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Geomorphic and Hydrological Impacts of River Sand Mining on Recent Floods and Groundwater Decline in Pakistan

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Abstract:

This research critically examines the geomorphic and hydrological impacts of riverbed sand mining on flood intensity and groundwater reduction in Pakistan, integrating local data with global perspectives. A thorough review of literature, field reports, and GIS-based analyses, along with case studies from international rivers such as the Mekong, Mississippi, Ebro, Yamuna, Meghna, and Athi, was conducted to assess how sediment extraction alters river morphology and hydrological functions. The findings indicate that excessive sand mining deepens river channels, accelerates bank erosion, disrupts sediment transport, and reduces floodplain storage, leading to geomorphic instability. In Pakistan, rivers within the Indus Basin, including the Ravi, Chenab, Jhelum, Swat, Indus, and Malir, show similar patterns, with deep pits, channel shifts, and loss of agricultural land weakening natural flood defenses. These changes exacerbated the 2022 and recent 2025 floods, resulting in more extensive water overflow, prolonged flooding, and increased damage. Hydrologically, the lowering of riverbeds and disrupted sediment dynamics have weakened groundwater–river connectivity, accelerating groundwater depletion in Punjab, Sindh, and Khyber Pakhtunkhwa. At the same time, climate-related stressors such as extreme rainfall, glacial melt, and rising temperatures further intensify flood risks and water shortages. Despite legal requirements for Environmental Impact Assessments, there is weak enforcement, inadequate monitoring, and widespread informal extraction allowing unsustainable practices to persist. Comparisons with international sediment management frameworks highlight the effectiveness of monitoring, sediment budgeting, and community involvement in mitigating negative impacts. This study underscores the urgent need for integrated, climate-resilient river management, evidence-based policies, and enhanced monitoring strategies to protect Pakistan's river systems, reduce flood vulnerability, and safeguard vital groundwater resources

Keywords: Climate change, Flood risk, Geomorphic impacts, Groundwater decline, Hydrological impacts, Pakistan rivers, Riverbed sand mining

1. Introduction

River sand mining (RSM) refers to the extraction of sand and gravel from river channels, floodplains, and occasionally from nearshore marine environments to meet the growing global demand for construction materials. After water, sand is the most widely used natural resource on the planet. Its annual consumption is at an estimated rate of 40–50 billion tonnes and is expected to rise to around 60 billion tonnes by 2030. This growing demand is primarily due to rapid urbanization and large-scale infrastructure development worldwide. Although sand extraction contributes significantly to economic growth, it also poses serious environmental challenges. Large-scale mining operations are carried out using dredging vessels that remove sediments from riverbeds and coasts, which have an impact on ecosystems. Such activities cause erosion of riverbanks and coastlines, degradation of aquatic habitats, and depletion of sediment that protects coastal aquifers from salinization. Recent findings from the UNEP Marine Sand Watch platform reveal that 4 to 8 billion tonnes of marine sand are extracted every year, with approximately 16% of dredging occurring inside protected areas, threatening biodiversity and ecosystem stability across regions such as Europe, Asia, and North America [1], [2].

When sand is removed from active river channels, it disrupts the natural flow of sediment, leading to channel incision, riverbed deepening, and bank erosion. This disrupts sediment balance, creates deep pits, and reduces floodplain stability, often leading to overbank flooding during high flows. It also lowers groundwater recharge, with each cubic meter of sand removal causing about 0.5 m^3 loss in aquifer storage [3].The effects aren't isolated to one region either. The Mekong Delta in Vietnam, for example, loses between 8.5 and 45.7 million cubic meters of sand each year[4], The Ebro Delta in Spain is retreating by about 10 meters annually because of a 99% reduction in sediment flow, and in the United States, the Mississippi Delta has deepened by nearly 6 meters, contributing to the loss of around 1,900 square miles of wetlands and worsening saltwater intrusion[5]

South Asia has become the most sand-consuming region in the world with its rapid urban growth and construction boom, particularly in countries like India, Bangladesh, and Nepal [1]. Recent studies on India's Yamuna River and Kenya's Athi River have shown that sand mining can alter river flow and channel shape [6]. In Kathmandu, researchers have found that while new embankments helped reduce local flooding, they also increased sediment movement by around 30%, causing reshaping of the river and increasing flood risk further downstream [7]. In Bangladesh, mining in the Meghna, Brahmaputra, and Jinjiram rivers has caused major riverbank erosion and loss of farmland, especially in Narsingdi and Jamalpur districts. Much of this extraction happens illegally, which only deepens the region's flood vulnerability and threatens local livelihoods [8] .Reports from (MoEFCC,2020) found that Illegal mining, weak enforcement of environmental clearance conditions, and inadequate sediment budgeting are the primary governance failures causing ecological degradation in Indian rivers[9].

