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ORIGINAL RESEARCH PAPER

Examining Insurance Mechanisms for Enhancing the Resilience of Iran's Water Resources to Climate Change

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ABSTRACT

BACKGROUND AND OBJECTIVES: Iran's water crisis poses a fundamental threat to national security, sustainable development, and social stability. The convergence of climate change, unsustainable consumption patterns, and institutional challenges has created an unprecedented water emergency, characterized by severe groundwater overdraft and the deterioration of traditional water-management systems. The present study addresses this crisis by developing a comprehensive insurance model tailored to Iran's distinctive hydrological, agricultural, and industrial conditions. The study has three primary objectives: first, to design innovative insurance mechanisms to protect and revitalize qanat systems as sustainable groundwater-management solutions by directly linking financial protection to maintenance activities; second, to develop incentive-based insurance products that promote efficient water use in industrial and household sectors through premium structures linked to verified conservation efforts; and third, to establish a robust framework for insuring critical water infrastructure, including treatment plants and dams, against climate-related damage and operational failures, thereby ensuring service continuity. The study focuses on adapting international best practices in water-related insurance to Iran's institutional and environmental context while addressing data scarcity, limited market capacity, and the need for effective public-private partnerships.

METHODS: This study employed an advanced mixed-methods approach that combined rigorous quantitative analysis with in-depth qualitative assessment through a carefully structured three-phase methodological framework. The first phase systematically reviewed water-related insurance schemes, ranging from flood insurance in Germany to index-based agricultural insurance in developing countries, including Iran, and analyzed their design features and impacts. The second phase conducted a detailed assessment of Iran's water-risk landscape, incorporating climate-scenario modeling based on World Meteorological Organization (WMO, 2024) projections, infrastructure-vulnerability assessments of key water assets, and a comprehensive evaluation of the domestic insurance industry's technical and financial capacity using data from the Central Insurance of Iran (2022). This phase was supplemented by case studies of critically endangered qanat systems. The third phase synthesized the findings to develop a validated roadmap for water-related insurance in Iran, informed by interviews with more than 20 stakeholders from the insurance, water, agricultural, and environmental sectors.

FINDINGS: The study identifies substantial market potential for water-related insurance in Iran. Based on historical data on water-related losses, estimates of the value of water infrastructure and agricultural assets at risk, and assessments of the premium-paying capacity of relevant stakeholders, water-related insurance could potentially account for 15-20% of Iran's insurance market, compared with the current coverage rate of less than 2% for natural disasters. This quantitative assessment indicates substantial growth opportunities for insurers while addressing critical national needs. Moreover, insurance products can create strong economic incentives for water conservation when premium structures are directly linked to verified reductions in water use and investments in water-efficient technologies. International examples indicate that industries have reduced water use by 20-30% to obtain more favorable insurance terms, illustrating how appropriately designed premiums can align financial incentives with sustainable water management. However, significant implementation barriers remain, including data limitations that constrain accurate risk assessment, limited technical capacity for insurance risk modeling, and regulatory challenges. In particular, product-approval processes, the establishment of clear legal frameworks, and the provision of appropriate government support require further examination to ensure the feasibility of water-related insurance. In addition, cultural barriers to insurance adoption necessitate comprehensive awareness campaigns to promote stakeholder engagement and the uptake of these products.

CONCLUSION: Implementing a specialized water-insurance framework in Iran would represent a crucial strategic advancement toward water security and enhanced climate resilience. By providing financial protection for critical water infrastructure, creating economic incentives for sustainable water use through carefully designed premium structures, and supporting the preservation of traditional qanat systems through dedicated conservation insurance, the proposed model could significantly strengthen Iran's adaptive capacity to address escalating water-scarcity challenges. The study demonstrates that successful implementation requires strong government support, strategic investment in data infrastructure, and effective public-private partnerships that leverage international expertise and reinsurance capacity. Given the current financial constraints of domestic insurers, international reinsurance arrangements and conditional government-backed funds are essential to ensure solvency, distribute risk, and maintain premium affordability. Specifically, the study recommends establishing a "Qanat Conservation Insurance Program," with premium subsidies linked to maintenance activities; developing parametric agricultural-insurance pilots in high-risk regions; and creating a "Conditional Government Guarantee Fund" to support market development while ensuring compliance with water-conservation standards. The proposed model provides a practical and actionable pathway for integrating insurance mechanisms into Iran's national water-management strategy. Its immediate applications in the agricultural, industrial, and municipal water sectors could contribute substantially to long-term water sustainability, economic stability, and climate resilience. Future implementation should prioritize pilot projects in severely water-stressed regions, coupled with continuous monitoring and evaluation to refine the approach and demonstrate tangible benefits for stakeholders across sectors.

