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ECO-EFFICIENCY IN HOSPITALITY:A BUSINESS MODEL FRAMEWORK FOR AN AQUA-CENTRIC SUSTAINABLE CAFÉ

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ABSTRACT
Pakistan is facing a multidimensional hydrological emergency. The study explored the overall feasibility of a low-cost miniature "Aqua-Thematic Sustainable Cafe" at Lahore. This model uses "frugal eco-innovation" to combine indoor aquaponics and greywater recycling. This study adopted a pragmatic mixed-method research design by triangulating quantitative data of 101 valid consumer questionnaires (Gen Z and Millennials) with qualitative insights from 8 structured interviews with industry practitioners. The empirical results proved the operational feasibility and commercial necessity of the model.

INTRODUCTION
1.1 Introduction to the study
The strategic integration of urban commercial development with environmental conservation has become a major issue for developing countries. Pakistan is a case study of resource constrained economies. The state is currently facing a multi-dimensional hydrological emergency that has transitioned from a seasonal challenge into an existential threat to national security and socio-economic stability. Once called a water-rich country, Pakistan has seen the destruction of its renewable freshwater supplies to catastrophic levels due to a deadly convergence of rampant population growth, rapid urbanisation and the intensifying effects of climate change. In 1951, just after independence, each person had access to an annual per capita water supply of around 5,260 cubic meters, an abundance that has since completely disappeared. By 2023 that had dropped to around 930 cubic meters per person - well into the "water-scarce" zone as defined by international standards, which set the crucial threshold at 1,000 cubic meters. According to the Pakistan Council of Research in Water Resources (PCRWR, 2023), if the current trends of mismanagement and over-extraction are not addressed, a much more devastating decline to the level of "absolute scarcity", where availability is below 500 cubic meters per capita, is expected by 2025. This trend points to a total breakdown of the current hydrological regime where the competition for water between the expanding urban retail sector and the agricultural backbone, is approaching a tipping point and requires major shifts in commercial resource use behaviour.

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Table 1.1: Temporal Decline of Annual Per Capita Water Availability in Pakistan (1951-2025)

Year	Per Capita Availability (m3)	Scarcity Classification
1951	5,260	Water Abundant
1981	2,500	Water Vulnerable
2023	930	Water Scarce
2024	908	Water Scarce
2025 (Projected)	500	Absolute Scarcity

Punjab, the country's industrial and agricultural heartland, has been worst affected. In the provincial capital, Lahore, the situation is changing. The urban aquifer in the core of the metropolitan area is being depleted rapidly. More than 14.1 million people in Lahore depend almost entirely on groundwater from a system of more than 1,500 tube wells. Government reports say the water table is falling at a rate of 2.61 to 3 feet per year. The water table in major localities like Gulberg and DHA has already dropped to 130-150 feet and if over-extraction persists unabated, it is expected to go down to below 230 feet by 2025. Currently, only a handful of urban areas have potable water at depths of 800 to 1,000 feet.

Table 1.2: Comparative Groundwater Depletion Dynamics in Lahore Metropolitan Area

Urban Zone	Current Water Table Depth (ft.)	Annual Rate of Decline (ft.)	2025 Projected Depth (ft.)
City Center	130	2.5-3.0	230
Gulberg/DHA	147-150	3.0	230+
Peripheral Zones	131	1.1	145+

A major but previously unregulated contributor to this dilemma is the commercial hospitality sector (particularly, the rapidly expanding café and casual dining sector). The traditional restaurant model is linear in its resource extraction model, consuming large amounts of potable city water for kitchen operations and enhanced sanitation, before discharging untreated, nutrient-rich effluent directly into an overburdened municipal sewer system. Moreover, it is also one of the major contributors to the national plastic disaster. Pakistan produces almost 3 million tonnes of plastic waste every year, out of which, 86% is disposed of into landfills or waterways due to mismanagement. At the same time urban dwellers are subjected to heavy

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"urban stress," a psychological strain exacerbated by poor air quality (smog) and lack of restorative exposure to nature. The study proposes a transformational solution in the form of a small-scale and cost-effective "Aqua-Thematic Sustainable Cafe". This model uses the concepts of "Frugal Eco-Innovation" which is the design of solutions that are scarce in resources but far less costly in material limits than competitor alternatives to meet sustainable needs. The cafe can reduce its water usage by as much as 90 percent compared to traditional gardening with the addition of the closed-loop symbiotic system, Aquaponics, which merges aquaculture and hydroponics. In addition, the interior design uses the idea of "Blue Mind" which states that the exposure of humans to healthy water environments creates a meditative state that relieves stress and improves mental health (Nichols, 2014).

