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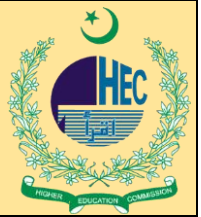
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Investigating the Effects of Anthropological Activities on Mangrove Forests in Balochistan

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ABSTRACT

Mangrove forests in coastal regions are essential, offering shoreline stabilisation, carbon sequestration, and biodiversity. This study investigates human impacts on Balochistan's mangroves, using a descriptive quantitative research design. Results reveal widespread community agreement on the ecological and economic importance of mangroves, especially for marine breeding and coastal protection. The most significant finding from the threat perception analysis is that the community views the lack of freshwater flow as the greatest threat to the mangroves. This perception, which differs from direct local activities, indicates a sophisticated understanding of the larger environmental and upstream issues affecting their coastal ecosystem. Although pollution, overfishing, and fuelwood cutting are also seen as serious threats, the consensus on freshwater flow underscores a desire for broader, systemic solutions. The factor analysis further supports this detailed understanding by dividing threats into three categories: direct local human activities (like pollution, overfishing, and grazing), large-scale environmental and developmental threats (such as climate change and encroachment), and resource management and use (including freshwater and fuelwood). Our study recommends adopting

sustainable harvesting practices, establishing regulations, and implementing community-based management to maintain sustainable timber and fuelwood extraction and promote forest regeneration.

Keywords: *Mangrove Forests, Coastal Regions, Shoreline Stabilisation, Carbon Sequestration, Biodiversity.*

Introduction

Background

Mangrove forests, found in tropical and subtropical coastal regions, are highly productive ecosystems providing essential ecological services such as shoreline protection, carbon sequestration, and supporting biodiversity (Ahmed et al., 2025; Giri et al., 2015; Friess, 2024; Akram et al., 2023; Islam et al., 2024; Khan et al., 2024, 2025; McClanahan, 2024; Rahman et al., 2025). These intertidal ecosystems are characterised by salt-tolerant shrubs and trees that flourish in brackish water, playing vital roles in maintaining coastal health and productivity (Khan et al., 2023; Salem et al., 2024; Akram et al., 2023). Worldwide, mangroves are facing unprecedented decline due to a combination of natural stressors and human activities (Alongi, 2014; Giri et al., 2015; Xiong et al., 2023; Ferreira et al., 2024; Liu et al., 2024; Rahman et al., 2025). In Pakistan, mangrove forests are mainly found along the coastlines of Sindh and Balochistan provinces, bordering the Arabian Sea (Khan et al., 2023; Mukhtar & Hannan, 2011; Qureshi, 1993; Rasool et al., 2002). While Sindh province historically supports larger and denser mangrove cover, Balochistan also hosts significant mangrove areas, including locations such as Sonmiani, Kalmat, and Gawatar Bay (Rahman et al., 2017; Mukhtar & Hannan, 2011; Qureshi, 1993; Rasool et al., 2002). The ecosystem's unique functions, such as providing breeding grounds, habitats, and niches for diverse flora and fauna, highlight their ecological significance (Khan et al., 2023).

Despite their critical ecological and socio-economic significance, mangrove forests worldwide are under severe threat from a variety of human-induced pressures (Bhagarathi & DaSilva, 2024; Xiong et al., 2023; Cahyaningsih et al., 2022; Akram et al., 2023). These threats include coastal development, expansion of aquaculture and agriculture, acquisition of timber for domestic use, and various forms of pollution (Ferreira et al., 2024; Liu et al., 2024; Rahman et al., 2025; Akram et al., 2023). The impact of human activities on mangroves is not confined to direct deforestation and habitat destruction; coastal development and urbanisation can also result in increased erosion and sedimentation in mangrove areas (Moustafa et al., 2023). For instance, in Southeast Asia, agriculture and aquaculture are identified as significant drivers of deforestation, alongside other human activities, although a large proportion of drivers remain unidentified (Fauzi et al., 2019). The increasing human population often correlates with a decrease in mangrove extent and quality, particularly in countries with large mangrove areas like Indonesia (Cahyaningsih et al., 2022). In Pakistan, a significant reduction in freshwater supply, increased marine pollution from industries, over-harvesting of mangroves and fish by local communities, sedimentation, and coastal erosion are recognised as major stressors on mangrove sustainability (Mukhtar & Hannan, 2011). The fragile nature of Pakistan's mangroves makes them increasingly susceptible to coastal hazards (Rahman et al., 2017).

The coastal area of Balochistan, Pakistan, is an arid region facing significant environmental challenges, including drought, which has profound impacts on vegetation dynamics (Ali et al., 2024; Ullah et al., 2022). A recent study conducted by Sanaullah et al. (2025) demonstrated that,

over the course of 36 years, mangrove coverage expanded from approximately 44,486.09 hectares to 106,636.64 hectares, corresponding to an annual growth rate of 3.88 %. All surveyed sites- namely Indus Delta, Miani Hor, Sandspit, Kalmat Hor, Jiwani, and Dasht River Delta- exhibited a discernible increasing trend. Furthermore, three newly documented sites- Ankara Creek, Darag Hor, and Kataho/shadi Kor- experienced a substantial increase in mangrove cover, rising from 48.15 hectares to 132.87 hectares, with an annual growth rate of 12.69 % during the period from 2016 to 2024. These findings underscore the effectiveness of targeted conservation measures implemented within Pakistan's coastal ecosystems. Additionally, the positive trend in rainfall patterns further supports reforestation efforts. Nonetheless, despite these encouraging overall trends, a dynamic reduction in mangrove coverage was observed at certain locations, attributable to anthropogenic pressures such as pollution, camel grazing, and fuelwood collection. This endorses that the region's coastal areas, while supporting mangrove ecosystems, are also subject to various anthropogenic activities and environmental pressures. Previous research has indicated that the direct value of mangroves in Balochistan province was estimated at USD 1,287 per hectare, highlighting their economic importance to local communities (Adhikari et al., 2010). However, the interplay between human activities, climate variability, and mangrove health in specific coastal districts like Lasbela remains underexplored. For example, while the broader Balochistan region has been studied for its overall drought impact on vegetation (Ali et al., 2024), and the population and household dynamics in its divisions including Balochistan, have been documented (Khan et al., 2024), a focused, comprehensive analysis specifically addressing the impact of local human activities on mangrove forests within Balochistan is limited.