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INTRODUCTION

Water scarcity and climate change pose existential threats to Iran's water, food, and economic security, pushing the country toward an unprecedented crisis (Ahmadi et al., 2021). Iran's arid geography, together with severely declining precipitation, continually depleting groundwater reserves, rising temperatures, and erratic rainfall patterns, has placed immense and unsustainable pressure on its limited water resources (WMO, 2024). These conditions threaten not only agriculture, the largest water consumer, accounting for approximately 90% of total use, but also industrial productivity, the integrity of urban water-supply networks, and, ultimately, social stability and rural livelihoods. In this context, the implementation of integrated risk management and robust climate-adaptation strategies is no longer optional but a national imperative. Among the available financial risk-management instruments, insurance occupies a distinctive and powerful position as a proven mechanism for transferring and distributing financial risk (Kousky et al., 2024). By providing timely compensation for a portion of the losses caused by natural disasters and unforeseen climate events, insurance can significantly accelerate recovery and reduce the economic burden on households, businesses, and government budgets (Clarke & Dercon, 2009). Internationally, innovative insurance products and schemes are increasingly regarded as integral components of comprehensive climate-change adaptation strategies (Global Water Partnership, 2020). For example, the long-standing U.S. National Flood Insurance Program has proven effective in managing flood-related damage and facilitating the reconstruction of critical urban infrastructure (Kousky et al., 2024). Similarly, several European countries have successfully implemented specialized insurance schemes designed to protect critical water infrastructure and support water-dependent industries, with the explicit aim of enhancing overall economic and social resilience (Ahmadi et al., 2021).

A substantial body of international research has demonstrated that the function of insurance extends well beyond financial compensation after a disaster. As a sophisticated financial institution, insurance can serve as a powerful driver of sustainable water-resource management through carefully designed risk-based pricing mechanisms (Global Water Partnership, 2020). For example, when the premium for an industrial facility is calculated on the basis of its specific water-consumption patterns, the efficiency of its water systems, and the verifiable risk-reduction measures it has undertaken, the company gains a direct economic incentive to invest in water-saving technologies and adopt more sustainable operational practices (Kousky et al., 2024). This alignment between the economic objectives of insurers and the broader environmental goals of society ultimately enhances the resilience of the entire socio-ecological system to the adverse impacts of climate change. Nevertheless, despite this clear potential and pressing need, the Iranian insurance industry has yet to take substantial and effective steps toward addressing water- and climate-related risks in a systematic manner.

The conceptual framework for addressing this gap through specialized water-insurance mechanisms is presented in Table 1.

Meanwhile, the water crisis has permeated all economic and social spheres of the country and has escalated in severity each year. Successful international experiences clearly highlight the considerable potential of insurance as a complementary pillar within national water-management strategies. Kousky et al. (2024) have empirically demonstrated that insurance, beyond its traditional role of compensating losses, can directly contribute to proactive risk reduction and long-term resilience-building, thereby positioning it as a key element of modern climate-risk-governance frameworks. Building on this potential, Fig. 1 presents a conceptual framework for adapting these international experiences to Iran's specific water challenges through specialized insurance mechanisms.