The UNEP (2020) emphasizes that South Asian nations with limited data availability and weak regulatory capacity are witnessing patterns of unsustainable sand extraction, underscoring the urgent need for regional sediment management frameworks and transboundary policy coordination mechanisms that remain largely absent in Pakistan's current context.[1]

In Pakistan, river-bed sand mining takes place in the major rivers of the Indus System, including the Indus and its major tributaries, like the Chenab, Jhelum, and Ravi rivers, as well as in the northern reaches like the Swat River. These corridors are used for the extraction of sand and gravel, given accessible braid-bars and floodplain sediments, and proximity to construction demand centers[10].The extraction frequency has significantly increased in recent years due to rapid urbanization and infrastructure growth. Weak provincial regulations, poor monitoring, and illegal riverbed extraction have further worsened the situation.[11][12].

While empirical research concerning sand extraction and its environmental impacts in Pakistan is relatively scarce, the present volume of studies and reports nevertheless indicates clear environmental impacts. For instance, a GIS-based study [10]identifies mining-induced water hazards in Pakistan, showing links between extraction activities and aquifer depletion, contamination, and flood-amplified pollution in Indus tributaries. In the Swat River (Khyber Pakhtunkhwa), heavy-machinery gravel extraction has altered the river's course, eroded its banks, damaged adjacent agricultural lands, and reportedly lowered the local water table[13]. Similarly, along the Ravi River near Lahore and Sahiwal villages, such as Dad Baloch and Chak Sheraza, ongoing river-bed deepening and bank collapse have raised flood-risk concerns, with residents warning of unchecked erosion[14]. In the urban setting of Karachi's Malir River, Studies show open-pit sand mining more than 100 ft deep has exposed bedrock, lowered groundwater, and reduced agricultural/grazing lands[15].Groundwater levels across Punjab, Sindh, and Khyber Pakhtunkhwa (KPK) have been falling consistently due to a combination of over-abstraction, reduced river recharge, and unregulated riverbed sand mining. According to the Pakistan Council of Research in Water Resources (PCRWR, 2023), more than five percent of the country's total groundwater reserves have declined within eight years, with the most critical depletion observed in Punjab's irrigated plains and the Peshawar Valley in KPK. In Sindh's lower Indus plains, reduced freshwater recharge and sediment over-extraction have allowed saline water intrusion, degrading aquifer quality and shrinking usable groundwater lenses [16].Studies confirm basin-wide groundwater mass loss across the Indus Basin, particularly in southern Punjab and northern Sindh, where lowered riverbeds and excessive pumping have compounded depletion. This constitutes a major research gap undermining evidence-based policy for sustainable extraction limits in Pakistan.

Pakistan's sand mining activities are nominally regulated as per the Pakistan Environmental Protection Act 1997 [17]and its provincial Environmental Protection Acts (Punjab, Sindh, Khyber Pakhtunkhwa, and Baluchistan), which require Environmental Impact Assessments (EIAs) for extractive operations near rivers and wetlands. However, EIAs are rarely conducted despite being legally required [18]. Most sand extraction continues informally or under temporary district-level permits, without proper environmental baselines or post-clearance monitoring. Provincial environmental agencies often lack the technical and institutional capacity to monitor river morphology, sediment transport, or groundwater impacts, leading to a governance gap that allows unregulated operations to expand unchecked [19].

In contrast, India's 2020 Sustainable Sand Mining Guidelines and its complementary Enforcement & Monitoring Guidelines [9] provide a structured framework for scientific sediment budgeting, replenishment studies, digital monitoring (e.g., drone and GIS-based tracking), and community participation. Pakistan currently lacks such a coordinated policy, resulting in fragmented and reactive governance. Moreover, no integrated national or provincial assessment exists that evaluates how riverbed mining collectively influences flood hazards, groundwater recharge, and long-term river stability. This absence of empirical data and management frameworks represents a critical knowledge and policy gap.