The current literature provides a general understanding of the threats to mangroves globally and in Pakistan (Bhagarathi & DaSilva, 2024; Mukhtar & Hannan, 2011; Akram et al., 2023). However, there is a research gap concerning the localised and specific impacts of human activities on mangrove forests in Balochistan. Existing studies in Pakistan have often focused on the Indus Delta in Sindh due to its denser mangrove cover (Rahman et al., 2017; Qureshi, 1993) or have provided broader overviews of Balochistan's mangroves without detailed, localised impact assessments (Adhikari et al., 2010; Mukhtar & Hannan, 2011; Rasool et al., 2002). Furthermore, while remote sensing techniques have been widely applied to monitor mangrove changes elsewhere (Ahmed et al., 2025; Xiong et al., 2023; Salem et al., 2024; Luo et al., 2024), a detailed spatiotemporal analysis of mangrove dynamics in Balochistan, specifically linking changes to quantifiable human activities within the district, is not readily available in the peer-reviewed literature. Understanding the specific drivers and their magnitudes in this particular arid coastal environment is crucial for effective local conservation and management strategies. The impacts of activities such as unchecked development and localised pollution (including heavy metal transport via rainfall runoff from areas like Windar, which is in Balochistan, Pakistan) (Ullah et al., 2023)), and resource utilisation practices in Balochistan need more targeted investigation. Hence, this research comprehensively assesses the impact of human activities on the mangrove forests in Balochistan, Pakistan.

This research contributes significantly to the understanding of localised human-mangrove interactions in arid coastal environments. By providing a detailed, geographically specific analysis of mangrove degradation drivers and their impacts in Balochistan, it will offer crucial empirical data for local policymakers and conservation bodies. The findings will support the development

of evidence-based conservation plans, resource management policies, and community-based ecotourism initiatives that are tailored to the unique socio-economic and environmental context of Balochistan. Furthermore, by identifying specific anthropogenic pressures, this study can serve as a model for similar assessments in other data-scarce regions, enhancing global efforts towards mangrove conservation and sustainable coastal development.

Literature Review

Mangrove ecosystems, vital to coastlines, are increasingly threatened by diverse anthropogenic activities that lead to their degradation and loss. These unique intertidal forests provide a multitude of ecological services, including coastal protection, carbon sequestration, and critical habitats for a wide range of flora and fauna (Ahmed et al., 2025; Akram et al., 2023). Despite their profound ecological and socio-economic importance, human pressures have resulted in a significant global decline in mangrove cover (Cahyaningsih et al., 2022; Xiong et al., 2023; Akram et al., 2023). This study delved deep to review the key human factors affecting mangrove forests.

Major Anthropogenic Drivers of Mangrove Degradation

The primary human activities impacting mangrove forests can be broadly categorised into direct habitat destruction and indirect degradation through pollution and altered environmental conditions.

Direct Habitat Destruction and Conversion

Coastal Development and Agriculture/Aquaculture

One of the most significant threats to mangroves is their direct conversion to other land uses. The global context shows that direct conversion of mangrove areas for coastal development, agriculture, and aquaculture are major drivers of deforestation (Bhagarathi & DaSilva, 2024; Fauzi et al., 2019; Cahyaningsih et al., 2022). While less prominent in the arid regions of Balochistan compared to Southeast Asia, any such development pressures would further fragment and weaken remaining mangrove stands, making them more susceptible to degradation from timber extraction. Coastal development, driven by urbanisation and infrastructure expansion, often involves clearing mangrove forests to make way for ports, resorts, housing, and industrial facilities (Akram et al., 2023). Rapid development and population inflow have resulted in the clearance of certain areas of mangrove forests (Singh et al., 1990). Coastal development and urbanisation can also result in increased erosion and sedimentation in mangrove areas (Moustafa et al., 2023). However, these mangrove forests ecosystems are significantly threatened by human activities and settlements and climate change worldwide (Ferreira et al., 2024; Liu et al., 2024; Rahman et al., 2025). The expansion of human settlements and urbanisation along coastlines has increased pressure on mangrove ecosystems (Choudhary et al., 2024; Roy et al., 2025; Thomson et al., 2024). This directly destroys the habitat and disrupts the natural hydrological cycles crucial for mangrove survival.

Expansion of aquaculture, particularly shrimp and fish farming, is a well-documented driver of mangrove deforestation, especially in Southeast Asia (Cahyaningsih et al., 2022; Akram et al., 2023; Fauzi et al., 2019). For instance, in Indonesia, which possesses the largest extent of mangroves globally, the increasing human population has corresponded with a decrease in mangrove extent and quality, often due to agricultural and aquaculture expansion (Cahyaningsih et al., 2022). A study analysing mangrove deforestation drivers in Southeast Asian countries from 2000 to 2012 revealed that while a significant proportion of drivers remained Unidentified, agriculture and aquaculture were notable contributors across several nations, including Vietnam,

Philippines, Malaysia, and Indonesia. This study illustrates the proportion of various drivers contributing to mangrove deforestation in Southeast Asian countries. While Unidentified causes form a substantial portion, Aquaculture and Agriculture are clearly visible as significant factors in countries such as Indonesia, Malaysia, and Vietnam (Fauzi et al., 2019). Agricultural expansion, including the establishment of plantations, also leads to the encroachment and conversion of mangrove lands (Akram et al., 2023). These activities eliminate mangrove stands, leading to habitat loss, increased erosion, and reduced ecosystem services.

Fuelwood Harvesting and Grazing as a Driver of Deforestation

The acquisition of mangrove timber for various domestic uses, such as fuelwood, charcoal production, construction materials, and grazing, is widely acknowledged as a cause of deforestation. This practice removes the structural components of the ecosystem, weakening its resilience and ecological functions (Akram et al., 2023). In the Andaman Islands, for example, rapid development and population inflow have led to the clearance of mangrove areas, impacting species richness and biomass production (Singh et al., 1990). When this extraction exceeds sustainable limits, it directly results in the removal of mangrove trees, leading to habitat loss, disruption of the ecosystem's structure, and diminished resilience (Bhagarathi & DaSilva, 2024). Unsustainable harvesting practices not only reduce the physical extent of the forest but also impair its ability to provide essential ecosystem services, making coastal areas more vulnerable to natural calamities and climate change impacts (Salem et al., 2024).

In the context of Balochistan, local communities living along the coast traditionally utilise mangrove products (Rasool et al., 2002). In Balochistan, a notable decline in mangrove coverage has been observed at certain locations, primarily due to anthropogenic pressures such as camel grazing and fuelwood collection (Sanaullah et al., 2025). This dependence can lead to significant pressure on mangrove resources, especially for fuelwood, given the arid nature of the region and limited alternative energy sources. The abstract of a study discussing the use and management of mangrove ecosystems in Pakistan found that households, particularly poorer ones, made relative use of mangrove products and services, meaning any decrease in ecosystem quality would disproportionately affect them (Adhikari et al., 2010).

