus and nitrogen from surface waters. Ponds provide various ecosystem services that can be harnessed to sustainably address critical water management and climate change issues in the study area.

Climate change adaptation

Despite having a significantly lower percentage of emissions than other developed and underdeveloped countries, the Global Climate Risk Index ranks Pakistan as one of the most vulnerable countries to climate change. The floods in August 2022, which resulted from a 1.2°C rise in global temperatures and were made worse by the melting of Himalayan glaciers, highlighted the country's susceptibility to climate change. In addition, Pakistan had its fifth warmest year on record between March and May 2022 [9].

The Intergovernmental Panel on Climate Change (IPCC) acknowledges carbon sequestration as a crucial strategy for reaching climate goals and limiting global temperature increases. The study area ponds with a relatively shorter surface area and more depth ratio than more extensive water reservoirs provided an excellent tool for climate change adaptation in an arid environment with high evaporation. Ponds sequester carbon by storing organic material in sediments, mitigating carbon dioxide's impact on the atmosphere. Ponds may serve as an effective mechanism for enhancing carbon sequestration at the landscape level. According to Taylor et al., ponds could mitigate carbon emissions if integrated into urban green infrastructure or agro-environmental programs.

Biodiversity: Permanent ponds are essential freshwater ecosystems and centres of biodiversity and in agroecosystems, they act as biodiversity hotspots, providing habitats for various freshwater species and resting and feeding locations for terrestrial organisms. Ponds support birds, insects, mammals and other terrestrial species in addition to endangered aquatic animals and maintain a higher diversity of life at the regional level than other freshwater ecosystems, such as lakes and rivers. Several resident and migrant birds were seen near the ponds during the field visits, namely See-see Partridge, Grey Partridge, Sand-grouse, White-cheeked Bulbul, House sparrow, Red-wattled lapwing, Wild pigeon, Dove, Hoopoe, Little Green Bee-Eater, Common Babbler, Swallows, Hume's Wheatear (flycatcher) and Indian Roller. Besides the birds, jackals, sand foxes, porcupines, cap hares and sand cats were the mammals. We also observed reptiles such

as desert monitor lizards, amphibians like frogs and various insects like dragonflies, butterflies, bugs and water beetles. Urbanization, encroachment and developmental activities in the cities have degraded the habitat, making rural ponds a prime habitat for insects, birds, mammals, amphibians and reptiles in the study area. Desert monitor lizards (reptiles), frogs (amphibians) and different species of dragonflies, butterflies, bugs and water beetles were the insects that were witnessed in the rural ponds area of Gwadar. Due to habitat degradation caused by urbanization, encroachment and city developmental activities, rural ponds serve as prime habitats for the study area's insects, birds, mammals, amphibians and reptiles.

Additionally, the diversity of ponds is more extensive than larger water bodies (dams) in the area under study due to their dispersed locations. In this context, ponds are a substantial aquatic habitat for biodiversity at the landscape and catchment scales.

Water resource management: Ponds in the arid rural region of Gwadar are practical tools for water management and water scarcity mitigation. The average depth was 2 m, the surface area was 10670 m² and the pond volume was 11 acre-feet. Moreover, they partially mitigate flash floods and offer excellent recreational opportunities. The lack of groundwater resources, an arid environment and climate change impact on the water resources could potentially limit socioeconomic development and threaten water security in such regions. Climate change presents a substantial environmental barrier to development because of its negative impact on water security, particularly in arid and semi-arid regions. Ponds are an effective and efficient way to manage water resources and help prevent water scarcity in the Gwadar district of Baluchistan due to their spatial suitability.

These ecological services highlight that the ponds in the study area play a vital role in climate change adaptation, biodiversity preservation, water management, quality maintenance and overall environmental health.

Geological conditions favoring pond formation in Gwadar: The high sedimentation rate in the Makran subduction zone is attributable to the interaction of tectonic processes, uplift, erosion, river discharge and climatic factors. The convergence plates and the associated geological dynamics create an environment conducive to the rapid accumulation of sediments in the study area. The buildup of sediment shortens the useful life of the reservoir. Therefore, large dams in the study area have shorter estimated lifespans due to the increased sediment load in the rivers and reservoirs. For instance, high sedimentation caused the Akra Kaur dam (17000 acre-feet), which supplied water to Gwadar city and neighbouring towns, to lose 70% of its storage capacity, despite its construction in 1995 and estimated life of only 30 years.

Water quality of ponds:

Statistical parameters: pH indicates the relative concentration of hydrogen and hydroxyl ions in water. Water with a higher concentration of hydrogen ions is acidic, whereas water with a higher concentration of hydroxyl ions is essential. The estimated pH (7.1-8) of 26 pond water samples is within the specific range (6.5-8.5) set by the World Health Organization.

The study area's Total Dissolved Solids (TDS) range between 170 and 1200 mg/l, with an average TDS value of 463 mg/l (Table 2). Except for sample no. 19 (Bundi Kappar), which has a TDS value of 1200 mg/l, slightly higher than the limits set by the WHO and

NSDWQ Pakistan, the remaining 25 samples had TDS values within the limits set by the WHO and NSDWQ Pakistan.