The 2022 floods in Pakistan affected over 33 million people, inundated one-third of the country, and caused losses exceeding US$30 billion. These events exposed how excessive riverbed sand mining worsens sediment imbalance, reduces floodplain capacity, and heightens flood risk. In parts of Punjab and Sindh, groundwater levels have also declined by 0.5–1.5 m per year, linking sand extraction to both flood vulnerability and water scarcity.

This paper critically reviews both global and local studies to analyze how riverbed sand mining influences flood risk and groundwater decline in Pakistan's major river systems and outlines strategic directions for sustainable sand resource management and research in Pakistan. The study also highlights key evidence gaps, particularly the lack of river-specific sediment budget and groundwater interaction data, and proposes management strategies and policy directions for developing a more sustainable, evidence-based framework for sand mining regulation in Pakistan.

2. Literature Review

2.1 *Impacts of Sand Mining on River Morphology*

Sand mining affects the physical structure of rivers by disturbing their sediment balance, altering channel geometry, and weakening the stability of banks and floodplains. Because alluvial rivers depend on continuous sediment transport, the removal of bed material triggers a chain of geomorphic adjustments that propagate both upstream and downstream. These adjustments create deeper channels, unstable banks, degraded floodplains, and reduced sediment supply to downstream reaches. This section synthesizes the key morphological impacts documented globally and observed increasingly across the Indus Basin.

2.1.1 *Channel Incision and Riverbed Deepening*

Channel incision and riverbed deepening are major geomorphological consequences of sand and gravel mining. When bed material is removed, the river develops a sediment-supply deficit that functions similarly to the "hungry water" that possesses the energy to move sediment but has little or no sediment load, so it begins eroding the channel bed and banks in an attempt to regain equilibrium. This incision is not localized; it propagates both upstream and downstream, sometimes extending 5–20 km beyond the mining zone, depending on river slope and extraction intensity. Instream pit mining in the 1950s and 1960s caused channel incision in excess of 3–6 m over an 11-km length of the Russian River near Healdsburg, California. Globally, mined rivers have shown 1–5 m of bed lowering within a decade, with some extreme cases reporting over 10 m of incision in heavily exploited reaches[20].

The Reno River in northern Italy, where severe degradation removed nearly 18 million cubic meters of sediment between the 1950s and 1970s, and an average bed incision of 3.78 meters over 70 years, a peak incision of more than 6 meters has been observed [21]. Such adjustments destabilize channel geometry, undermine bridge foundations, and increase vulnerability to lateral migration. In the United States, for example, channel deepening linked to extraction has contributed to failures at more than 100 bridge sites due to excessive scour [22].Similar patterns appear in Asia, where segments of the Mekong near Phnom Penh have experienced 1.5–4 m of bed lowering due to commercial mining operations [23]