This highlights the complex interplay between socio-economic factors and resource utilisation, where livelihood needs can drive unsustainable harvesting if not properly managed. While explicit quantitative data on the exact volume of fuelwood, timber extracted and grazing from Balochistan's mangroves is scarce in the provided literature, the general pattern of unsustainable resource extraction identified in Pakistan and globally suggests this is a significant local issue (Bhagarathi & DaSilva, 2024; Qureshi, 1993).

Indirect Degradation

Mangrove forests also suffer from various indirect anthropogenic impacts that degrade their health and functionality.

Altered Hydrology and Freshwater Supply

Mangroves are highly sensitive to hydrological changes, relying on a delicate balance of freshwater and saltwater (Akram et al., 2023). Alterations to riverine flows, often caused by upstream damming, irrigation projects, or other water diversions, can significantly reduce the freshwater supply to coastal mangrove areas (Akram et al., 2023; Khan et al., 2023). This increases salinity stress, impacting the growth, health, and survival of mangrove species, particularly in arid and semi-arid regions like Pakistan. Reduced freshwater availability is a major

stressor on mangroves in Pakistan, alongside pollution and over-harvesting. Mangroves in arid regions like Balochistan are particularly susceptible to changes in freshwater supply. Damming, irrigation projects, and other upstream water diversions reduce freshwater inflow, increasing salinity stress on the mangroves (Khan et al., 2023). This stress can weaken trees, making them more vulnerable to the impacts of harvesting and reducing their regenerative capacity.

Pollution

Various forms of pollution severely impact mangrove ecosystems. Increased marine pollution from industrial discharges, including chemical and oil pollution, contaminates mangrove habitats, making them toxic for mangrove trees and the diverse organisms they support and hinder their growth and survival (Akram et al., 2023; Khan et al., 2023; Bhagarathi & DaSilva, 2024). Eutrophication, resulting from excessive nutrient inputs (e.g., from agricultural runoff and sewage), can lead to algal overgrowth, oxygen depletion in the water, and disruption of nutrient cycling, thereby harming mangroves and associated aquatic life. Marine debris, noise pollution, and thermal pollution also contribute to the degradation of mangrove health (Akram et al., 2023). While the specific extent of industrial pollution in Balochistan's mangrove areas is not detailed, the broader issue of marine pollution in Pakistan's coastal zones suggests that it likely contributes to the overall degradation of mangroves in Balochistan (Qureshi, 1993).

Over-harvesting and Resource Exploitation

Beyond timber extraction, over-harvesting of fish and other marine resources within mangrove-associated waters can disrupt the delicate food webs that mangroves support (Akram et al., 2023). Local communities often depend on mangroves for their livelihoods, leading to potential over-exploitation if management practices are unsustainable (Walters, 2008). In Balochistan, Pakistan, the direct value of mangroves was estimated at USD 1,287 per hectare, emphasizing their economic importance and the potential for both sustainable use and over-exploitation (Khan et al., 2023).

Sedimentation and Erosion

While mangroves naturally trap sediments, excessive sedimentation caused by human activities such as land-use changes, coastal development, or mining can overwhelm these systems. Heavy sediment loads can bury pneumatophores, restrict gas exchange, and reduce mangrove vitality, eventually leading to their loss. Conversely, coastal erosion, exacerbated by human activities like inappropriate coastal construction or the removal of natural coastal defenses, can undermine mangrove root systems and cause physical damage or loss (Akram et al., 2023).

Climate Change (Anthropogenic Contribution)

While climate change is a global phenomenon, its anthropogenic drivers contribute significantly to threats faced by mangroves (Akram et al., 2023; Khan et al., 2023). Rising sea levels, increased frequency and intensity of storms, and changes in temperature and precipitation patterns directly impact mangrove survival. Sea-level rise can inundate forests, while extreme weather events can cause physical damage and destruction (Akram et al., 2023; Khan et al., 2023). Though a global stressor, the severity and impact of these changes are amplified by human-induced greenhouse gas emissions.

The conceptual framework presented by Akram et al. illustrates the hierarchy of threats, categorizing coastal development, expansion of aquaculture and agriculture, and timber acquisition as Severe Threats. Climate change, eutrophication, and hydrological alteration are

listed as Moderate Threats, while diseases, tourism, and various forms of pollution are considered Low-Level Threats (Akram et al., 2023).

In Pakistan, mangrove forests are present in the Indus Delta (Sindh) and coastal areas of Balochistan, including Sonmiani, Kalamat, and Gawatar Bay. Three species, *Avicennia marina*, *Ceriops tagal*, and *Rhizophora mucronata*, are found naturally in Sonmiani (Rasool et al., 2002). Despite their ecological and socio-economic importance, mangroves in Pakistan face severe threats. A major issue is the reduction in freshwater supply, leading to increased salinity. Industrial pollution, over-harvesting of mangroves and fish, and coastal erosion are also significant stressors (Khan et al., 2023). Studies utilizing satellite imagery from Landsat-5 and Landsat-8 have shown spatial and temporal dynamics of mangrove forests, indicating both increases and decreases in cover overtime in regions like the Indus Delta (Ahmed et al., 2025). However, the overall trend in Pakistan highlights concerns regarding diminishing mangrove cover due to these anthropogenic pressures (Khan et al., 2023).

Indonesia hosts the world's largest mangrove areas, but these are rapidly declining due to human activities, especially with increasing population density (Cahyaningsih et al., 2022). Deforestation and degradation are primarily driven by the expansion of agriculture and aquaculture, as well as general human activities (Cahyaningsih et al., 2022; Fauzi et al., 2019). In the Western Irrawaddy River Delta (Myanmar), dynamic changes in mangrove forests from 1988 to 2022, quantified using remote sensing, demonstrate significant declines attributable to human activities and climate change (Xiong et al., 2023).

Methodology

This study uses the quantitative research methodology to investigate the impact of human activities on mangrove forests along the coast of Balochistan, Pakistan. The study utilised a descriptive research design, gathering primary data through a structured survey questionnaire from 316 local respondents. The data were then analysed using descriptive statistics to identify key trends and patterns.

A descriptive quantitative research design was adopted for this study. This approach was selected to systematically gather and present factual information about the state of human activities and their perceived effects on the mangrove ecosystem. The design aimed to provide a comprehensive snapshot of the respondents' knowledge, attitudes, and behaviours, without establishing a causal relationship between variables. The past tense is used throughout this section to reflect that the study has already been completed.