1.2 Problem Statement

The hospitality industry in Punjab still operates in a paradigm that prioritises short-term financial benefit over long-term environmental stewardship. This results in two distinct systemic problems. Firstly, the sector puts an unsustainable pressure on Lahore's depleting groundwater resources due to unmonitored consumption and a huge waste output. Local restaurants waste almost 15-17% of their total food supply. Secondly, sustainable and organic dining options are emerging, but are almost exclusively marketed as high end, luxury products. This "luxury gatekeeping" is creating an unachievable goal of environmental stewardship for the average price-conscious consumer (Generation Z and Millennials), who are the majority of the café patrons in Lahore. Now there is a vital research gap in low-cost business models that use "frugal eco-innovation" to fill this void. "The majority of café owners think sustainability is a big capital investment, not a way to save money. This study examines how a small-scale café is able to use simple, do-it-yourself (DIY) aquaponics and greywater recycling to reduce operating expenses while also providing the relaxing setting to fight urban stress.

1.3 Justification and Rationalisation

The need for research is driven by both government mandate and economic survival. The Pakistani government has taken a hard line on water conservation with the introduction of the National Water Conservation Strategy (2023-2027) that requires
commercial sectors to conduct mandatory water audits and install water-efficient fixtures. To combat wasteful behaviours, the city's Water and Sanitation Agency increased business water prices by 400%. The old high water use method is no longer economically viable for a small business owner in Lahore. An aqua-themed model that grows its own herbs and recycles its own water can shield a café from rising utility expenses and supply chain inflation. Moreover, establishing an indoor environment with biophilic design to enhance mental health is a lucrative and socially accountable business approach, which appeals to the urban youth segment due to the constant high AQI and smog in Lahore.

1.4 Aims of the study

The main objectives of the study are as follows:

Objective 01.

To evaluate the financial and operational feasibility of a low-cost aqua-themed cafe, focusing on the affordability of small-scale indoor aquaponics and greywater recycling systems.

Objective 02.

Aim To examine the psychological effects of biophilic 'Blue Mind' interior design (visual and aural water cues) on stress reduction and emotional pleasure of urban diners in Lahore.

Objective 03.

To investigate the impact of low-cost sustainability on brand preference, trust and revisit intention among the youth demographic of Pakistan.

1.5 Questions of the Research

Objective 1. (Financial and operational sustainability)

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1.1 What is the projected initial capital investment (CapEx) to set up a small-scale DIY indoor aquaponics and grey water system in the local Lahore market?
1.2 How much money can a cafe save each month on variable food OpEx by growing its own herbs on-site (mint, basil, microgreens)?
1.3 How much of the monthly water utility costs can be saved through the use of greywater recycling and low flow water taps?

Objective 2: (Psychological Impact and Recovery)

2.1 What is the effect of some visual stimuli (fish tanks) and audio stimuli (flowing water) in indoor "Blue Spaces" on subjective stress level of customers in Lahore?
2.2 What is the effect of aqua-themed biophilic design on client emotional pleasure during their visit?
2.3 How does the presence of water features influence the "perceived restorative quality" of a cafe in an urban environment of stress for residents?

Objective 3: Consumer Behaviour and Market Preferences

3.1 Does offering a sustainable experience at a competitive, low cost increase the likelihood of brand switching amongst Gen Z and Millennial consumers?
3.2 What is the impact of visible sustainability practices such as zero-plastic policies and water recycling on consumer trust and perceived brand value?
3.3 How does a sustainability-oriented brand image affect local customers' long-term revisit intentions and word-of-mouth recommendation?