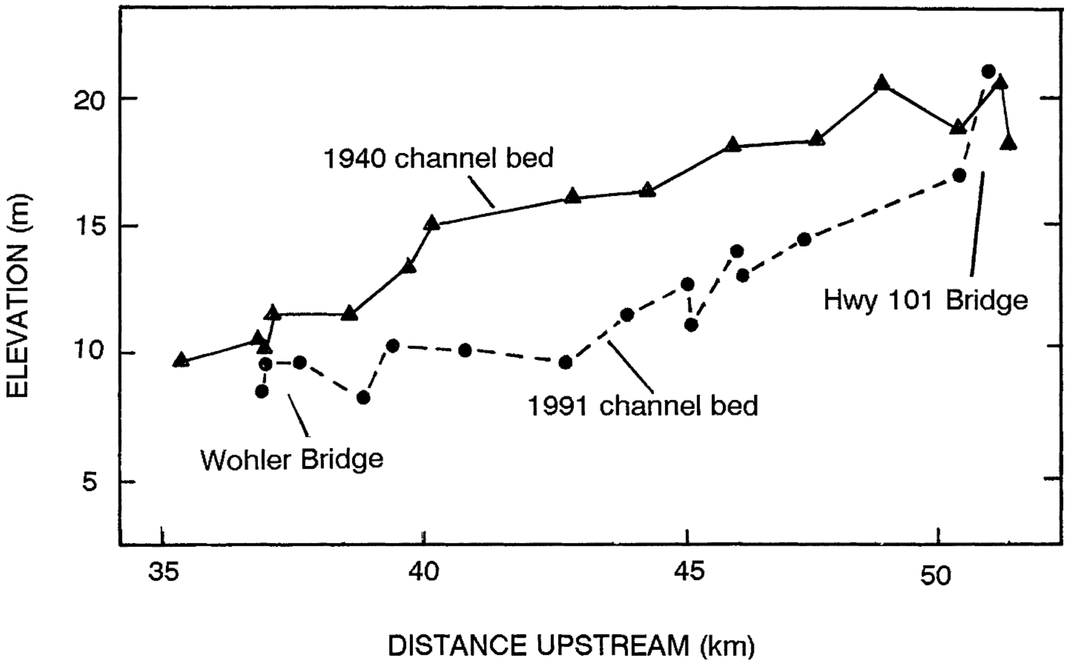

Figure 1: Longitudinal profile of the Russian River, near Healdsburg, California, showing incision from 1940 to 1991

2.1.2 *Bank Erosion*

The process of channel incision creates deep vertical changes in riverbed depth, but bank erosion describes the lateral destruction of riverbanks, which results from unbalanced sediment loads and excessive flow power [20].The channel expansion process through bank erosion leads to damage of agricultural land and constructed facilities, while it makes riverbanks more unstable [24]. The Yamuna River in India shows bank erosion that reaches more than 20 meters annually because of instream mining activities [25], and the Mekong River near Phnom Penh experiences major bank collapses because of its deep dredging operations . The Middle Loire River experienced major channel transformations during the past 50 years because of human activities including gravel mining which resulted in a narrower active channel width and deeper river bed [26]. The process of Bank erosion creates three major problems which include increased flood risk , destroyed infrastructure and decreased agricultural output in surrounding areas

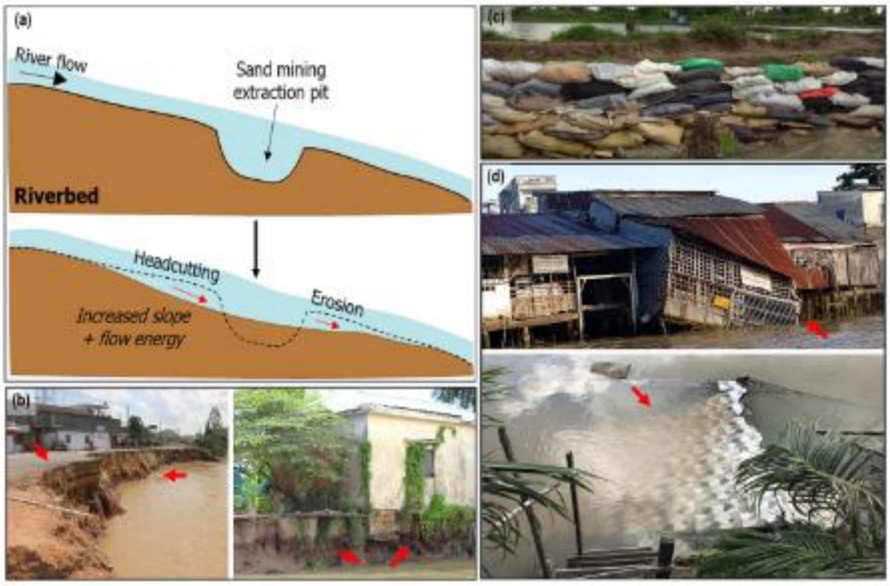

Fig. 2. Riverbank erosion in the Vietnamese Mekong Delta (VMD), showing head cutting–induced channel widening and bank destabilization extending beyond sand mining sites, severe bank collapse, sandbag reinforcement measures, and damage to riverside houses

2.1.3 *Floodplain Degradation*

The practice of sand mining near rivers creates two major problems which affect river channels and banks and simultaneously damages surrounding floodplain areas that lose their ability to manage floodwater storage and release [20]. The process of sediment removal creates a lower riverbed, which separates water channels from their surrounding floodplains while blocking the natural process of soil accumulation outside banks. The process of sediment removal creates three major environmental problems which damage wetland ecosystems ,reduce soil fertility and eliminate the natural flood protection system. The Mississippi Delta region has experienced a total loss of 1,900 square kilometers of wetlands because of channel deterioration and sediment extraction, and the Mekong River has lost 15-25% of its floodplain territory during the last twenty years .Some studies suggest that mining-related erosion along the Indus River in pakistan likely contributes to floodplain changes and may affect groundwater recharge, though direct links remain under-investigated.A study on the Indus River (Chashma-Taunsa reach) modeled floodplain behavior with HEC-RAS and found that sediment deposition over the floodplain has reduced flood-carrying capacity significantly (17.75% reduction according to the model)[27]