The study was conducted in Balochistan, Pakistan. This region was selected due to its significant mangrove forest ecosystem, which is under increasing environmental pressure. The target population for this study consisted of local residents living in communities directly adjacent to the coastal area of Balochistan. This included individuals from various demographic groups, such as fishermen, farmers, small business owners, and other community members whose livelihoods and daily lives are connected to the coastal environment.

A convenience sampling technique was employed to select the study participants. This non-probability sampling method was chosen due to the geographical constraints and the need to access a large number of respondents within a limited timeframe and budget. We approached individuals who were readily available and willing to participate in the survey. The final sample size was 316 local respondents, which was deemed adequate to provide a representative overview of the community's perceptions and experiences.

The survey was conducted in coastal communities within the Balochistan area to identify specific human activities impacting mangroves and to understand local perceptions and reliance on mangrove resources. The data was collected face-to-face during September/October 2021, employing a systematic approach to ensure data validity and reliability. The primary data collection instrument was a structured survey questionnaire. The questionnaire was developed in both English and Urdu to ensure all respondents could understand the questions accurately. The questionnaire was distributed among local communities, fishermen, and other stakeholders, following similar approaches used in other mangrove-dependent communities (Untari et al., 2020; Hidayat et al., 2024). The surveys gathered information on practices such as fishing, firewood collection, and waste disposal, providing a direct link between human behaviour and environmental outcomes.

The questionnaire was divided into four main sections. First, we gathered information on the respondents' demographic profiles, including age, gender, occupation, and educational level. This data was used to characterise the sample. Secondly, we assessed the respondents' perception of mangrove importance, where we used a Likert scale to assess respondents' awareness and valuation of the ecological and economic importance of mangrove forests. Thirdly, we examined the human activities and their impacts which consisted of a series of closed-ended questions and rating scales to identify the types of human activities respondents were engaged in or aware of (e.g., fishing, livestock grazing, fuel wood collection, solid waste disposal, pollution from commercial activities) and to gauge their perception of the severity of the impacts of these activities on the mangroves. Finally, we explored potential solutions and feedback is essential for suggesting effective recommendations. Prior to its full-scale implementation, the questionnaire was pilot-tested with a small group of 20 respondents to ensure clarity, validity, and reliability. Feedback obtained from the pilot testing phase was incorporated to refine and enhance the final version of the instrument.

The data were analysed using Stata-18 software. Descriptive statistics served as the primary analytical tool to summarise and describe the characteristics of the sample and overall response trends. Descriptive analyses are widely used in research (Berndt, 2009). Descriptive statistics is a fundamental method for summarising and presenting data in a meaningful way (Baffoe-Djan & Smith, 2019; Downie & Starry, 2019). It involves analysing quantitative data to describe patterns and characteristics of a sample group (Delaney, 2010; Sharma et al., 2018). The descriptive statistical measures were calculated using frequencies and percentages, means and standard deviations, as well as cross-tabulations to ensure robust and reliable results (Downie & Starry, 2019; Dong, 2023). Additionally, frequencies and percentages illustrate the demographic characteristics of the sample (e.g., the proportion of male and female respondents) and the response frequencies for categorical variables (e.g., the most frequently reported human activity) (Cleff, 2013; Dong, 2023). Means and standard deviations were obtained from Likert scale questions to indicate the central tendency of responses and to illustrate the dispersion or variability within the data (e.g., the average perceived importance of mangroves). An understanding of descriptive statistics is essential for researchers, decision-makers, and consumers of research to interpret and assess data effectively across diverse fields of social sciences (Baffoe-Djan & Smith, 2019; Cleff, 2013).

Besides, we used Principal Component Analysis (PCA) to explain most of the variation (Jolliffe, 1986; Wold et al., 1987). Principal component analysis is one of the oldest and most well-known

techniques in multivariate analysis, developed independently. PCA main goal is to reduce the dimensionality of data with many related variables while preserving as much variation as possible. This is achieved by transforming data into uncorrelated principal components, ordered so that the first few captures most of the variation. Computing these components involves solving an eigenvalue-eigenvector problem for a positive-semidefinite symmetric matrix. Despite its simplicity, it has diverse applications and different derivations (Jolliffe, 1986).

Ultimately, cross-tabulations were utilised to explore relationships between different variables, such as the connection between a respondent's occupation and their perceived level of environmental impact. The results of the descriptive analysis are presented in tabular form in the results chapter to facilitate clear and straightforward interpretation of the findings. The analysis aimed to provide a foundational understanding of human-mangrove interactions within the study area, establishing a basis for future, more complex inferential studies.

Results and Discussion

Demographics of the Sample

The result presented in Table 4.1., shows that the sample is heavily skewed towards male respondents, who make up 79.75% of the survey participants. This suggests a significant gender imbalance, which could influence the results, especially regarding activities and perceptions that differ between men and women. For example, if men are more involved in fishing and women in household chores, their perspectives on overfishing and fuelwood cutting may differ.

The majority of respondents (80.38%) have lived in the area for all my life, which indicates a deeply rooted local community with a strong historical connection to the coastal environment. This long-term residency suggests their opinions are based on extensive, lived experience rather than recent observation. The high percentage of lifelong residents adds significant weight to their collective views on environmental changes over time.

The occupational breakdown shows that a third of the respondents are fishermen (32.91%), making them the largest occupational group in the sample. This is an expected and highly relevant finding given the survey's focus on a coastal community and the importance of fishing to the local economy. Other significant groups include housewives (19.62%), farmers (15.19%), and students (14.56%). The high representation of fishermen is particularly important, as their livelihoods are directly tied to the health of the mangrove ecosystem.

Table Error! No text of specified style in document..1: Demographic information

Category	Characteristic	Frequency (n)	Percentage (%)
Gender	Male	252	79.75
	Female	64	20.25
Occupation	Fisherman	104	32.91
	Housewife	62	19.62
	Farmer	48	15.19
	Student	46	14.56
	Small business owner	40	12.66
	Livestock herder	14	4.43
	Government employee	2	0.63
	Years Lived in Community	All my life	254

Single Biggest Threat	5-15 years	46	14.56
	Less than 5 years	16	5.06
	Freshwater Flow	92	29.11
	Cutting for fuel	60	18.99
	Overfishing	60	18.99
	Pollution	60	18.99
	Climate change	28	8.86
	Grazing	14	4.43
	Encroachment	2	0.63
Encourage Participation	Community ownership & management	120	37.97
	Educational programs	84	26.58
	Financial incentives	60	18.99
	Providing alternative resources	50	15.82
	Enforcement of laws	2	0.63

Perceptions of Threats and Conservation Strategies

Following the demographic section, the subsequent part of the questionnaire solicits respondents' perceptions regarding the significance, threats, and conservation of mangroves. The results are presented in Table 4.2. When asked to identify the single biggest threat to the mangroves, the most frequent response was freshwater flow at 29.11%. This is a critical finding, as it points to a major concern about the upstream management of water resources, which is often a cause of mangrove degradation. This suggests that the community understands the link between river health and coastal ecosystems.

