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Integrated Flood Management and Sustainable Tourism: A Case Study of Lorestan Province in Iran

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Abstract

Iran is one of the top ten countries in the world for the frequency of natural disasters, with floods being a frequent and destructive occurrence. In Lorestan Province, the complex interrelationships among dams, floods, and tourism offer both benefits and difficulties. Dams can provide recreational opportunities and are essential for managing water resources, but they can also harm tourism infrastructure and disturb natural habitats. Resilience and flexibility in the face of adversity, however, can demonstrate the potential of regional organizations. The terrible flood that occurred in February 2019 in Lorestan Province is the main topic of this investigation. Two short-term, high-yield technical solutions rubber dams and gabion dams are suggested in light of the province's high vulnerability to floods and the absence of focused flood management strategies. These buildings are suited to the unique circumstances of the province and provide quick construction, the use of regional resources, dependability, environmental friendliness, and possible tourism attractions. In order to improve performance and aesthetic appeal, a thorough flood control plan for Lorestan Province should incorporate aesthetic concepts into planning, take into account floods with different return durations, carry out flood zoning, and create cascading structures. This strategy fosters natural harmony and tourism potential in addition to reducing the risk of flooding.

Keywords: Sustainable tourism; flood control; resilience; sustainable cities; societies; Lorestan province.

1. Introduction

Climate change, by altering environmental and socioeconomic conditions, influences tourist behaviour and destination attractiveness, exerting significant pressure on both the supply and demand sides of the tourism sector. On the supply side, climate change threatens tourism infrastructure, natural attractions, recreational opportunities, and destination accessibility. Coastal destinations are particularly vulnerable to sea-level rise and coastal flooding, which can damage tourism assets. On the demand side, shifting climatic conditions alter visitor comfort levels, health risks, and seasonality of destinations, influencing tourist choice [1]. Additionally, island and nature-based tourism destinations, highly dependent on climate-sensitive economic activities, are particularly exposed to such threats. Adapting the tourism sector to these challenges necessitates reducing vulnerability through diversified flood control measures, green infrastructure, ecosystem conservation, community-based adaptation, and supportive policies. Minimizing the tourism sector's contribution to climate-induced flooding requires minimizing visitor exposure and promoting innovations in energy consumption, transitioning to renewable energy, improving efficiency, reducing long-haul travel, and fostering sustainable production [2].

A collective and coordinated effort by all stakeholders is required to transition to a climate-resilient and low-carbon tourism sector that continues to deliver socio-economic benefits while minimizing its environmental footprint [3]. Climate change exacerbates flood risks, leading to widespread casualties and economic losses. Consequently, building resilience to floods has become a focal point. Comprehensive and holistic metrics are essential for accurately assessing resilience and creating flood-resilient tourist attractions [4]. However, performance-based metrics related to surface inundation, socioeconomic impacts, and damage costs do not fully capture the ability of urban systems to recover, hindering the assessment of climate change impacts on flood resilience [5]. Further research can identify multiple resilience strategies. One approach involves adopting resilience strategies that allow for controlled flooding and minimize damage through land use adaptation, as seen in the Netherlands. This includes using flood control reservoirs and "green rivers" to manage floodwaters, which can also enhance ecological and visual values and potentially attract tourism [6]. By creating tourism attractions, the negative impacts of flood damage costs can be mitigated. Floods pose a significant threat to socio-economic systems, and risks are expected to intensify in the future due to factors such as climate change and urbanization.

Research on flood resilience and creating tourism opportunities in urban planning highlights several intelligent approaches. One such approach integrates the social-ecological-technological systems (SETS) framework with the flood resilience cycle, emphasizing smart flood risk management in urban environments, particularly in developing countries [7]. Another strategy is the use of water-sensitive urban design (WSUD), which links resilience to extreme climate events through urban planning and enhances resilience to both floods and droughts. The aim of these approaches is to transform flood threats into opportunities by increasing urban resilience and creating sustainable tourism attractions, aligned with broader sustainable development goals. Furthermore, the concept of community resilience is emphasized, which encompasses risk governance and community-based risk reduction policies to enhance inherent and adaptive resilience.

2. Ecological Resilience vs. Engineering Resilience in Flood Management

Two distinct concepts, ecological resilience and engineering resilience, are employed in flood management. Ecological resilience refers to the capacity of ecosystems to absorb

disturbances and reorganize while undergoing change, maintaining essential functions and structures. This concept emphasizes adaptation and transformation in response to external shocks [8]. Engineering resilience, on the other hand, focuses on the ability of systems to return to a pre-disturbance state and emphasizes stability and recovery [9].
In flood management, ecological resilience encompasses adaptive strategies that integrate human and natural systems, acknowledging the dynamic interactions and uncertainties inherent in these systems. This approach calls for flexible and adaptive actions that can evolve over time [8]. In contrast, engineering resilience often involves fixed and robust measures designed for specific conditions, such as dams and levees, aimed at controlling and resisting floods [10]. Sörensen also emphasizes the importance of integrating these two approaches in flood management [10].

The application of resilience concepts in flood management is a recent development, and further research and exploration are needed to effectively integrate these approaches into disaster prevention and sustainable urban planning [11-13]. Floods and earthquakes are significant natural disasters that impact human health, economies, and the environment. The transformation of these events into disasters often results from a lack of awareness and preparedness to mitigate their adverse effects. Factors such as heavy rainfall, snowmelt, riverbed changes, and dam failures can cause floods [8]. Traditional flood defence infrastructure, such as levees, dams, and channels, often fail to address evolving flood challenges, highlighting the need to develop flood resilience. This involves integrating adaptive and flexible strategies that consider both ecological and engineering resilience [8]. Ecological resilience focuses on the system's ability to adapt and transform in response to external shocks, while engineering resilience emphasizes returning to a pre-disturbance state [9].