Year	**Bank-full Discharge (m^3/s)**	**Discharge capacity reduction (%)**	**Levee-overtop discharge (m^3/s)**	**Flood-capacity reduction (%)**
1994	19,850	—	32,480	—
2010	17,600	11.34%	31,100	4.25%
2018	11,080	37.00%	26,900	13.50%
Total	—	**48.34%**	—	**17.75%**

Table 1 HEC-RAS modeling indicates 4.3 BCM of sediment deposition over the floodplain downstream of the Kotri Barrage, associated with a 17.75% reduction in flood-carrying capacity of the Indus reach.

2.1.4 *Sediment Imbalance and Downstream Effects*

River sand mining disrupts the natural sediment balance because it extracts bed material at rates that exceed natural replenishment rates which results in a sediment deficit throughout river systems. The river system develops an unbalanced state which leads to channel erosion, deeper water levels and stronger water erosion because the river system works to achieve its natural state [20], [21]. Sediment-starved flows cause riverbanks and infrastructure to erode while they decrease the process of bar formation and floodplain sediment accumulation.

The decrease in sediment transport to lower river sections and delta areas diminishes flood protection capabilities of natural barriers which leads to faster delta sinking and coastal land loss according to research on the Mekong and Mississippi rivers .[20], [21].The Indus Basin of Pakistan experienced channel instability and modified flood patterns because of uncontrolled sand extraction and river flow management which created sediment imbalances. The absence of research about sediment budgets for specific rivers makes it impossible to measure exactly how river changes affect downstream areas [27].

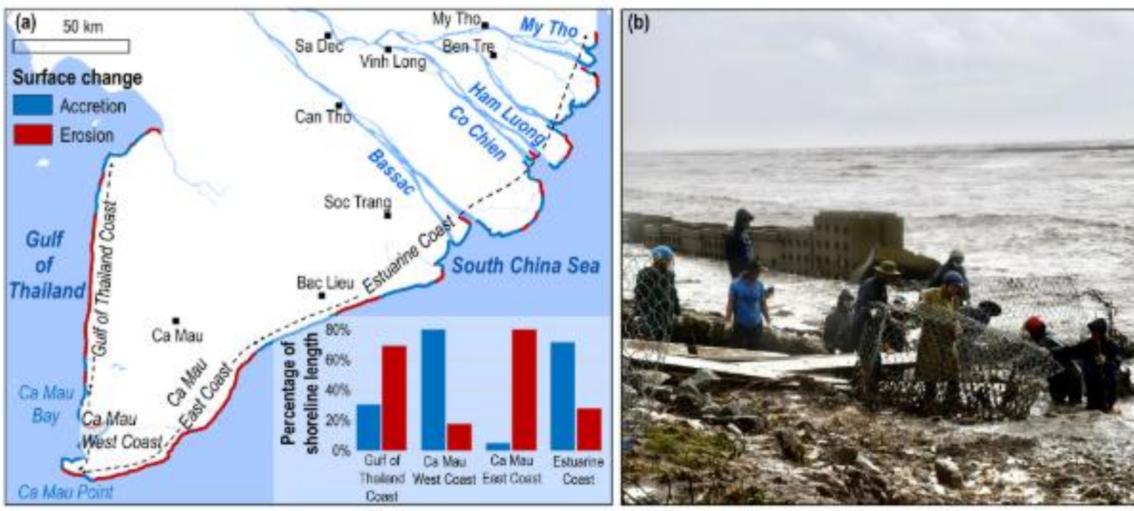

Fig. 3. Extent of erosion and accretion along the VMD shoreline (1973–2015), highlighting erosion hotspots along the Gulf of Thailand and southeastern Ca Mau, with field evidence of eroded sea dykes in the Ca Mau Peninsula.

2.1.5 Case Studies: Pakistan and Global Perspectives

The Mekong River Basin serves as a well-documented worldwide example which shows how extensive sand mining operations have created major geomorphic changes by lowering riverbeds and causing bank failures which lead to increased flood risks in downstream floodplains and deltas [4]. The Mississippi Delta region shows similar long-term effects because decreased sediment delivery has caused wetland destruction and diminished flood defense capabilities [5].