The next most-cited threats were cutting for fuel, overfishing, and pollution, all tied at 18.99%. This indicates a shared perception of multiple, significant human-caused pressures on the mangroves. The fact that fuelwood cutting is seen as a major threat by a notable portion of the community confirms its importance as an issue and highlights the difficult balance between daily survival needs and environmental protection.

Regarding how to encourage participation in conservation efforts, the community's top choice was community ownership and management, with 37.97% of the responses. This result strongly suggests that locals want a direct role in managing their resources and believe that giving them authority will be more effective than top-down approaches. This finding is particularly important for designing sustainable conservation programs.

educational programs (26.58%) and financial incentives (18.99%) were also popular choices. This shows that the community recognises the need for both increased awareness and economic support to make conservation a viable option. The low percentage for Enforcement of laws (0.63%) suggests that the community may view external enforcement as less effective or desirable compared to locally led initiatives.

Perceptions of Mangrove Importance

The results of the perception of mangroves' importance show that the mean importance score is 2.90 on a scale of 1 to 4 (where 1=Not very important and 4=Very important, based on the

frequency table). A mean of 2.90 with a small standard deviation of 0.32 indicates a very high degree of consensus and that the average perception leans strongly towards Very important.

The results presented in Table 4.2 provide a more detailed breakdown. An overwhelming majority of the respondents, 90.51% (286 out of 316), rated mangroves as Very important. This is a definitive finding. Only a small percentage, 8.86%, considered them Somewhat important. A negligible number of respondents, 0.63%, considered them Not very important.

This confirms that the community as a whole perceives mangroves as a critical asset. This strong consensus underscores the high level of environmental awareness and the perceived value of mangroves for the local community, which aligns with the previous qualitative findings about their importance for livelihoods and coastal protection.

For the other six questions related to the importance of mangroves, all have a mean score above 3, which is the midpoint of the Likert scale, indicating that, on average, respondents agree or strongly agree with the statements. The findings show that the highest-rated importance is for the environment, with a mean of 4.95 and a very low standard deviation of 0.22. This shows a near-unanimous agreement that mangroves are important for the environment. The mean for breeding ground is also extremely high at 4.90 (with a standard deviation of 0.32), indicating that a vast majority of the community agrees that mangroves are crucial as a breeding ground for marine life. Coast protection and livelihoods also received high mean scores of 4.60 and 4.59, respectively, confirming that locals see mangroves as vital for both coastal safety and economic well-being. The mean scores for wood source and fodder are notably lower at 3.81 and 3.22. The higher standard deviations (1.09 and 0.98) for these variables suggest a greater diversity of opinions on these uses, with some respondents likely disagreeing or being neutral on their importance for these specific purposes.

Perception of Threats to Mangroves

The mean scores for the perceived threats reveal a clear hierarchy of concern within the community. The greatest perceived threat is the lack of freshwater flow, with a high mean of 4.66 and a low standard deviation of 0.49. This shows strong community consensus that this is a major environmental issue. Pollution is the next highest-rated threat with a mean of 4.41, followed by climate change at 4.22. These high scores suggest that the community is highly concerned about these broader environmental issues. Overfishing and fuelwood cutting have moderate mean scores of 3.73 and 3.63, respectively, indicating that they are considered significant but not as pressing as freshwater flow or pollution. The standard deviations for these variables are also higher, suggesting a wider range of opinions on their severity. The lowest-rated threat is grazing, with a low mean of 2.34 and a standard deviation of 0.97. This suggests that, on average, the community does not perceive livestock grazing as a significant threat to the mangroves.

Support for Conservation Strategies

The results for support of various conservation strategies show strong backing across the board. The community displays the strongest support for reforestation, with a high mean of 4.86 and a very low standard deviation of 0.46, indicating near-unanimous agreement on the importance of replanting mangroves. Support for local committees and freshwater management is also very robust, with means of 4.65 and 4.67, respectively. This aligns with the community's perception of threats, as they desire local control and solutions for the freshwater issue. Awareness, livelihoods, and enforcement received means ranging from 3.90 to 4.39, demonstrating solid

support for these strategies as well. The lower means for livelihoods and enforcement compared to reforestation and freshwater management suggest that, while supported, they are not viewed as the most critical conservation measures by the community. This analysis helps simplify the complex set of seven threat variables into a few cores, underlying concepts.

Table Error! No text of specified style in document..2: Perceived importance, perceived threats, and support for conservation

Variable Category	Variable	Mean	Standard Deviation
<i>Importance</i>	Overall Importance	2.9	0.32
	Breeding Ground	4.9	0.32
	Environmental Importance	4.95	0.22
	Coast Protection	4.6	0.58
	Livelihoods	4.59	0.52
	Wood Source	3.81	1.09
	Fodder	3.22	0.98
<i>Perceived Threats</i>	Freshwater Flow	4.66	0.49
	Pollution	4.41	0.73
	Climate Change	4.22	0.74
	Overfishing	3.73	1.08
	Fuelwood Cutting	3.63	1.02
	Encroachment	3.44	0.81
	Grazing	2.34	0.97
<i>Support for Conservation</i>	Reforestation	4.86	0.46
	Freshwater Management	4.67	0.47
	Local Committees	4.65	0.57
	Awareness	4.39	0.63
	Livelihoods Support	3.92	0.7
	Enforcement	3.9	0.71

Note: The importance scale is 1 = Not very important, 2 = Not important at all, 3 = Somewhat important, and 4 = Very important. The threat and support scales are both 1 = Strongly Disagree to 5 = Strongly Agree. The variables within each category have been sorted in descending order of their mean for easy comparison.

Reliability test using Cronbach's Alpha

Furthermore, we used *Cronbach's Alpha* (Cronbach, 1951) to check the reliability of the perceived mangroves' importance and threat scale, assessing the internal consistency of the perception of importance and threat scale and measuring how well all the items in the scale capture the same underlying concept. The results are shown in Table 4.3.