Developing flood resilience requires a comprehensive approach, including community awareness, risk assessment, and sustainable urban planning to effectively mitigate the impacts of floods and enhance recovery [13]. The goal of this approach is to transform potential threats into opportunities for sustainable tourism development and flood risk reduction.

The concept of resilience complements traditional flood risk management approaches and offers novel strategies to mitigate the economic impacts of natural disasters and climate change. Urbanization and the removal of vegetation reduce infiltration and increase surface runoff, intensifying flood severity and its destructive effects [8]. This increased runoff contributes to erosion and sedimentation, which can reduce river channel capacity and diminish local natural beauty [9]. Resilience strategies focus on adaptive and flexible approaches that integrate environmental and engineering perspectives. The aim of these strategies is to enhance the system's capacity to absorb disturbances and reorganize, while maintaining essential functions and structures [8]. By incorporating green infrastructure, such as permeable surfaces and vegetation, urban areas can improve infiltration, reduce runoff, and enhance aesthetic and ecological values [13]. This integrated approach not only addresses immediate flood hazards but also contributes to long-term sustainability and disaster risk reduction, transforming potential threats into opportunities for urban and environmental improvement.

Sudden floods often occur as a result of dam and levee failures, as well as extreme weather events linked to climate change. These floods can be partially predicted using advanced modeling techniques, particularly in rivers that experience regular flooding due to heavy rainfall or snowmelt. However, unpredictable flash floods can occur during intense rainfall on saturated or frozen ground, especially in areas with low soil permeability, leading to significant ecological and infrastructural damage [14]. Coastal floods can also be triggered by storms, which are exacerbated by climate change and alter coastal morphologies, increasing flood risk in low-lying areas [15]. Furthermore, the frequency and intensity of floods are expected to increase due to climate change, affecting different regions in varying ways depending on local conditions and urban development [16]. Overall, the interplay between climate change and hydrological factors is crucial for understanding and effectively managing flood risks.

Hurricane Katrina, which struck the southern United States in 2005, caused widespread flooding in New Orleans due to storm surges that breached levees, submerging nearly 80% of the city in some areas with water depths exceeding three meters [17]. The storm surge, reaching a height of 8.5 meters, significantly impacted coastal areas and highlighted the vulnerability of low-lying regions to such events [18]. Flooding can also result from intense rainfall, especially during short, intense downpours that saturate the ground and lead to runoff and riverine flooding. Seasonal rains, particularly those occurring outside of normal patterns, can exacerbate flood risks, as observed in various regions [19]. When floodwaters recede, they often leave behind debris and sediment, complicating recovery efforts and damaging infrastructure [20]. To mitigate the effects of flooding, engineered structures and natural barriers, such as mangroves, can be employed to reduce storm surge impacts and enhance resilience to flooding [21].

Floods have profound and long-lasting impacts on communities. For instance, the devastating 2007 flood in Bangladesh destroyed over one million homes, highlighting the immediate and long-term risks associated with such disasters [22]. Post-flood, health crises including outbreaks of diseases such as cholera and malaria become prevalent, particularly in refugee camps with inadequate sanitation, as witnessed in the 1999 Mozambique flood [23]. In the United States alone, floods claim approximately 100 lives annually and cause around $7.5 billion in economic damage each year [24]. Historically, the Yellow River flood of 1310 in China stands as one of the deadliest natural disasters, killing nearly a million people and causing widespread displacement [25]. These examples demonstrate the far-reaching consequences of floods, encompassing economic, health, and social dimensions.

3. Flooding in Iran

Iran is ranked among the ten most disaster-prone countries globally, with floods being a recurring and devastating phenomenon. The nation faces increasing challenges from flooding, necessitating a comprehensive understanding and innovative management strategies to mitigate the impacts of these events and capitalize on the development of visually appealing attractions. As the fourth most flood-prone country globally, after

China, India, and Bangladesh, Iran must prioritize effective flood management. Considering the annual influx of 835,000 tourists to the natural attractions of Lorestan Province, proper flood management is crucial not only to minimize casualties and financial losses but also to preserve these attractions for the tourism industry [26]. Therefore, investigating and understanding this phenomenon is of paramount importance and necessitates a novel approach. Floods, as natural disasters, inflict significant damage on various aspects of human society when they occur. A concurrent focus on flood management and sustainable tourism development is imperative. The damages caused by floods are diverse, broadly categorized into tangible and intangible losses. The tangible and intangible losses resulting from floods in Iran are substantial and, unfortunately, are increasing significantly year after year, highlighting the urgent need for improved crisis management frameworks, including early warning systems and effective evacuation plans. While the focus is often on immediate physical damages, the long-term psychological and social impacts of floods are equally critical and require attention in disaster response strategies [11-12].