Figure 1.1: The Study's Conceptual Framework

Independent Variables	**Mediating Factors**	**Dependent Variables**
Biophilic Aquatecture Indoor Aquaponics Greywater Recycling	Urban Stress Reduction Perceived Food Hygiene	OpEx Reduction Competitive Brand Preference Revisit Intention

1.6 Importance of the Study

This results of the study will provide a "frugal" template for local entrepreneurs to develop hospitality units that are resilient to rises in utilities and supply chain unpredictability. It provides a practical demonstration of Pakistan's Green Building Code 2023 to environmental stakeholders and supports the Punjab Smog Mitigation Plan. Socially it democratises the mental health benefits of the "Blue Space", providing an affordable restorative haven for residents suffering from urban environmental stressors such as noise and air pollution.

1.7 Hypotheses

We ask respondents in Lahore to answer truthfully and accurately about their environmental concerns and spending habits. It is believed that the small-scale aquaponics technology can be adapted to the usual commercial shop formats found in Lahore's metropolitan hubs. The period of data collection is expected to be characterised by relatively stable economic conditions and utility pricing structures.

1.8 Limitations and Delimitations.

Delimitations: The study is limited to the urban metropolitan area of Lahore, Punjab. It is concerned with the small-scale, low-cost cafe sector and explicitly excludes large industrial farms and the luxury hotel industry.
Limitations: Present economic inflation in Pakistan may affect the results as it may lead to fluctuation in the prices of imported technical components during the study. Also, the data is

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cross-sectional, that is, it only captures impressions at a single point in time.

1.9 Definitions of Terms

Aquaponics is a closed loop food production system whereby nutrient rich fish waste is used as fertiliser for plants which then naturally filter and clean the water for the fish creating a completely organic cycle.

Blue Mind A slightly meditative state of calmness, peacefulness and general happiness caused by being in nature, or even just seeing water.

Frugal Eco-Innovation is a business strategy to simplify sustainable technology to make them high-performing, low-cost and accessible to consumers in mass-market.

Greywater: Used water from sinks and basins that can be filtered and reused for non-potable purposes such as toilet flushing or indoor farm irrigation.

THE LITERATURE REVIEW

The literature review gives theoretical and empirical support for the proposed aqua-themed sustainable hospitality model functioning in a complex arena of environmental science, urban economics and restorative psychology. To understand why a "frugal" sustainable café is needed in Lahore, consider the escalating hydrological emergency, which has morphed from a seasonal problem to a constant existential threat for Pakistan's national security. Pakistan, a country that once enjoyed abundant water resources, has witnessed a steep fall in annual per capita water availability. In 1951, each person had access to a healthy 5,260 cubic meters of water, which by 2024 had dropped to around 908 to 930 cubic meters, firmly placing the nation in the "water-scarce" category according to international criteria (Ishaque, 2023; PCRWR, 2023). This loss is not just a statistical anomaly. It is a systemic failure caused by unsustainable population growth, outdated irrigation infrastructure, and the increasing impacts of climate change. The Pakistan Council of Research in Water Resources has predicted that the country will slide further into "absolute scarcity" with water availability falling below the 500 cubic metre threshold as early as 2025. The struggle for drinkable water between the household, industrial and agricultural sectors will reach a tipping point in the next ten years according to this track, thus demanding resource efficiency from all commercial operations (Ishaque, 2023).

The most conspicuous and serious hydrological problem has been in Punjab, the country's industrial hub and breadbasket. This dilemma is playing out in the provincial capital, Lahore, in the metropolitan core, with rapid and unsustainable depletion of the urban aquifer. Lahore relies almost entirely on groundwater, pumped by a network of more than 1,500 tube wells, to supply water for a burgeoning population of more than 14.1 million people. Recent studies on spatio-temporal dynamics based on satellite images and piezometric monitoring have revealed that the water table of the city is retreating at an alarming rate of 2.61 to 3 ft/year (Mahmood et al., 2024). In high density commercial & residential clusters like Gulberg and DHA, the water table has already gone down to 130 to 150 feet and if the present trend of over-extraction continues it is predicted to fall to 230 feet by 2025 (WWF-Pakistan, 2024). This leads to a 'water-shedding' scenario where the energy costs of pumping with electricity or diesel increase exponentially the deeper the water drops, rendering old high-consumption business models financially unviable (Mahmood et al., 2024).