In Pakistan, available case studies indicate comparable trends. Along the Swat River, mechanized sand and gravel mining has altered channel morphology, intensified bank erosion, and lowered local groundwater levels [13]. In the Ravi River near Lahore and downstream settlements, riverbed deepening and bank instability have raised flood-risk concerns[14]. In Karachi's Malir River, deep open-pit sand mining has exposed bedrock, reduced groundwater recharge, and degraded agricultural land [25].European rivers such as the Reno and Loire also exhibit persistent channel incision and floodplain degradation decades after large-scale sediment extraction [26].

The research findings show that sand mining operations produce identical geomorphic effects which affect different river systems thus indicating Pakistan's rivers will face identical long-term deterioration and increased flood danger unless experts develop proper sediment management.

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Fig. 4 Extensive Sand mining from Jhelum River at Anantnag,Kashmir

2.2 Impacts on Flood Risk

River sand mining increases flood risk by altering channel geometry and reducing floodplain storage. Channel incision caused by sediment extraction has been reported to lower riverbeds by 1–5 m within a decade in heavily mined alluvial rivers, resulting in deeper and faster flood flows and reduced energy dissipation during high-discharge events [20], [21]. Modeling studies indicate that incision and sediment imbalance can increase peak flood discharges by 10–30% in downstream reaches by constraining lateral floodplain spreading .

Comparable impacts are observed globally. In Nepal's Kathmandu Valley, altered sediment transport and embankment-confined channels increased downstream flood risk despite local protection benefits, with sediment mobility rising by approximately 30% . In India, sand mining along rivers such as the Yamuna has caused bank retreat rates exceeding 20 m yr^{-1}, increasing flood damage to adjacent settlements . In the Mekong River Basin, commercial sand extraction has lowered riverbeds by 1.5–4 m, reducing floodplain buffering and increasing flood vulnerability in downstream floodplains. Similarly, in the Mississippi Delta, sediment deprivation has contributed to the loss of nearly 1,900 km² of wetlands, weakening natural flood defenses against extreme floods and storm surges[25]

Reduced floodplain connectivity further amplifies flood severity. In the Indus Basin, sediment deposition and channel modification have reduced flood-carrying capacity by approximately 17.75% in the Chashma–Taunsa reach, increasing flood depths during extreme events.During Pakistan's 2022 floods, which affected over 33 million people and caused losses exceeding US$30 billion, altered channel morphology and floodplain encroachment intensified inundation in Punjab and Sindh [27].

2.3 Impacts on Groundwater Recharge and Aquifer Decline

River sand mining directly alters river–aquifer interactions by deepening riverbeds and reducing hydraulic connectivity between surface water and groundwater systems. In alluvial rivers, hydraulic gradients drive vertical and lateral seepage from rivers into adjacent aquifers, particularly during flood events. However, riverbed incision of 1–4 m caused by intensive sand extraction has been shown to significantly reduce river-induced recharge, effectively decoupling rivers from their underlying aquifers..Numerical modeling and field observations indicate that each cubic meter of sand removed can reduce effective aquifer storage by 30–60% of that volume, depending on sediment gradation and saturation conditions Recent quantitative studies demonstrate that sand mining can cause groundwater table declines of 0.3–1.2 m yr^{-1} in heavily mined river corridors, even in the absence of increased pumping, due to reduced recharge efficiency and exposure of low-permeability strata,[3],[4],[24]

The groundwater depletion patterns in Pakistan demonstrate an extreme mismatch between water recharge rates and extraction levels. The PCRWR (2022–23) reports that groundwater levels in Punjab and Sindh and Khyber Pakhtunkhwa provinces show negative trends at rates between 0.5–1.5 meters per year while certain areas experience more than 2 meters of annual groundwater level decrease. The Indus Basin shows evidence of major groundwater depletion according to GRACE satellite data, which makes it one of the most vulnerable aquifer systems worldwide [27][28]. While over-abstraction remains the dominant driver, recent studies emphasize that riverbed lowering and reduced river recharge significantly accelerate depletion, particularly along Indus tributaries experiencing unregulated sand mining[29]

In Sindh's lower Indus Basin, sediment extraction and reduced freshwater inflows have intensified salinity intrusion, degrading groundwater quality in shallow and intermediate aquifers Hydro chemical analyses reveal rising electrical conductivity and chloride concentrations, indicating inland migration of saline fronts as sediment-starved riverbeds lose their buffering capacity Similar processes have been documented in the Mekong Delta, where large-scale sand mining has contributed to declining groundwater levels and widespread aquifer salinization

Overall, emerging evidence shows that river sand mining weakens groundwater recharge pathways, accelerates aquifer decline, and increases salinity vulnerability. In Pakistan, the lack of integrated river–aquifer monitoring and sediment-informed groundwater management prevents the establishment of sustainable extraction thresholds, posing a long-term threat to water security[30].