Perceptions of Mangrove Importance Scale

The *Cronbach's Alpha* for the entire scale is 0.7274, which is above the widely accepted threshold of 0.70. This indicates that all items measuring the perceived importance of mangroves have good internal consistency. They are reliably measuring a single, underlying concept. While the overall scale is reliable, the Item-rest correlation column shows how each individual item

correlates with the total score of the other items. The perceived importance of breeding and livelihood items has relatively low item-rest correlations (0.3625 and 0.3558). This suggests they are not as strongly correlated with the other items in the scale as the other items. Removing them would slightly improve the scale's overall alpha, but since the overall alpha is already good, they can be retained. The perceived importance of the fodder item has the highest alpha if removed (0.6053), indicating a weak correlation with the rest of the scale. This suggests that this item might not be a good measure of overall mangrove importance for this community.

Perceived Threats Scale

The *Cronbach's Alpha* for the Perceived Threats scale is 0.7910, as shown in Table 4.3. This value is well above the 0.70 threshold, indicating that this scale also has good internal consistency. The seven items in this scale reliably measure the same construct, or the community's overall perception of threats to the mangroves. The 'Item-rest correlation' for the threats scale shows that the perceived threat of pollution (0.6941) and climate change (0.8135) items have the strongest correlations with the rest of the scale. This means they are the most representative items of the overall perceived threat level. The perceived threat of fuelwood, grazing, and overfishing items have lower item-rest correlations, suggesting they are slightly less consistent with the overall threats concept as measured by this scale. The negative sign (-) next to perceived threat of fuelwood, grazing, and freshwater indicates that these items may be reverse-coded or that their responses are negatively correlated with the overall scale score. For this specific scale, which measures threats on a scale of 1 to 5, the negative sign is likely a data coding issue and should be checked for accuracy. However, since the item-rest correlations are all positive and the alpha is high, this is a minor issue that doesn't invalidate the results.

Table Error! No text of specified style in document..3: Perceptions of mangrove importance and threats scale

Scale	Overall, Alpha	Item	Item-Rest Correlation	Alpha if Item Dropped
Perceptions of Mangrove Importance	0.7274	Mangrove as Breeding Ground	0.3625	0.725
		Mangrove for Coast Protection	0.5654	0.6661
		Mangrove as a Wood Source	0.5912	0.6708
		Mangrove as Fodder	0.695	0.6053
		Mangrove for Livelihoods	0.3558	0.7176
		Mangrove for Environment	0.6738	0.7066
Perceived Threats	0.791	Threat from Fuelwood Cutting	0.4616	0.7797
		Threat from Grazing	0.4444	0.7814
		Threat from Pollution	0.6941	0.7365
		Threat from Overfishing	0.445	0.7865
		Threat from Encroachment	0.5104	0.7659

	Threat from Freshwater Flow	0.4565	0.7815
	Threat from Climate Change	0.8135	0.7144

Note: The Cronbach's Alpha for both scales is above the commonly accepted threshold of 0.70, indicating good internal consistency. A high Item-Rest Correlation indicates that an item is well-correlated with the total score of the other items in the scale. A lower Alpha if Item Dropped value suggests the item contributes positively to the scale's overall reliability.

Principal Component Analysis (Unrotated Factors)

Moreover, we used Principal Component Analysis (PCA) to explain most of the variation (Jolliffe, 1986; Wold et al., 1987). The initial output shows the Principal Component Analysis (PCA) before any rotation. The most important part of this table is the Eigenvalues. An eigenvalue represents the amount of variance explained by each factor. A common rule of thumb is to retain factors with an eigenvalue greater than 1, as they explain more variance than a single variable on its own. In this case, three factors have an eigenvalue greater than 1 (3.37, 1.50, and 1.17). This suggests that the seven individual threat variables can be effectively summarised by three underlying dimensions of threat perception. These three factors collectively explain 86.27% of the total variance in the data (Cumulative column). This is a strong result, as it means a high percentage of the information from the original seven questions is captured by the three new factors. The LR test is highly significant ($Prob > chi^2 = 0.0000$), which confirms that the variables are not independent and are suitable for factor analysis.

Varimax Rotated Factors and Interpretation

The varimax rotation simplifies the factor structure, making it much easier to interpret which variables load onto which factor. The goal of this rotation is to make the loadings on each factor either very high (close to 1 or -1) or very low (close to 0), clarifying the underlying concepts. Based on the rotated factor loadings, we can identify and name three distinct factors, as presented in Table 4.4.

- a) **Factor 1: Direct Local Human Activities:** This factor has high loadings for perceived threat from grazing (-0.91), pollution (0.83), and overfishing (0.65). This dimension represents threats that are a direct result of local, day-to-day human activities like fishing, waste disposal, and livestock grazing.
- b) **Factor 2: Large-Scale and Long-Term Threats:** This factor is defined by a very high loading for perceived threat from encroachment (0.94) and a high loading for perceived threat from climate change (0.73). This dimension represents threats that are often perceived as larger-scale issues, such as development-related encroachment and global climate patterns.
- c) **Factor 3: Resource Management and Usage:** This factor is dominated by high loadings for perceived threat from freshwater (0.86) and fuelwood (0.83). This dimension captures the community's concerns about the availability and management of key natural resources—water and wood—that are essential for their survival.

The Uniqueness column shows the proportion of a variable's variance not explained by the factors. For example, perceived threat from encroachment has a very low uniqueness of 0.0813, meaning 91.87% of its variance is explained by the three factors, primarily Factor 2. This confirms that it is a very good measure of that particular dimension. Ultimately, the factor analysis successfully reduced the seven individual threat variables into three meaningful dimensions, providing a more focused and interpretable view of how the community perceives threats to the

mangrove ecosystem. These findings can be used to inform targeted conservation and management strategies.

Table Error! No text of specified style in document..4: The factor analysis used Principal Component Factoring with a Varimax rotation

Variable	Factor 1: Direct Human Activities	Factor 2: Large-Scale Threats	Factor 3: Resource Management	Uniqueness
<i>Threat from Grazing</i>	-0.9148	0.1247	0.2313	0.0942
<i>Threat from Pollution</i>	0.8292	0.3123	-0.1689	0.1863
<i>Threat from Overfishing</i>	0.6523	0.5955	0.3359	0.1071
<i>Threat from Encroachment</i>	-0.0313	0.9362	-0.203	0.0813
<i>Threat from Climate Change</i>	0.3302	0.7277	-0.4987	0.1128
<i>Threat from Freshwater Flow</i>	-0.2214	-0.0512	0.855	0.2173
<i>Threat from Fuelwood Cutting</i>	-0.0396	-0.3836	0.83	0.1624
<i>Eigenvalues</i>	2.11	2.02	1.9	
<i>Proportion of Variance</i>	0.3	0.29	0.27	Cumulative: 0.86

Notes:

- a) *The perceived threat from grazing variable has a negative loading on Factor 1, which may indicate that this threat is perceived in an inverse manner to others in the factor.*
- b) *Factor loadings greater than |0.30| are typically considered significant and are bolded for clarity.*
- c) *The three extracted factors explain a cumulative total of 86% of the variance in the original seven variables, indicating a highly reliable and valid model.*

Cross-tabulations and the t-test

Furthermore, we employed cross-tabulations and the *t*-test to conduct a detailed analysis of survey results, investigating the relationship between occupation and gender in relation to key perceptions and beliefs.