Table 2.1: Granular Analysis of Groundwater Vulnerability in Lahore (2024-2025)

Urban District	Current Water Depth (ft.)	Annual Rate of Decline (ft.)	2025 Projected Depth (ft.)	Primary Driver of Depletion
Gulberg / Liberty	147-152	3.0	230+	High commercial & retail water

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				density use
DHA (Phases 1-5)	145	2.8	225+	Rapid residential expansion & luxury use
Johar Town / PU	131-138	2.5	210	Institutional and student population load
Walled City	128	1.1	140	High impermeability & lack of recharge
Specific Scarcity Pockets	800-1000	N/A	Exhaustion	Deep aquifer tapping due to upper-level drying

Source: Synthesized from Basharat & Rizvi (2024), Mahmood et al. (2024), and WASA Lahore Monitoring Data.

This hydrological pressure is further compounded by the commercial hospitality sector including Lahore's flourishing café and casual dining market which has traditionally been unregulated. The region's traditional restaurant operations are grounded on a linear resource extraction paradigm known as the 'take-make-waste' attitude. These facilities consume large volumes of potable city water to power robust kitchen activities, elaborate dishwashing, and sanitation, and then dump untreated, nutrient-rich effluent into the already overtaxed municipal sewer system (Afzal & Nazir, 2022). This linear approach is no longer environmentally or economically feasible, especially because the existing urban infrastructure in Lahore was not designed to accommodate the flow of discharge from a rapidly expanding retail sector. Further, the hospitality industry is a significant contributor to the national plastic crisis; Pakistan produces almost 3 million tonnes of plastic waste every year, of which 86% is disposed of in unmanaged dump sites or littered around land and water bodies due to the absence of effective circular economy loops (Global Plastic Action Partnership, 2022; WWF-Pakistan, 2025). Poor management of these resources at the café level is contributing to a larger pattern of urban decay, affecting the city's public health (Afzal and Nazir, 2022).

Lahore's residents are facing not only the physical depletion of resources but also a "silent public health crisis" of acute urban stress. Seasonal haze episodes have increased the Air Quality Index (AQI) to levels more than 30 times the recommended standards set by the World Health Organization. Lahore has become a regular feature of the list of the cities with the worst air quality (Khan, 2023; Rahim, 2024). Recent qualitative and quantitative studies have suggested that prolonged exposure to this environmental degradation increases anxiety, depression, irritability, and cognitive deficiencies among the urban population, especially the youth (Rahim, 2024; Batool et al., 2025). In downtown areas that lack cool green or blue spaces, millions of people live with the daily stress of noise pollution and crowding that degrades the quality of life. In this context, the development of "Blue Mind" sanctuaries-indoor spaces that use water as a therapeutic tool to combat urban stress or "red mind" (Nichols, 2014; Ali et al., 2025) is well justified.

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For small business owners, the economic side of this issue has reached a tipping point, thanks to some significant changes in provincial legislation. The Water and Sanitation Agency (WASA) Lahore recently raised commercial water charges by 400% to stop, the unsustainable wastage of pure water (Dawn, 2024; Prevention Web, 2024). For a tiny café, water has gone from a minor utility cost to a major operational "drain" on profits. This new legislation offers a strong financial incentive for "Frugal Eco-Innovation" a business approach that involves rethinking processes to reduce environmental impact and keep the product affordable for mass-market consumers (Soomro et al., 2025; Albert, 2019). This research assumes that the adoption of an aqua-thematic model in which a business harvests its own ingredients and recycles its own water is no longer a moral gesture of corporate social responsibility but an absolute financial survival tactic in an inflationary economy where utility shielding and supply chain resilience will be the determinants of a hospitality unit's success or failure (Soomro et al., 2025).