Within the Iranian context, few studies have directly examined the role of insurance in water management, although related research has identified key challenges

Table 1. Conceptual framework for integrating water insurance into Iran's water and climate risk management strategy

Level	Key Components	Description
1. Driving Pressures	• Climate Change Impacts • Unsustainable Water Management	Fundamental forces creating Iran's water crisis
2. Key Water Risks	• Severe Droughts • Destructive Floods • Qanat System Collapse • Groundwater Depletion	Specific hydrological challenges facing Iran
3. Insurance Framework	• Qanat Conservation Insurance • Parametric Agricultural Insurance • Incentive-Based Industrial Insurance	Proposed specialized insurance mechanisms
4. Ultimate Goals	• Water Security • Socio-Economic Resilience • Sustainable Water Governance	Long-term strategic objectives

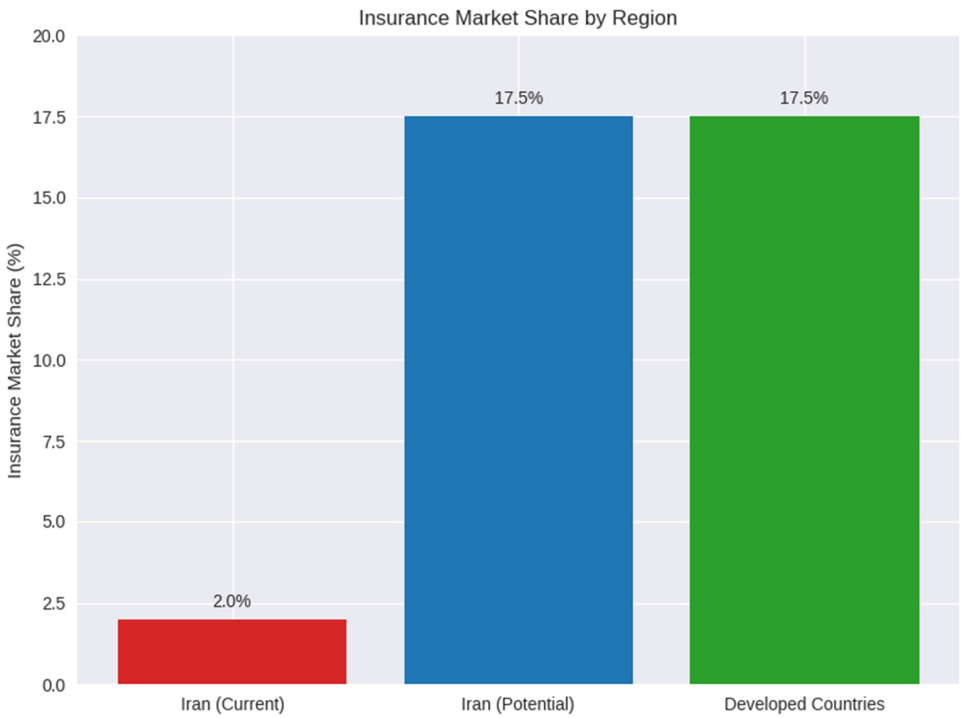


Fig. 1. Conceptual framework for integrating water insurance into Iran's climate-adaptation strategy. (This figure illustrates the proposed conceptual framework, showing how water insurance can be integrated into Iran's national climate-adaptation strategy and highlighting key stakeholders, financial mechanisms, and expected outcomes).

in providing natural-disaster coverage (Ghafory-Ashtiany & Motamed, 2024). At the same time, these studies confirm the existence of significant, untapped opportunities for developing innovative insurance products in environmental risk management and climate adaptation in Iran (Ghafory-Ashtiany & Motamed, 2024). Scholars argue that insurance can serve as a valuable complement to government policy in managing complex water crises and can substantially contribute to strengthening the country's economic and social resilience to hydrological shocks. Against this backdrop, the central research question guiding this study is as follows: How can the latent and underutilized capacities of Iran's insurance industry be effectively harnessed and strategically mobilized to achieve the critical national goals of optimal water-resource management and successful adaptation to climate change? This question forms the intellectual core of the present article, which seeks to propose practical, evidence-based pathways for developing and implementing specialized insurance products in the water and climate domain. This aim is pursued by critically examining and adapting relevant international experience while conducting an in-depth analysis of Iran's unique local conditions, constraints, and opportunities, with particular emphasis on developing viable models for qanat-rehabilitation insurance and consumption-based incentive schemes.

As illustrated in Fig. 1, the framework translates global insurance principles into actionable solutions for Iran by addressing the chain of drivers, risks, and solutions specific to the Iranian context, ultimately leading to enhanced water security and climate resilience.