4. Recent Flood Events in Iran

Following an unprecedented downpour and the subsequent rise in the water level of the Qomrud River, the city of Qom was inundated by floodwaters on March 25, 2009. This catastrophic event caused substantial damage to the province of Qom, with the Qom Municipality reporting losses to urban infrastructure amounting to 70 billion Tomans. Additionally, various reports indicated that the 2009 flood significantly impacted the tourism sector, with a decline of 10–20% in tourist arrivals in the following years [27]. In 2015, widespread flooding swept across Iran, particularly affecting northern and western regions, delivering a severe blow to the country's tourism industry, especially rural tourism. The Road and Housing Organization of Mazandaran Province reported damages exceeding two billion Tomans to rural roads. The province of Ilam experienced extensive infrastructure damage, including the destruction of 770 kilometers of main and secondary roads, 820 kilometers of rural roads, and 3040 bridges. Similarly, North Khorasan Province suffered losses surpassing 116 billion Tomans across various sectors. These floods led to a substantial decline in tourism, with tourist arrivals falling by 30–50% and rural incomes dropping by approximately 30%. Comprehensive and long-term recovery measures were deemed necessary to mitigate the impact of these losses [28]. The 2016 floods, triggered by rising waters of the Dez River and the opening of the Dez Dam's gates, devastated villages along the river in Shush County and other areas of Khuzestan Province, causing widespread damage. Over 500 kilometers of rural roads and highways in Khuzestan were impacted. In Sistan and Baluchestan Province, the floods inflicted significant losses, with initial estimates reporting 150 billion Tomans worth of damage to agricultural, road, and building infrastructure [29].

Table 1. Impact of Floods on Lorestan Province, Iran.

Number of Tourists (thousands)	Human casualties	Rural road km	Paved road km	Bridge (span)	Number of flood events	Decade
10	5553	15	860	43	179	30
25	718	21	877	97	215	40
50	783	44	832	94	405	50
100	3329	105	5019	826	814	60
150	1687	12689	8106	2950	2038	70
200	573	19997	293	1641	746	80
300	1500	5000	2000	400	1200	90
835	12651	33655	16538	5695	5443	Total

The beginning of the new Persian year of 2019 coincided with severe torrential rains across Iran. From March 17 to April 1, 2019, the country was affected by three relatively strong weather systems, resulting in unprecedented rainfall and flooding, particularly in the regions bordering the Caspian Sea, as well as the western and southwestern parts of Iran. During this period, the nationwide average rainfall was 58.5 millimeters, nearly three times the long-term average for the same period. The highest rainfall was recorded in Lorestan Province with 299 millimeters [30], approximately seven times the long-term average of 44.5 millimeters. Following Lorestan, Chaharmahal and Bakhtiari Province experienced the second highest rainfall. The peak rainfall in Lorestan occurred between March 24 and April 1, during the activity of two weather systems, leading to two devastating floods. These floods, especially the second one, submerged most parts of Pol-e Dokhtar County and several areas in Khorramabad, Delfan, and Kuhdasht Counties [31].

The occurrence of floods in a region is contingent upon its specific characteristics. Although the province exhibits above-average rainfall compared to the national average, the seasonal nature of these precipitations, coupled with a lack of natural retention mechanisms, not only fails to benefit the local population but, when transformed into floods, consistently inflicts substantial damage. Lorestan Province possesses a unique topography that predisposes it to runoff and flooding. Approximately 89% of the province's land has a slope of less than 4%, which is less susceptible to runoff generation. However, the remaining portion of the province, due to its topography, is prone to runoff and flooding [32].

Although a significant portion of the province is covered by Zagros forests, the dominant winter and early spring rainfall, coinciding with leafless trees, limits the vegetation's capacity to mitigate flood flows. The formation of deep, stable soils is hindered by the region's steep slopes. Given that a majority of the province comprises highly inclined terrains, deep soils with substantial water retention capacity are scarce. Consequently, even moderate rainfall saturates the soil rapidly, leading to high runoff. Furthermore, the province is underlain by numerous geologically sensitive formations. The mountainous landscape aligns with the geological structures, resulting in elongated, arcuate ridges-oriented northwest-southeast. In addition to mountainous features, the region is characterized by hilly terrains, primarily composed of the Gorgan Formation's shale-marl units, the Amiran Formation's flysch, the Gachsaran Formation's gypsum sequences, and the Bakhtiari Formation's conglomeratic deposits. The presence of easily erodible formations such as the Gorgan Formation's shale-marl, the Amiran Formation, and the Gachsaran Formation's gypsum, and their extensive distribution in Lorestan Province, contribute to a high sediment production potential. Notably, Pol-e Dokhtar County, situated at the outlet of the Karkheh watershed, has historically experienced the most severe flood damage and is considered the most flood-prone county in the province, followed by Khorramabad County.

5. Proposals for Developing Tourism Concurrently with Flood Control Structures in Lorestan

Floodgates and cascading dams play crucial roles in water flow management and mitigating flood risks. Often integrated into dam systems, floodgates regulate water discharge and prevent overtopping, while cascading dams can enhance aesthetic and environmental benefits. These structures are integral components of flood control systems, each serving distinct yet complementary functions. Floodgates act as barriers that regulate water flow, especially during heavy rainfall or storms, thereby preventing flooding in downstream areas. In contrast, cascading dams are designed to allow water to flow over their crest, creating a waterfall effect that safely releases excess water and reduces the risk of dam failure. This design is particularly beneficial in regions with high rainfall as it aids in effectively managing water levels. Both structures operate concurrently with spillways, facilitating the safe passage of excess water and further enhancing flood management efforts. Ultimately, the strategic utilization of floodgates and cascading dams is instrumental in mitigating the risks associated with dam failure, ensuring the safety and stability of water management systems. The absence of adequate flood management measures in the province underscores the urgent need for short-term, high-yield solutions. Flood management measures can be categorized into long-term, medium-term, and short-term actions. Given the recent floods and the approaching rainy season, immediate actions are necessary to prevent a recurrence of the events that occurred in early spring. These short-term measures will create a conducive environment for planning and implementing long-term initiatives [39].