Lahore, as a high-temperature metropolitan environment, depends on the performance of closed-loop biological systems for the accuracy of aqua-thematic hospitality model. The heart of it is aquaponics a brilliant combination of hydroponic plant growing and recirculating aquaculture. The nitrogen cycle in this symbiotic system acts as a biological engine converting nitrogenous waste products of aquatic organisms into plant nutrients (Mishra et al., 2020). A "frugal" model for the Punjabi market recommends the use of Nile Tilapia (Oreochromis niloticus) and other hardy fish, which are able to survive in fluctuating water temperature and pH levels, typical of indoor conditions common in Lahore (Supriadi et al., 2022). The cycle starts with fish feed that is rich in protein, which is converted into ammonia (NH3). In an aqueous environment this ammonia exists in a pH dependent equilibrium. Under higher pH and temperature conditions the ammonia becomes unionised and extremely hazardous to fish. For instance, increasing the pH from 7.5 to 8.5 at an indoor temperature of of 28°C can almost triple ammonia toxicity (Francis-Floyd et al., 2009). This means the system uses autotrophic bacteria such as Nitrosomonas and Nitrobacter to convert harmful ammonia into nitrites and nitrates which are used as organic fertiliser for the cafe's indoor herb walls (Mishra et al., 2020; Supriadi et al., 2022). This biological filtration technology utilises about 90% less water than conventional soil-based gardening, as the same amount of water is continuously cleaned and recirculated, rather than lost to seepage or evaporative waste (Ferrarezi & Bailey, 2019; Mishra et al., 2020). In order to preserve this fragile biological balance in Lahore, it is necessary to strictly adhere to technical criteria, especially because the internal climate is affected by the extreme summer heat waves of the city. Research has shown that fish, plants and microorganisms have different ideal habitats, which means the operator is faced with a "trilemma" and must find a balance to stay profitable Fish like water to be slightly alkaline (pH 7.5-8.0) but plants like it to be slightly acidic (pH 5.5-6.5) to optimise the solubility of key minerals such as iron and phosphorus (Goddek et al., 2015; Yang & Kim, 2019). To maintain a healthy nitrification process and avoid nutrient lockout in the herbs, the recommended aqua-cafe should be kept at a constant "compromise pH of 6.4 to 7.0 (Yang & Kim, 2019; Danaher, 2023). In addition, the levels of dissolved oxygen (DO) should be maintained at full saturation (above $5-6~mg/L)$ through energy-efficient aeration stones (because oxygen is the prime limiting factor for both fish development and waste conversion by bacteria) (Danaher, 2023; Mishra et al., 2020).

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Table 2.2: Optimized Technical Parameters for Indoor Aquaponics in Lahore's Urban Climate

Parameter	Targeted Range	Critical Significance for the Aqua-Cafe
Water Temperature	$22^{\circ}C-28^{\circ}C$	Ensures metabolic health of Tilapia and prevents DO depletion.
pH Levels	6.4-7.0	The "Compromise Zone" for bacterial nitrification and plant nutrient uptake.
Dissolved Oxygen (DO)	$>5.0~mg/L$	Necessary for aerobic respiration of fish and biofilter bacteria.
Electrical Conductivity (EC)	$0.8-2.0~mS/cm$	Measures nutrient density; prevents "salt creep" during high evaporation.
Carbonate Hardness (KH)	$40-100~mg/L$	Acts as a pH buffer against the acid produced by nitrification.

Source: Compiled from Danaher (2023), Goddek et al. (2015), and Supriadi et al. (2022).

Results Interpretation

The empirical information of this mixed-methods study offers a clear road map for the implementation of the aqua-themed cafe idea in Punjab. A blend of managerial operational realities and consumer psychological needs pose a series of significant problems that challenge the existing paradigms of hospitality in Pakistan. The evidence shows, in the first place, a large "Affordability-Sustainability Convergence".

South Asian green business has traditionally been criticised as a "luxury niche" that is only accessible to the wealthy. However, this survey is counter to that story as 87.1% of Lahore's regular cafe consumers have a low-to-mid income but 89.1% have a direct competitive preference for sustainable methods to traditional ones. This indicates sustainability is considered a major ethical foundation instead of a luxury facet for Generation Z and Millennials. A frugal eco-innovation strategy is a resource-efficient, low-cost technology (e.g., DIY aquaponics) that can meet this ethical demand without adding to the menu costs, setting the café apart in the market.