S. no	Sample collection points (Ponds)	EC (µS/cm)	TDS (mg/l)	pH	Latitude	Longitude
1	Kumb Pishukhan	570	380	7.2	25.14061	62.04411
2	Passo Hotag	1060	690	7.1	25.13994	62.00525
3	Ganz Band	1090	680	7.1	25.10306	61.86542
4	Barag	650	440	7.3	25.14239	61.94894
5	Robar Khargushi	420	290	7.4	25.16	61.88106
6	Parahitook	520	350	7.5	25.18694	61.93636
7	Burz Kappar	910	580	7.3	25.30048	62.74125
8	Nalient	530	360	7.4	25.41575	62.695
9	Palleery Abdul Rahim Bazar	1290	710	7.1	25.26419	61.97742
10	Palleery Sheik Moosa Bazar	900	590	7.3	25.29412	61.99269
11	Pishal	670	410	7.4	25.32774	61.98074
12	Jiwni Aftar Ghar	570	240	7.6	25.07839	61.77111
13	Jiwni Airport	270	180	7.1	25.07278	61.80417
14	Kulanch Chibwari	570	350	7.6	25.56122	62.75347
15	Kulanch Hadduki	310	200	7.5	25.54947	62.80317
16	Kulanch Koh bazar	400	280	7.5	25.56569	62.82392
17	Kulanch Kuchudak Bazar	630	430	7.8	25.53853	62.84725
18	Kappar Ghar	1010	680	7.4	25.27586	62.71586
19	Bundi Kappar	1550	1200	8	25.28358	62.80165
20	Kumbi Bazar Hotag	1270	980	7.4	25.34677	63.07374
21	Chakuli	630	400	7.5	25.39729	63.12868
22	Baruki Sunt	1180	800	7.6	25.35827	63.10381
23	Saiji Balochani Bazar	380	250	7.3	25.42806	62.06853
24	Saiji Essa Bazar	240	170	7.4	25.44726	62.12102
25	Saiji Faqeer Mahmad Bazar	280	190	7.4	25.44598	62.0897
26	Saiji Hasan Bazar	350	220	7.5	25.4561	62.0512
Note: EC: Electrical Conductivity (µS/cm), TDS: Total Dissolved Solids (mg/l)						

Table 2: The physiochemical parameters of the pond water samples.

Caroll proposed four classes of water based on TDS values.

- Freshwater with TDS 0-1,000 mg/l.
- Brackish water with TDS between 1,000-10,000 mg/l.
- Saline water with TDS from 10,000 to 100,000 mg/l.

- Brine water with TDS>100,000 mg/l.

According to Carroll classification, most of the studied samples (25) fall into class 1 (freshwater), with only one pond water sample classified as type 2 (brackish water), whereas no water sample belongs to class 3 (saline water) and class 4 (brine water).

The EC of the pond water samples varies from 240 ($\mu\text{S}/\text{cm}$) to 1550 ($\mu\text{S}/\text{cm}$), with a mean value of 702 ($\mu\text{S}/\text{cm}$). Except for one pond water sample (1550 $\mu\text{S}/\text{cm}$) out of 26, all values are within the WHO maximum permissible limit of 1500 $\mu\text{S}/\text{cm}$.

The EC classification divides water into six types:

- Non-saline if $\text{EC} < 700 \mu\text{S}/\text{cm}$.
- Slightly saline if EC is between 700 and 2,000 $\mu\text{S}/\text{cm}$.
- Moderately saline if EC exceeds 2,000 but less than 10,000 $\mu\text{S}/\text{cm}$.
- Highly saline with EC values from 10,000 to 25,000 $\mu\text{S}/\text{cm}$.
- Very highly saline if EC values are between 25,000 and 45,000 $\mu\text{S}/\text{cm}$.
- Brine water with EC greater than 45,000 $\mu\text{S}/\text{cm}$.

Type 1 (non-saline) accounts for 65.39% of pond water samples, while type 2 (slightly saline) accounts for 34.61% of the studied sample. Whereas no sample value of the study area is categorized into moderately saline (type 3), highly saline (type 4), very highly saline (type 5) or type 6 (brine water) (Figure 3 and Table 3).

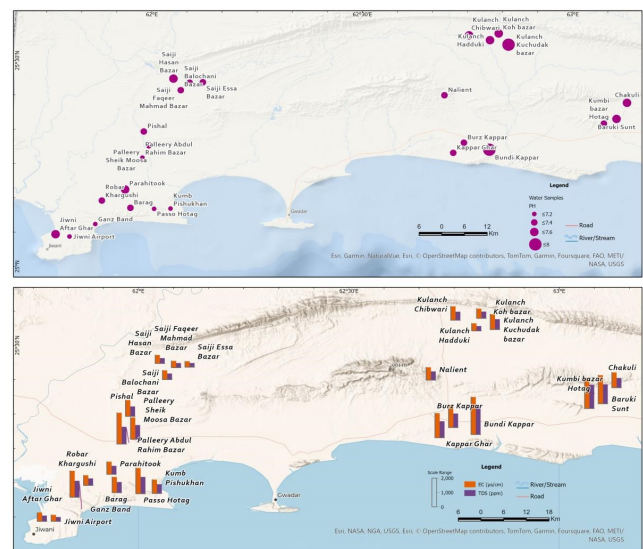


Figure 3: The EC, TDS and pH of different pond water samples in the study area.