The objective of this research is to propose short-term structural solutions for flood management. Given the current temporal and geographical conditions, the proposed designs possess the following characteristics:

1) Rapid Construction: The proposed designs do not require an extensive timeframe for implementation and commissioning [39].
2) Utilization of Local Materials: The use of local materials and tools significantly reduces construction time, eliminating the need to procure equipment and materials from outside the region.
3) High Reliability: The proposed designs have been widely implemented globally and have undergone real-world testing with favourable results, thus demonstrating their efficacy.

4) Geographical Compatibility: While there are various structural methods for flood management, not all are suitable for Lorestan Province due to its unique geographical and topographical conditions. The proposed designs exhibit the highest compatibility with the region.
5) Aesthetic Appeal: The modular design and diverse color options allow for the creation of visually appealing river landscapes, serving as tourist attractions. Furthermore, these dams can be integrated into the surrounding river environment as decorative elements through appropriate design.
6) Flexibility in Water Resource Management: The ability to adjust water levels in a stepped manner enables the creation of recreational water areas with varying depths. This feature facilitates a diverse range of aquatic activities such as swimming, boating, and fishing.

Considering the need for water resource management, tourism development, and environmental protection in the non-urban areas of Lorestan Province, two designs are proposed: cascading rubber dams and gabion dams. These designs encompass all of the aforementioned characteristics [39].

6. Construction and conversion of waterfall rubber dam into tourist attractions

Rubber dams, also referred to as Flexi Dams, Inflated Dams, or Flexible Membrane Dams, are widely recognized terms in the field of hydraulic engineering. For cascade rubber dams, commonly used terms include Cascade Rubber Dams or Modular Rubber Dams, which are well-established among manufacturers, designers, and researchers specializing in these structures [40].

The concept of employing such devices was first introduced in 1974 by a French engineer named Mesnager. However, the idea of constructing dams from synthetic materials, including rubber, dates back to 1950, when it was initially proposed by Norman Imberston, the head of the Water and Power Engineering Department in Los Angeles. The first rubber dam was subsequently implemented in Los Angeles in 1958 [33]. At the time, the results were not entirely predictable.

Nevertheless, in developed countries, the emphasis on innovative ideas in engineering led to significant investments in research, fostering advancements and the progression of this technology. This commitment to innovation has been instrumental in the development of rubber dam systems. As a result, the history of this innovation and the application of rubber dams can be traced back approximately 50 years.

A rubber dam (Figure 1) is a flexible hydraulic structure that is inflatable and scalable. Compared to other hydraulic structures with similar functions, rubber dams offer numerous advantages, including low cost, short construction periods, ease of operation and maintenance, and long service life. Currently, rubber dams are widely used in industrial and agricultural applications, contributing to environmental improvement and enhancing urban landscapes.

These structures can be implemented in rivers with foul and polluted water, which can otherwise have a detrimental impact on the city's appearance. In this study, they examine the characteristics of constructing multi-level cascade rubber dams, which not only improve water quality and beautify the environment but also enhance urban ecosystems, create a favourable living environment for residents, and generate sustainable social and economic benefits. Additionally, these structures can serve as tourist attractions by creating unique natural landscapes and contributing to the aesthetic and ecological value of tourist destinations [34]. Moreover, the ability of rubber dams to regulate water levels can provide recreational opportunities such as fishing and boating, further attracting tourists [35]. Rubber dams are globally recognized as efficient hydraulic structures, particularly in the context of sustainable tourism and environmental management. Over the years, the development of cascade rubber dams has evolved by integrating engineering innovations with the growing demands of tourism. As one of the most recent hydraulic solutions, these structures offer economic and operational advantages while promoting environmental sustainability [36]. The ability of rubber dams to create unique natural landscapes enhances the aesthetic and ecological value of tourism destinations, making them an attractive option for sustainable tourism development [34]. Additionally, rubber dams can support multipurpose projects, providing benefits such as flood control, irrigation, and recreational opportunities, all of which align with the goals of sustainable development [35]. Overall, rubber dams represent a strategic choice for improving water management systems and enhancing the natural beauty of environments, thereby contributing to the growth of sustainable tourism [35].

Cascade rubber dams have seen limited application in our country. Their primary purpose in water management projects includes the construction of dams and weirs, increasing the height and storage capacity of reservoirs, replacing gates with rubber membranes, sediment trapping, water diversion and regulation, utilization in hydropower plants, and promoting scientific and educational tourism. Additionally, they have been proposed for creating artificial lakes for camping, fostering cultural and historical tourism, enabling water sports, establishing ecotourism hubs, preventing the salinization of coastal rivers, creating evaporation reserves, extracting salt, and providing habitats for wildlife. These features also support the development of health and wellness tourism [38]. As flexible and adjustable hydraulic structures, cascade rubber dams hold significant potential for advancing tourism in the country. By creating artificial lakes, they enable diverse water-based activities and facilitate the growth of nature-based tourism. Moreover, hosting cultural and sporting events in these areas can attract visitors and stimulate local economies. The rapid construction and installation process, low maintenance costs, environmental compatibility, and ability to diversify tourism activities are among the key advantages of these dams in promoting tourism development.

However, achieving sustainable tourism in these areas requires careful attention to environmental carrying capacities, the establishment of adequate infrastructure, the promotion of responsible tourism practices, and active collaboration with local communities. Overall, cascade rubber dams can serve as a powerful tool for advancing tourism and creating employment opportunities in rural areas [38, 45].