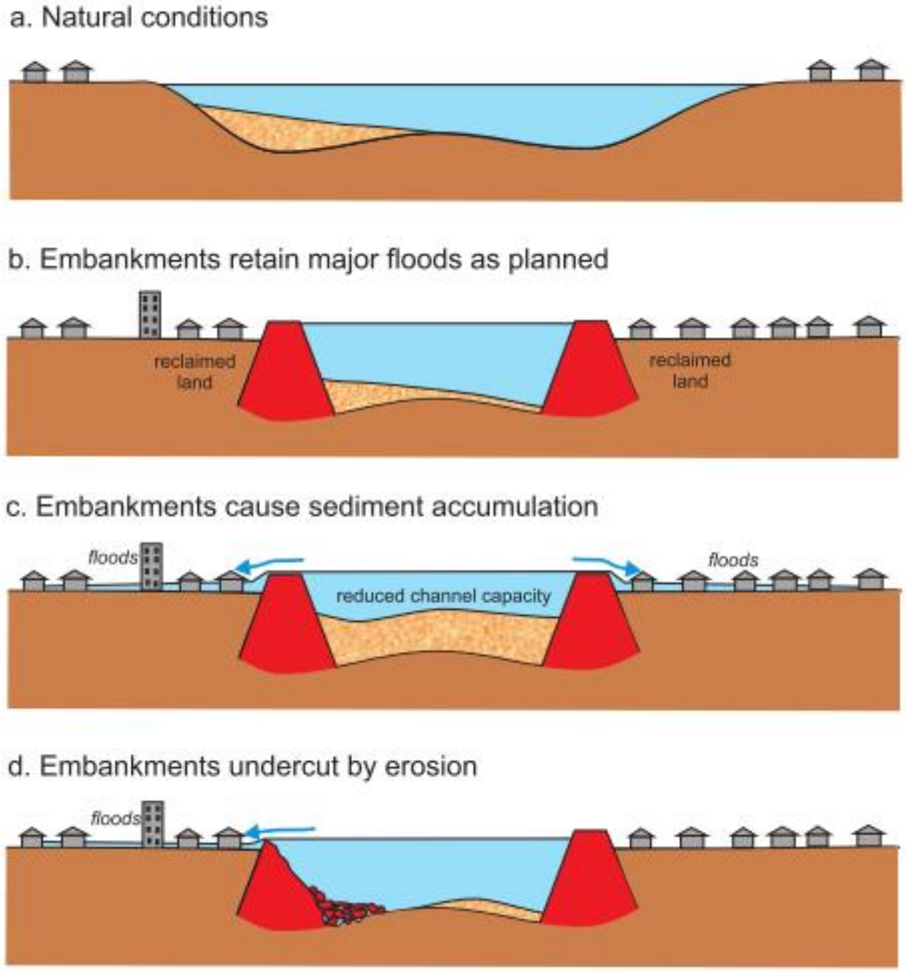

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Figure 5. Sketches compare river cross-sections before and after embankments, showing natural flow conditions and later flood risks from sedimentation and erosion.

3. Governance, Policy Failures, and Regulatory Gaps

The ongoing practice of unsustainable river sand mining in Pakistan exists because Sketches compare river cross-sections before and after embankments, showing natural flow conditions and later flood risks from sedimentation and erosion.of poor governance structure and insufficient law enforcement capabilities. The distribution of responsibilities exists between federal and provincial institutions because their authorities for irrigation and environmental and mining matters operate independently from each other. The process of Environmental Impact Assessments (EIAs) fails to deliver proper results because they get dismissed and the absence of sediment planning at river basin level enables widespread unauthorized mining which threatens river stability and groundwater replenishment. The current regulatory system which lacks coordination between different agencies allows mining operations to persist even though scientists have proven that these activities cause environmental destruction.