Parameters	Total sample	Min	Max	Median	Mean	SD	NSDWQ Pak (2008)	WHO (2017;2004)
TDS (mg/l)	26	170	1200	390	463	264	<1000	<1000
EC ($\mu\text{S}/\text{cm}$)	26	240	1550	600	702	365	-	1500
pH	26	7.1	8	7.4	7.4	0.2	6.5-8.5	6.5-8.5
Height (m)	26	6	108	26	29	20	-	-
SA (m^2)	26	566	183360	3526	10670	35317	-	-
AD (ft)	26	2.5	15	6	1.95	2.3	-	-
PV (Acre-feet)	26	0.84	135	5	11	26	-	-

Note: TDS: Total Dissolved Solids (mg/l), EC: Electrical Conductivity ($\mu\text{S}/\text{cm}$), HT: Height (m), SA: Surface Area (m^2), AD: Average Depth (feet), PV: Pond Volume (Acre-feet), SD: Standard Deviation, NSDWQ Pak*: National Standard Drinking Water Quality Pakistan. NSDWQ Pak, Pakistan Environmental Protection Agency, 2008. WHO, World Health Organization (2017), World Health Organization, Geneva, 2004

Table 3: The basic statistical parameters of pond water samples in the Gwadar district.

Conclusion

The TDS values of the pond water samples rose from 170 mg/l to 1200 mg/l within an average of 463 ppm and the EC values varied from 240 $\mu\text{S}/\text{cm}$ to 1550 $\mu\text{S}/\text{cm}$ within an average of 702 $\mu\text{S}/\text{cm}$. The average pH was 7.4 and varied from 7.1 to 8. The average depth, surface area and volume of the ponds in the study area were 1.95 m, 10670 m^2 and 11 acre-feet, respectively.

The pond water of rural areas of Gwadar is analyzed to assess its quality for drinking purposes. The pH, TDS and EC values of studied pond water samples are within the permissible limit of WHO and NSDWQ Pak. However, Sample no. 19 is slightly saline (1550 $\mu\text{S}/\text{cm}$) and has TDS concentrations of 1200 mg/l. This slightly high salinity of the pond water sample may be due to the catchment area's geology, the pond's low height about mean sea level and its closer location to the sea in the study area. The analysis findings show that the pond water at the research location is fresh.

The variability in pond water quality is relatively low, as indicated by the low standard deviations. This may be influenced by the geology of the catchment area and the elevation of the ponds above mean sea level. In contrast, the measurements of pond height (m), surface area (m^2), average depth (ft) and volume show significant variability in the dataset, which may depend on water demand.

In the Gwadar district, rural ponds sustain rural communities, enhance their livelihoods and well-being and strengthen social and cultural advantages. Nevertheless, ponds, being smaller than rivers and lakes, continued to be largely absent from provincial and national water policies. The policy circle has yet to recognize the contributions and potential of ponds due to their small size, vulnerability to drought and inadequate data about ponds in the study area. Therefore, ponds are undocumented and lack environmental regulations in the province. Despite the significant roles and provision of nature-based solutions by ponds, they have failed to seek attention from conservationists,

water resource managers, climate scientists and environmentalists in water policies.

Conversely, ponds in the arid rural Gwadar areas provide many benefits to the locals, recognized as Nature's Contributions to People (NCP). These ponds offer a variety of nature-based solutions for the sustenance of local communities and their livestock, including the provision of food and drinkable water, adaptation to climate change, management of water scarcity, carbon storage and other diverse ecosystem services like flood mitigation, biodiversity hotspots, water purification and recreational areas. The study area's arid climate and geological conditions also promote pond formation. Accordingly, the ponds in the research region are pertinent to the rationale of the land.

Therefore, it is crucial to consider them as an integral part of the water framework policy to ensure sustainable development and effective water management. By properly conserving, managing and increasing the number of ponds, we can enhance water storage, boost the socio-economic status of rural dwellers and provide practical solutions to water scarcity. This research will help policymakers, water conservationists, hydrologists, water managers and engineers understand ponds' potential as nature-based solutions in drought-prone rural areas of Gwadar district, Baluchistan.

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Contributions

Both authors played a crucial role in designing and conceptualizing the study. Pazeer Ahmed wrote the main manuscript and prepared all the tables, while Nadeem Ahmad Usmani created the maps. Both authors visited the study sites, collected primary data, and observed how the community relies on ponds and the role these ponds play in the area. Both authors also reviewed the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

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