From a spatial perspective, these types of structures can be constructed in various regions for a wide range of purposes. The integration of geotextiles and geomembranes in water storage projects and their use as impermeable barriers in dams and weirs, along with the utilization of recycled automobile tires in check dam construction, are notable innovations in hydraulic engineering. Consequently, rubber-based applications are viable in diverse water management projects across the country, ranging from small- and large-scale watershed management to agricultural, industrial, and rural development initiatives. One such permeable gravity structure, built using recycled tires and riverine materials, stands 3 meters tall with a crest length of 16 meters, a reservoir capacity of 700 cubic meters, and incorporates approximately 1,260 used car tires equivalent to Peugeot 405 tires. The primary objectives of this structure include flood moderation and delay, soil erosion control, sediment management, and enhancement of vegetative cover.

These structures, constructed using recycled materials, not only fulfil engineering functions such as flood and soil erosion control but also serve as natural and unique tourist attractions. They contribute to the creation of scenic water landscapes, offer diverse recreational opportunities, and support the development of ecotourism. Moreover, promoting local handicrafts and hosting cultural events around these sites can foster rural tourism and preserve the cultural identity of the regions.

However, optimal utilization of this potential requires precise planning, effective waste management, and intersectoral collaboration. Rubber-based hydraulic structures can act as powerful tools for promoting sustainable tourism and improving the economic conditions of local communities [38].

Figure 1. Rubber Dam in the evaluated cases.

7. Gabion Walls (Stone Cages)

The earliest known gabion structure in history was built by the Egyptians during the reign of the Pharaohs. These structures were constructed along the Nile River using reeds and stones to protect against flooding and river overflow. Since the time of the Pharaohs, gabions have evolved, with reeds being replaced by stone cages. Today, these structures are widely used in various fields, including tourism, due to their flexibility, high durability, and environmental compatibility. Gabions have proven to be one of the most effective methods for combating soil erosion globally.

Gabion cages, characterized by their exceptional flexibility and strength, allow the construction of stone structures that effectively reduce rock slippage and soil erosion while controlling sediment flow. Gabion baskets filled with materials are interconnected to form a flexible, permeable, and unified structure capable of withstanding significant ground movements caused by floods, erosion, or land shifts [39].

These integrated structures can be employed as retaining walls, seawalls, channel linings, and embankments to protect land and prevent soil and rock collapse in steep terrains along roadsides. Gabions stabilize steep slopes and, due to the voids between the stones, exhibit high permeability. This enables them to efficiently drain water, making them ideal for dissipating the energy of floodwaters and waves. Their application in natural channels and rivers provides an excellent method for creating roughness that guides water and flood flows, preserving the natural appearance of the channel while mitigating the destructive energy of floods.

As mentioned, gabion baskets, as flexible and unified support systems, can be installed consecutively and filled with natural stones. In alluvial rivers, where cobblestones are abundant, gabion walls are a cost-effective and practical choice for shoreline reinforcement and the construction of flood control walls. In this method, cobblestones are placed inside large wire cages, which are stacked like stone walls to create robust and effective flood barriers.

These structures, apart from their functional engineering applications, offer aesthetic and ecological benefits, making them suitable for both practical and ornamental uses in tourism and environmental management [39].

8. Applications of Gabions in Tourism

Gabions (Figure 2), mesh structures filled with stones, have gained significant attention as a key element in the design of tourism spaces due to their numerous advantages, including environmental compatibility, sustainability, and flexibility. These structures contribute to enriching the tourism experience by creating visually appealing natural landscapes, attractive walking and cycling paths, diverse recreational spaces, and iconic artistic installations [41, 45].

Moreover, gabions play an essential role in protecting coastlines and rivers against erosion and flooding. Their use in tourism not only results in the creation of visually captivating environments but also greatly supports sustainable tourism development and environmental conservation [41, 43].

Additionally, the low construction costs and ease of implementation make gabions an economical and practical choice for tourism projects. By integrating aesthetics with functionality, gabions offer a versatile solution for enhancing the visual and ecological appeal of tourism destinations while promoting environmental stewardship [41].

Figure 2. Gabion Dam for flood management and tourism destinations.

9. Flood Management Study Phase in Lorestan Province

Comprehensive flood management studies in Lorestan Province not only mitigate flood-related risks but also create valuable opportunities for sustainable tourism development. By utilizing data from flood routing and floodplain zoning, precise planning for flood-resistant tourism infrastructure and the development of new attractions becomes feasible [39].

9.1 Flood Routing and Tourism with Different Flood Return Periods

Flood routing refers to the process of determining the timing and magnitude of flood waves at specific points along a river, based on assumed or real data. This process is essential for understanding the changes in flood wave characteristics as it progresses downstream, especially in irregular rivers with high roughness and turbulence [39].

By accurately identifying areas with low flood risk, safe locations for constructing tourism facilities such as campsites, eco-lodges, and walking trails can be designated. Additionally, nature-based tourism tours can be designed and implemented in these regions. During flood formation in upstream areas, the flood's behaviour—shaped by factors such as vegetation cover, topography, and geological structure—can be predicted [43].

The return period of a flood indicates its severity and volume. Thus, for effective flood management, flood routing must be conducted for various return periods specific to each watershed. This enables an understanding of flood height and flow characteristics across all sections of the basin, aiding in preemptive management strategies.

9.2 Floodplain Zoning and Tourism

An essential step in flood management is assessing the potential destructive impacts of floods on specific areas. Following flood routing, the flow dynamics of the flood are analyzed, and necessary maps are used to identify flood-prone zones.