Multiple nations show how their governments achieve better results through their established governance systems and their unified regulatory frameworks. The 2020 Sand Mining Guidelines from India established district-level sediment budgets and required replenishment studies and remote monitoring systems which have successfully decreased illegal mining activities in monitored districts. The Australian government has established river-specific sediment management plans and implemented strict licensing requirements and ecological audits which have resulted in better riverbank stability and decreased illegal mining activities[31]. Vietnam enforces river basin management frameworks with hydrological modeling and community-based monitoring, successfully limiting sand extraction in sensitive delta areas[32]. The Netherlands combines sediment budgeting with controlled dredging and restoration programs, reducing downstream erosion and protecting floodplains[33]. South Africa uses permit-based sand mining with strict compliance checks and penalties, resulting in measurable reductions in riverbed degradation in the Vaal and Olifants rivers[34]. By comparison, Pakistan lacks sediment budgeting, real-time monitoring, and enforcement, allowing river degradation and groundwater decline to continue unchecked despite growing awareness of the risks.

Critical Analysis: Contradictions, Data Gaps, and Methodological Limitations

Research about river sand mining has gained international attention but scientists continue to disagree about its main issues. Research findings show that river systems experience major geological and water cycle disruptions but the extent of these effects depends on river characteristics and the strength of extraction operations and natural environmental factors. The country of Pakistan lacks sufficient quantitative data which forces researchers to depend on qualitative reports and regional case study extrapolations for their findings thus creating significant doubts about sediment loss rates and groundwater depletion and flood expansion. Research conducted across the world shows that channel erosion and floodplain destruction and aquifer drying exist as connected processes but these findings need specific adjustments for Pakistan's river systems because of its unique hydrological characteristics and environmental conditions. The research lacks understanding about how sand mining interacts with climate change and persistent water shortages because scientists have not studied this relationship sufficiently. The research conducted in Pakistan faces challenges because it lacks proper field data collection methods and extended observation periods and complete modeling approaches which prevents scientists from making accurate predictions about future effects and creating policy recommendations based on evidence. The existing knowledge gap requires immediate research into specific rivers which must study their geomorphic and hydrological aspects together with their social economic elements to create sustainable management plans.

4. Conclusion

River sand mining operations create major threats to both landforms and water systems throughout the world because research has shown that the Mekong and Mississippi and European rivers experience channel incision and bank erosion and floodplain degradation and aquifer depletion. Research conducted in Pakistan shows evidence which supports the same patterns that rivers are deepening while flood storage capacity of floodplains decreases and groundwater levels drop and floods become more dangerous in the Indus Basin region. The impacts create threats to water security and agricultural productivity and infrastructure stability which demand sustainable management of sand resources. The government of Pakistan needs to establish sediment budgeting systems while improving their monitoring capabilities and enforcement powers and implementing digital surveillance methods and creating a complete national sediment policy framework to handle these problems. The Indus Basin requires Pakistan to establish regional coordination for its national sediment policy development. The situation demands immediate intervention to stop environmental deterioration while protecting people and their communities and maintaining river and aquifer sustainability against urban expansion and climate shifts and dwindling water resources.

5. Recommendations and Future Directions

The following recommendations serve as guidance for sustainable river sand mining management in Pakistan while solving both environmental problems and governance issues:

1-The process of sediment-budget assessment needs to occur before mining permit approval because it helps prevent mining activities from causing river channel instability and floodplain storage reduction.

2-The use of GIS-based mapping technology enables researchers to identify mining hotspots which helps them determine the most critical areas for intervention and restoration work and extraction activity planning.

3-River monitoring systems which use artificial intelligence and predictive modeling can predict erosion and flooding and aquifer depletion in different mining conditions to support early intervention.

Abbreviations

The following abbreviations are used in this manuscript:

RSM	River Sand Mining
GIS	geographic Information System
UNEP	United Nations Environment Programme
MoEFCC	Ministry of Environment, Forest and Climate Change
EIA	Environmental Impact Assessment
PCRWR	Pakistan Council of Research in Water Resources
PEPA	Pakistan Environmental Protection Act
PAK-EPA	Pakistan Environmental Protection Agency

WWF	World Wide Fund for Nature
GRACE	Gravity Recovery and Climate Experiment
UNO	United Nations Organization
VMD	Vietnamese Mekong Delta

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