Occupation and Perceived Threats

The cross-tabulation reveals a statistically significant and strong association between an individual's occupation and the most important threat they perceive, as shown in Table 4.5. The Pearson Chi-Square test results (*Pr* = 0.000) confirm that this relationship is unlikely due to chance. The findings illustrate a clear pattern: respondents tend to identify the main threat based on their primary livelihood. All farmers (48 respondents) selected freshwater flow, highlighting their direct concern for water resources essential to agriculture. Most fishermen (60 respondents) identified overfishing as the primary threat, reflecting the direct impact on their daily work and income. A significant number of fishermen (44 respondents) also chose freshwater flow, demonstrating their understanding of the broader ecosystem. All livestock herders (14 respondents) chose grazing, showing a strong awareness of the potential

environmental effects of their activities. All housewives (60 respondents), along with two other respondents, identified cutting for fuel, a vital activity for many households in the community. Students and small business owners were the only groups to recognise pollution as a key threat, possibly due to increased environmental awareness or concerns about its aesthetic impact on tourism and daily life.

Table Error! No text of specified style in document..5: Cross-tabulation of occupation and the biggest threat

<i>Occupation</i>	<i>Climate change</i>	<i>Cutting for fuel</i>	<i>Encroachment</i>	<i>Freshwater Flow</i>	<i>Grazing</i>	<i>Overfishing</i>	<i>Pollution</i>	<i>Total (n)</i>
<i>Farmer</i>	0	0	0	48	0	0	0	48
<i>Fisherman</i>	0	0	0	44	0	60	0	104
<i>Government employee</i>	2	0	0	0	0	0	0	2
<i>Housewife</i>	0	60	0	0	0	0	2	62
<i>Livestock herder</i>	0	0	0	0	14	0	0	14
<i>Small business owner</i>	0	0	2	0	0	0	38	40
<i>Student</i>	26	0	0	0	0	0	20	46
<i>Total (n)</i>	28	60	2	92	14	60	60	316
<i>Chi-Square Test</i>	$\chi^2(36)=1.2e+03, p<0.001$							

Gender and Conservation Awareness

The results for cross-tabulation of gender and conservation awareness are provided in Table 4.6. The Chi-Square test for gender and awareness of conservation efforts is also highly significant ($P = 0.000$), indicating a strong relationship between the two variables. While 50% of the female respondents reported being aware of conservation efforts (32 out of 64), a much higher percentage of male respondents reported awareness (186 out of 252, or 73.8%). This disparity suggests that conservation programs and communication efforts may not be reaching female community members as effectively as they are reaching men.

Table Error! No text of specified style in document..6: Cross-tabulation of gender and conservation awareness

<i>Gender</i>	<i>Aware of Conservation Efforts</i>	<i>Unaware of Conservation Efforts</i>	<i>Total (n)</i>
<i>Female</i>	32	32	64
<i>Male</i>	186	66	252
<i>Total (n)</i>	218	98	316

Chi-Square Test	$\chi^2(1)=13.52, p<0.001$		
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Gender and Overall Perceived Threat

The two-sample *t-test* results show, as presented in Table 4.7, a statistically significant difference between the mean total threat scores of male and female respondents (*Pr* = 0.000). The average total threat score for males (27.0) is significantly higher than the average score for females (24.19). This finding suggests that, on average, men in the community perceive the combined threats to the mangroves to be more severe than women do. This difference in perception could be linked to the fact that men are more involved in occupations that directly depend on and interact with the mangrove ecosystem (e.g., fishing, farming), making them more acutely aware of the issues.

Table Error! No text of specified style in document..7: Two-sample T-test for total perceived threat score by gender

Group	N	Mean	Standard Deviation	Standard Error
Female	64	24.19	0.77	0.1
Male	252	27	2.26	0.14
Combined	316	26.43	2.34	0.13

The results indicate a statistically significant difference (Table 4.8) in perceived threat scores between male and female respondents. The mean total threat score for males is significantly higher than that for females.

Table Error! No text of specified style in document..8: Test statistics

	Value
Mean Difference (Female - Male)	-2.81
<i>t</i> -statistic	-9.79
Degrees of Freedom	314
<i>P</i> -value	< 0.001

Discussion of Research Findings

This study investigated community perceptions of mangrove importance, threats, and conservation efforts, providing a nuanced understanding of local environmental attitudes. The analysis of survey data revealed significant patterns shaped by demographics, particularly occupation and gender.

Community Perception of Mangrove Importance

The findings demonstrate a near-universal consensus on the critical importance of mangrove forests to the local community. The overall Cronbach's Alpha of 0.7274 confirms the high internal consistency of the importance scale. Specific items, such as the role of mangroves in coastal protection and as a breeding ground for marine life, had the highest scores, indicating these are the most salient benefits perceived by the community. This aligns with the fact that many community members, particularly fishermen, depend directly on these ecosystem services. The high mean score on the overall importance variable (2.90 on a 3-point scale, where 3 = Very Important) further underscores this strong positive perception. This collective belief in the value of mangroves provides a solid foundation for engaging the community in conservation initiatives.

Perceived Threats to the Mangrove Ecosystem

The community does not see threats as a single, uniform issue, but rather through three separate dimensions, as shown by the factor analysis. These factors, accounting for a high cumulative variance of 86%, reliably explain most of the differences in perceived threats. For example, factor 1, the direct human activities factor, includes threats such as pollution, overfishing, and grazing. These are all localised issues closely linked to human behaviour and resource use. Likewise, factor 2, the large-scale environmental threats dimension, connects global issues like climate change with local encroachment, indicating that the community recognises wider systemic pressures on the ecosystem. Finally, factor 3, the resource-based threats factor, groups together concern about lack of freshwater flow and fuelwood cutting, highlighting perceptions of threats related to the availability and management of key natural resources. The cross-tabulation of occupation and perceived threats reinforces these findings, showing that threat perception is directly linked to livelihood. Farmers and fishermen, who depend on water resources, overwhelmingly chose freshwater flow and overfishing as the biggest threats. This personal connection makes their perception of threats more acute and specific.