Flood control structures must be strategically placed to maximize their impact without causing additional damage elsewhere in the basin. This necessitates comprehensive

floodplain zoning. Identifying high-risk zones allows for the declaration of such areas as protected regions, preventing overdevelopment and uncontrolled construction [43].
Conversely, low-risk areas can be developed as ecotourism destinations. Activities such as boating, fishing, and birdwatching can attract tourists to these zones. Using floodplain zoning results, safe tourism routes can be planned to avoid high-risk areas. Regardless of the flood management approach—structural, non-structural, or a combination—flood routing and zoning must be conducted along the primary river to enable informed planning and selection of optimal solutions [43].

9.3 Flood Control Structures and Tourism

Once floodplain zoning is complete and the locations for flood control structures are determined, another round of zoning is conducted, incorporating these structures to verify their effectiveness under various flood return periods. Flood control structures can also serve as attractive tourism elements. For example, these structures can be integrated into recreational spaces, such as walking and cycling paths or leisure areas. In riverside villages, flood control structures can enhance the potential for rural tourism by creating safer environments. Following a thorough evaluation of available options, the flood control structure with the highest efficiency, shortest installation time, and lowest cost is selected for implementation [43].

9.4 The Importance of an Integrated Approach

To fully capitalize on the tourism opportunities presented by flood management studies, an integrated approach involving all stakeholders—tourism managers, local authorities, and local communities—is essential. Such an approach facilitates the development of sustainable tourism while minimizing the adverse effects of flooding.

Iran's position in these global tourism metrics reflects both opportunities and challenges. Limited implementation of sustainable tourism monitoring systems (Figure 3a) highlights the need for developing robust mechanisms to account for the economic, social, and environmental impacts of tourism. Given its rich cultural heritage and historical landmarks, Iran has the potential to attract more international tourists (Figure 3b), which could help boost its economy. However, balancing this growth with sustainability is critical.

In terms of environmental impact, Iran’s moderate domestic aviation emissions (Figure 3c) highlight a growing dependency on air travel for internal connectivity, given its vast and mountainous terrain. Efforts to develop sustainable aviation practices and improve alternative transportation infrastructure are vital to mitigating this impact.

The lower rate of international tourist departures (Figure 3d) suggests that outbound tourism from Iran is constrained by economic and political factors, though there is gradual growth. This reflects a potential area for improvement as international relations and economic conditions evolve. By addressing these aspects, Iran can leverage its unique tourism appeal while aligning with global sustainability goals, fostering both economic development and environmental stewardship.

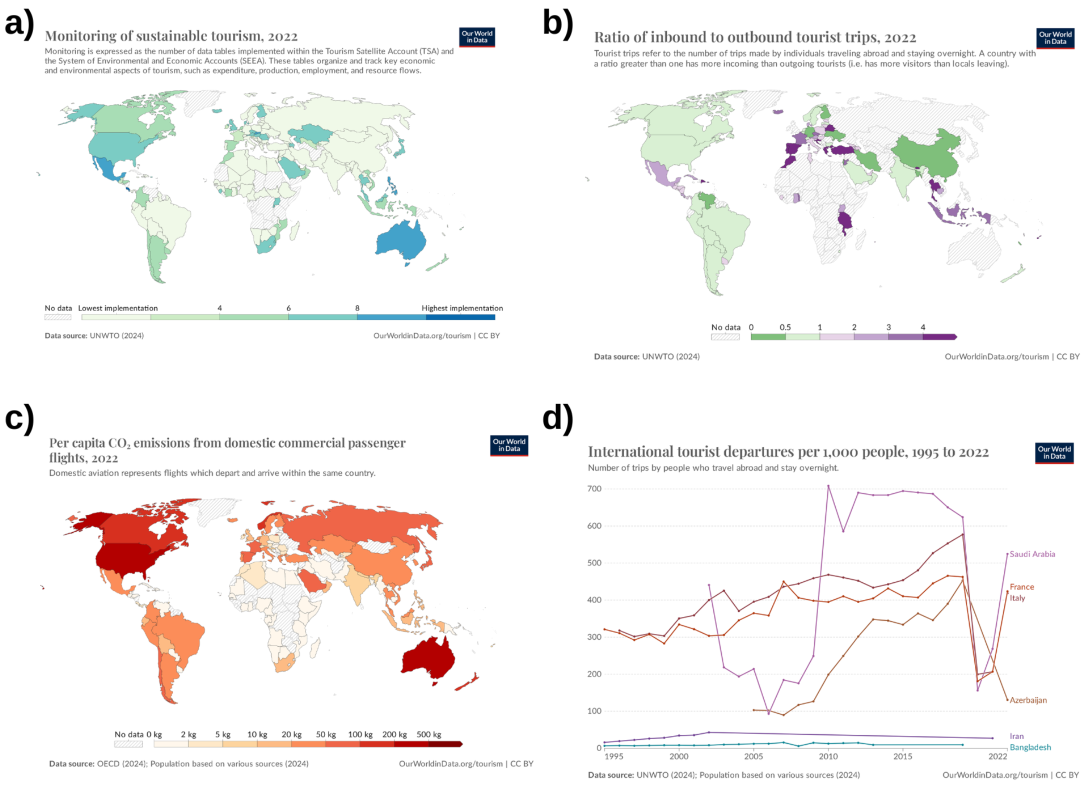

Figure 3. Global Metrics on Tourism and Sustainability based on a) Monitoring of Sustainable Tourism, b) Ratio of Inbound to Outbound Tourist Trips, 2022, c) Per Capita CO_2 Emissions from Domestic Commercial Passenger Flights, 2022, and d) International Tourist Departures per 1,000 People (1995-2022) [37]

Floods, as a recurring natural disaster in Iran, significantly affect the country's economy, society, and environment, with profound implications for its tourism industry. Figure 4a highlights the high variability in precipitation, contributing to extreme weather events such as flash floods. Iran's topography, with numerous mountainous regions and river systems, exacerbates the risk of floods, particularly in urbanized and touristic areas.