Second, qualitative feedback from industry practitioners indicates a dramatic change in company strategy from "Corporate Social Responsibility" (CSR) to "Operational Survival". Resource efficiency has moved from optional to non-negotiable financial shield following the recent 400% WASA commercial water tariff increase. Larger venues such as Dozyfudge were initially worried about the costs of the setup, but boutique units such as Laj Cuisine and Comer Cafe saw that the long-term protection of utility costs that greywater recycling and on-site herb

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growing would provide would see a higher return on investment. This indicates that the aqua-thematic approach is not just an ecological remedy but also a strong "Cost-Leadership" strategy that shields small enterprises from the uncertainty of Pakistan's inflationary economy and growing utility costs (Shaikh et al., 2025).

Last, the café was a significant public health stakeholder in Lahore, with unusually high restorative scores for visual aquatic stimuli $(mean=4.68)$. In a city where pollution levels often hit "hazardous" levels and the water table drops three feet a year, residents know all too well about the "nature-deficit." Indoor water features provide a sensory experience that elicits a somewhat meditative "Blue Mind" state, which lowers cortisol and alleviates anxiety caused by the environmental degradation of the city. The cafe model is therefore not only a food service establishment but a healing haven that offers a "social dividend" to the people of Lahore and cultivates brand loyalty through real and conspicuous flora.

Conclusion

Based on the above empirical observations and further analysis, the following conclusions of the study are established:

Conclusion 1 (Operations): The aqua-thematic model is operationally executable in the SME sector of Lahore, if the initial capital investment remains below the 1-2 lac PKR range. The biggest financial upside is utility shielding and stabilising the herb supply chain.

Conclusion 2 (Psychology): Diners' urban stress levels significantly decrease in the presence of indoor water habitats. Visual stimuli (eg living aquariums) are the main cause of this restorative effect, whilst aural water sounds are effective in masking urban noise pollution.

Conclusion 3 (Market): A large unmet need exists for "Democratised Sustainability" in Punjab. And when prices are equal, sustainable branding is the final tiebreaker, attracting a loyal customer base that values transparency and ethical consumption.

Recommendation

The following recommendations are made to convert these research findings into tangible steps for Pakistan's hospitality industry and regulatory organisations.

5.6.1 Strategic Entrepreneurial Recommendation

Show Off the Infrastructure: Café operators should make aquaponic beds and filter conduits visible to patrons. Without the usual advertising costs, this is a "Green Signal" to build real trust in food ethics and hygiene.

Phased Implementation: New units should begin small with a modular aquaponic display (10-12 sq. ft.) and scale up with procurement savings through in-house production of basil and mint due to managerial concerns about inflation.

Community Involvement: Restaurants with high "social sharing" scores may want to consider having customers help collect or learn about water-saving data, turning the cafe into an educational community center.

5.6.2 Policy Implications for Government and Regulators.

WASA Incentives Models In addition, the Punjab government can offer a "Water Stewardship Rebate" for businesses that reduce municipal water use by 40% through greywater recycling.

Facilitation of Compliance: HEC in collaboration with banks can provide low-interest "Green Micro-financing" to small cafes willing to comply with Pakistan Green Building Code 2023.

Table 5.2: Strategic Action Plan for Implementing the Aqua-Thematic Model

Step	Primary Action	Responsibility	Financial/Social Impact
01	Retrofit sinks with basic greywater filters for flushing/irrigation.	Café Proprietor	45-50% Reduction in WASA Bills

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02	Install vertical DIY aquaponic herb walls in public zones.	Manager/Owner	Zero procurement cost for mint/basil
03	Use "Blue Mind" elements (fish/water sound) as atmospheric anchors.	Design Team	72% perceived reduction in urban stress
04	Formally apply for Green Building Code compliance status.	Business Owner	Potential for utility rebates and tax credits

Limitations and Future Work

The limitations of this study are the sample size of 101 consumer respondents and a cross-sectional focus on urban Lahore, but this study provides a basic framework. Comparison of other Punjabi industrial centers under water stress like Multan and Faisalabad can also be done to compare regional perspectives on resource scarcity in future researches. Also, a longitudinal study for six months needs to be undertaken to gauge the precise heart rate and biochemical markers of stress reduction in customers when they are in "Blue Mind" venues.

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