Demographics and Conservation Engagement

The study identified a significant gender gap in both conservation awareness and perceived threat levels. A chi-square test showed that men were significantly more likely than women to be aware of existing conservation efforts. This is further supported by the *t-test* results, which found that men's overall perceived threat scores were significantly higher than women's. This disparity suggests that conservation outreach programs may not be effectively reaching or resonating with female community members. Given the prominent role of women in household activities (e.g., fuelwood collection), their engagement is crucial for the success of any conservation strategy.

Community-Based Conservation Priorities

The findings provide a clear mandate for future conservation efforts. Instead of relying solely on external enforcement, the community strongly favours community ownership and management as the most effective way to encourage participation in conservation. This preference, chosen by 38% of respondents, indicates a desire for empowerment and self-governance rather than top-down enforcement. The second most popular choice, educational programs, highlights a recognised need for increased knowledge and awareness, particularly among women and other less-engaged groups. This finding points toward a path for future conservation efforts that is both participatory and educational, addressing the community's own identified priorities.

Hence, this study demonstrates that the community holds a sophisticated, multi-dimensional view of its mangrove ecosystem. Their perceptions are not static but are shaped by their daily lives and economic realities. The strong link between occupation and perceived threat, combined with the significant gender gap in awareness, provides a clear roadmap for future conservation interventions. For a sustainable and successful program, it is essential to move beyond a one-size-fits-all approach and to implement targeted, community-led initiatives that empower local people and address their specific concerns and priorities.

Implications and Mitigation

The degradation of mangrove forests due to anthropogenic activities has profound implications for coastal ecosystems and human security (Walters, 2008). The loss of mangroves reduces natural coastal protection against storms and erosion, diminishes carbon sequestration capabilities, and leads to a decline in biodiversity and fisheries productivity (Akram et al., 2023).

Mitigation strategies emphasise a multi-faceted approach, including managed coastal-based activities, smart land-use planning, integrated regional management networks, community education and outreach, and active restoration and rehabilitation efforts. Continuous risk analysis, documentation, communication among stakeholders, and regular review of management strategies are crucial for long-term sustainability (Akram et al., 2023). Addressing specific drivers such as fuelwood collection and camel grazing, freshwater diversion, pollution control, and promoting sustainable aquaculture and agricultural practices are critical steps towards protecting these invaluable ecosystems (Sannaullah et al., 2025 ; Bhagarathi & DaSilva, 2024; Akram et al., 2023). The main anthropogenic activities affecting mangroves in Balochistan, Pakistan, primarily stem from human-induced pressures that lead to their degradation and loss.

Conclusion

Mangrove forests in coastal regions, including those in Balochistan, Pakistan, are increasingly threatened by human activities, with the harvesting of woody resources for fuelwood and timber being a significant contributing factor to their deforestation and degradation. While mangroves are globally recognised for their critical ecological services—such as coastal protection, carbon sequestration, and provision of habitats for diverse flora and fauna— despite this value, the mangroves in Balochistan, Pakistan, generally face severe threats, including reduced freshwater supply, industrial pollution, over-harvesting of marine resources, and coastal erosion. Their unsustainable exploitation undermines these functions and leads to ecological decline. This study aimed to investigate the effects of human activities on mangrove forests in Balochistan.

Key Findings

The survey results highlight a strong and nearly unanimous agreement on the high ecological and economic significance of mangroves. The community overwhelmingly concurs that mangroves are essential as breeding grounds for marine life and for coastal protection, with a high degree of reliability in these assessments. However, there is less consensus on their importance as a source of wood and fodder, indicating that not all traditional uses are valued as highly as the ecosystem services they provide.

The most crucial finding from the threat perception analysis is that the community recognises lack of freshwater flow as the single most significant threat to the mangroves. This perception, which differs from direct local activities, suggests a sophisticated understanding of the broader environmental and upstream issues impacting their coastal ecosystem. While pollution, overfishing, and fuelwood cutting are also regarded as significant, the consensus on the importance of freshwater flow points to a desire for broader, systemic solutions.

The factor analysis further supports this nuanced understanding by categorising threats into three separate dimensions: direct local human activities (such as pollution, overfishing, and grazing), large-scale environmental and developmental threats (like climate change and encroachment), and resource management and use (including freshwater and fuelwood). This indicates that the community does not view threats as a single issue but rather as a combination of localised impacts and larger external pressures. Moreover, the study reveals that an individual's occupation is a strong predictor of their threat perception. Fishermen are most concerned with overfishing, farmers with freshwater flow, and housewives with fuelwood cutting. This underscores the importance for conservation programmes to recognise and address these distinct, livelihood-based priorities.

Additionally, there is a noticeable gender gap in conservation awareness. Men in the community are significantly more likely to be aware of conservation efforts and to perceive a higher overall level of threat. This suggests that current programmes may be failing to effectively engage women. Consequently, future conservation initiatives must adopt more inclusive, gender-sensitive outreach strategies.

Recommendation

Our study recommends adopting sustainable harvesting practices and establishing regulations and community-based management plans to ensure that timber and fuelwood extraction rates are sustainable, promoting forest regeneration. Additionally, this study suggests utilising alternative livelihoods and energy sources to provide local communities with income-generating activities and affordable energy options, thereby reducing their reliance on mangroves for fuelwood. Although the Forest and Wildlife Department has been actively involved in reforestation and rehabilitation in Balochistan, resulting in an increase in mangrove forests over the last four decades (Sanaullah et al., 2025), further active efforts are still required to replant mangroves in degraded areas, supported by scientific methods for species selection and site preparation (Ahmed et al., 2025; Salem et al., 2024). Moreover, our study recommends the adoption of Integrated Coastal Zone Management and the development of comprehensive plans that address all anthropogenic pressures, including pollution control, freshwater allocation management, and coastal development regulation (Ullah et al., 2022). Finally, the findings indicate that effective community engagement entails involving local communities in conservation initiatives, leveraging their traditional knowledge and fostering a sense of ownership concerning mangrove preservation resources (Rasool et al., 2002).

In conclusion, harvesting mangroves for fuelwood and timber, as well as grazing, are significant human activities that contribute to deforestation in Balochistan, Pakistan, alongside other pressures, including declining freshwater supplies and pollution. Although specific, detailed data for Balochistan are not extensively covered in the available literature, the overall trends and identified drivers across Pakistan and globally strongly indicate that unsustainable woody resource extraction remains a significant threat to these vital coastal ecosystems. Implementing sustainable management strategies that combine ecological conservation with socio-economic development is crucial to protecting and restoring mangroves in Balochistan, Pakistan, and other at-risk coastal areas.

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