Floods, as depicted in Figure 4b, are a leading cause of economic damage, often destroying critical infrastructure, including roads, bridges, and historical sites, which are central to Iran’s tourism sector. Such damage disrupts accessibility to tourist destinations and imposes heavy reconstruction costs. Additionally, floods contribute to the degradation of natural landscapes, reducing their appeal to eco-tourists.

The death rates shown in Figure 4d underline the severe human cost of floods, which can deter tourism by creating perceptions of insecurity. However, improvements in disaster management and mitigation strategies in recent decades have reduced mortality rates, signalling progress in resilience and preparedness.

To mitigate the impact of floods on the tourism industry, Iran could implement integrated water management strategies, improve urban planning in flood-prone areas, and strengthen infrastructure near tourist sites. Promoting eco-tourism and sustainable practices could also support recovery efforts while showcasing Iran's resilience and commitment to sustainability. In summary, addressing flood risks is essential for safeguarding Iran's tourism potential, preserving cultural and natural assets, and ensuring the safety of visitors and local communities.

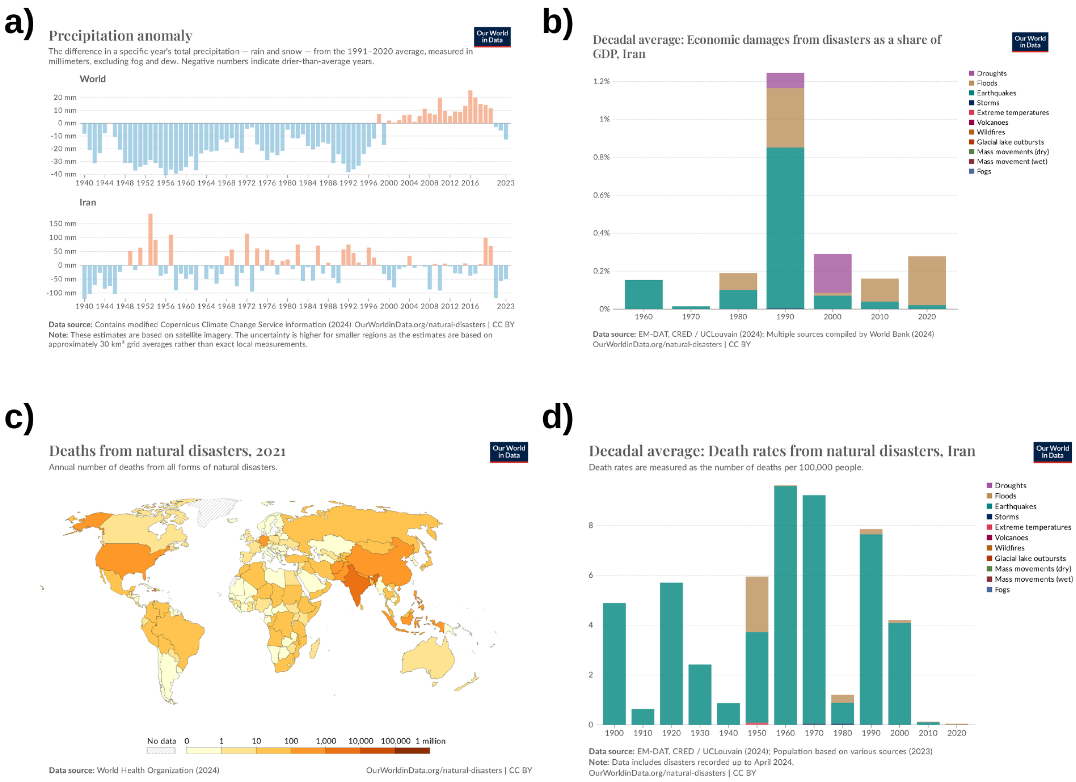

Figure 4. Impact of Natural Disasters and Climate Variability in Iran and Globally as per a) Precipitation Anomaly (1940–2023), b) Decadal Average: Economic Damages from Disasters as a Share of GDP, Iran, c) Deaths from Natural Disasters, 2021, and d) Decadal Average: Death Rates from Natural Disasters, Iran. [37]

The comparison of our findings with those of Abd-Elhamid et al. (2018) [42] underscores both convergent and divergent approaches to flood management in tourism-sensitive regions. Both studies emphasize the critical importance of structural flood mitigation measures in safeguarding tourism infrastructure and sustaining economic growth. Abd-Elhamid et al. proposed an integrated system of drainage channels and embankment dams to mitigate flash flood risks in Hurghada, Egypt, effectively protecting critical tourism areas along the Red Sea coast. Similarly, our research in Lorestan Province advocates for cascading rubber and gabion dams, tailored to the region's topography and environmental conditions, to manage flood risks while creating opportunities for sustainable tourism. Both approaches recognize the necessity of combining hydrological assessments and structural interventions to enhance flood resilience, with each design incorporating local environmental and hydrological characteristics [42].

Despite these parallels, our study uniquely highlights the dual-purpose design of flood control structures, incorporating aesthetic and ecological enhancements to promote tourism. While Abd-Elhamid et al. (2018) [42] focused primarily on risk mitigation, our work integrates tourism development into flood management strategies, transforming potential flood-related adversities into opportunities. The use of cascading rubber dams in Lorestan not only ensures rapid deployment and regional material utilization but also enriches the visual and recreational appeal of rivers, fostering tourism. In contrast, Abd-Elhamid et al. emphasized the functionality of dams and drainage systems for immediate hazard prevention. These differences reflect the contextual priorities and objectives of the respective regions, illustrating the adaptive potential of flood management frameworks when aligned with local socio-economic and environmental needs [42].

The comparison of our findings with those of Dube et al. (2023) [43] reveals both shared insights and unique considerations regarding the intersection of flood hazards and tourism. Both studies highlight the vulnerability of tourism infrastructure to flooding, with an emphasis on the critical need for adaptive strategies. Dube et al. [43] documented the frequent occurrence of floods in South African national parks, such as Kruger and Mapungubwe, identifying riverine flooding and tropical cyclones as primary causes. Similarly, our study in Lorestan Province emphasizes how floods, exacerbated by dam discharges and extreme weather, threaten the stability of tourism-related assets. Both research efforts underscore the importance of integrating engineering and nature-based solutions, such as early warning systems (EWS) and flood zoning, to minimize infrastructural and economic losses. However, while Dube et al. focus extensively on mapping flood-prone areas and evaluating the impact on existing infrastructure, our study delves deeper into the proactive role of flood management structures, such as rubber dams and gabion systems, not just for risk mitigation but also for fostering sustainable tourism development. In contrast to Dube et al., who emphasize relocating vulnerable infrastructure, our findings advocate for localized, eco-integrated solutions that enhance the dual-purpose functionality of flood control systems. This approach aligns with the principles of community-driven adaptation, providing both immediate protection and long-term economic opportunities. Together, these studies emphasize the need for tailored flood management frameworks that account for the unique geographical and socio-economic contexts of tourism-dependent regions [43].

The comparison of our findings with those of Zhang et al. (2021) [44] reveals shared concerns and contrasting methodologies in addressing the risks of flash floods to tourism. Both studies emphasize the vulnerability of tourism infrastructures to flood hazards, acknowledging the compounded risks posed by climate change and increasing precipitation intensities [44]. Zhang et al. projected significant increases in flash flood occurrences for the Nanshan Scenic Zone in China due to extreme precipitation events, estimating a 72% to 78% rise by 2070–2099 under the RCP4.5 scenario. Similarly, our research identifies Lorestan Province's tourism sector as vulnerable to flood hazards but focuses on the mitigating role of rubber and gabion dams in both controlling floods and fostering sustainable tourism. While Zhang et al. rely heavily on climate modeling to project long-term risks, our study integrates engineering and ecological solutions to address immediate and long-term challenges. The use of cascading rubber dams in Lorestan not only reduces flood risks but also enhances the region's aesthetic and recreational appeal, promoting year-round tourism. In contrast, Zhang et al. primarily advocate for predictive measures, such as early warning systems and adaptive planning, emphasizing the necessity for proactive disaster management. Despite these differences, both studies underline the importance of localized and context-specific flood mitigation strategies, highlighting the intricate link between climate resilience and sustainable tourism development [44].

The comparison of our findings with those of Rindrasih et al. (2019) [45] provides valuable insights into disaster impacts and recovery strategies for tourism-dependent regions. Both studies recognize the vulnerability of the tourism sector to natural disasters, emphasizing the importance of mitigation strategies tailored to local contexts. Rindrasih et al. analyzed the long-term impacts of disasters on Indonesia's tourism industry, highlighting spillover effects where some regions gained from redirected tourist flows while others suffered losses. Similarly, our study in Lorestan Province underscores the need for flood mitigation measures such as rubber and gabion dams to not only protect critical tourism infrastructure but also to prevent negative spillover effects that may disrupt regional tourism dynamics [45].

While Rindrasih et al. emphasize the importance of structural policy responses, including financial and organizational resilience, our study focuses on integrating flood control measures with sustainable tourism development. The dual-purpose infrastructure in Lorestan aims to transform disaster-prone areas into attractive tourism sites, fostering long-term economic benefits. Additionally, our work contributes to disaster management by combining engineered solutions with ecological preservation, whereas Rindrasih et al. call for a comprehensive structural approach to disaster recovery that includes economic, social, and political dimensions. Both studies collectively advocate for proactive and adaptive strategies to ensure the sustainability and resilience of tourism in disaster-prone areas [45].

10. Conclusion

Comprehensive flood management studies in Lorestan Province offer significant opportunities for sustainable tourism development alongside risk reduction. Considering the extensive damages caused by the 2019 floods in Iran, particularly in Lorestan, researchers have proposed solutions such as constructing rubber and gabion dams as fast, eco-friendly, and reliable measures. These structures not only control floods but also serve as attractive tourism elements. The first phase of this study involves flood routing for various return periods, floodplain zoning, and selecting the most suitable flood control structures. Utilizing the data from these studies enables precise planning for resilient tourism infrastructure and the development of new attractions. Furthermore, identifying low-risk areas facilitates the design of nature-based tourism tours and interactive tourism spaces. By integrating flood control structures with tourism elements, unique attractions can be created, enhancing tourist retention in the region. Ultimately, adopting an integrated approach and engaging local communities can foster sustainable tourism development and mitigate the destructive impacts of floods in Lorestan Province.

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