Theoretical Foundations of the Study

Insurance is widely recognized in the economics and risk-management literature as one of the most powerful financial instruments for managing uncertainty (Kousky et al., 2024). Its function extends far beyond a simple compensatory mechanism. By creating an integrated financial safety net, insurance systematically reduces uncertainty and, through the strategic design of incentive structures, actively promotes sustainable behavior and risk-reduction practices among policyholders (Clarke & Dercon, 2009). At the international level, insurance schemes linked to water security and climate adaptation are increasingly regarded as indispensable components of comprehensive national adaptation strategies because they perform a critical dual role. On the one hand, they act as financial shock absorbers against climate-induced disasters such as droughts and floods. On the other hand, they provide tangible economic incentives that facilitate the implementation of preventive and adaptive measures by individuals, industries, and governments (Kousky et al., 2024).

Comparative policy studies consistently indicate

that insurance can serve as an effective and efficient component of broader climate-risk-governance systems. The Global Water Partnership (2020) introduced and developed the concept of index-based insurance as a major innovation in this field, offering a practical and administratively efficient solution for water-dependent sectors such as agriculture and hydropower. Under this approach, compensation payments are triggered not by traditional, often lengthy and contentious, on-site damage assessments, but by the objective realization of predefined climate or environmental indicators, such as rainfall levels measured at specific meteorological stations, satellite-based soil-moisture data, or regional temperature thresholds. Importantly, this methodology requires a clear specification of index calculation, including measurement frequency, baseline reference values, and threshold determination. It also requires predefined mechanisms to address basis risk, which arises when actual losses deviate from index-triggered payouts, as well as formal dispute-resolution procedures to address disagreements between policyholders and insurers. This structured approach has proven particularly effective and scalable in developing countries with limited financial resources and weak institutional capacity for claims verification (Clarke & Dercon, 2009). In parallel, leading international organizations emphasize that insurance should be formally incorporated into comprehensive, government-led disaster-risk-management programs related to water crises and scarcity (Global Water Partnership, 2020; UNESCO, 2023), supported by appropriate regulatory and technical oversight to ensure the reliability and credibility of index-based mechanisms.

In advanced economies with mature financial markets, sophisticated insurance systems have been developed over several decades to address natural hazards and proactively manage water resources. The U.S. National Flood Insurance Program (NFIP) is a notable and widely studied example, having played a significant role in managing flood damage and supporting the reconstruction of urban infrastructure, although it also faces challenges related to moral hazard and fiscal sustainability (Kousky et al., 2024). Similarly, many European countries have established national flood-insurance systems explicitly designed to encourage risk-reducing behavior among property owners and municipalities by offering substantial premium discounts to policyholders who undertake verified preventive measures, such as installing flood barriers or adopting water-resistant building materials. These measures contribute directly to loss reduction and enhanced community resilience (Kousky et al., 2024).

Recent research in behavioral economics has also drawn attention to the psychological and behavioral dimensions of insurance uptake in the context of natural hazards. Clarke and Dercon (2009) demonstrate that behavioral factors, such as risk perception, optimism bias, and trust in institutions, significantly influence the willingness of individuals and firms to purchase insurance coverage against low-probability, high-impact events. Consequently, the design of successful insurance products must take into account the motivations, biases, and concerns of potential policyholders in order to achieve adequate market penetration. Clarke and Dercon (2009) also highlight the vital role of insurance in protecting economically vulnerable groups against climate risks, framing it not merely as a financial tool but also as a potential instrument for advancing social justice and establishing reliable safety nets for populations that are often disproportionately affected by water-related disasters.

In Iran, water scarcity has escalated into one of the country's most serious and deeply entrenched structural challenges. Ahmadi et al. (2021) provide evidence that climate change has placed severe and intensifying pressure on water resources, particularly in the southeastern regions of the country, where precipitation patterns have become increasingly erratic. Declining rainfall and rising temperatures have imposed serious constraints on reliable access to both surface water and groundwater resources, thereby directly jeopardizing national water security and agricultural output. Despite these critical and worsening conditions, the Iranian insurance industry has yet to take substantial, market-transforming steps toward addressing water- and climate-related risks in a systematic and scalable manner.

Existing insurance products in Iran remain largely concentrated in traditional domains such as life, health, and motor insurance and have not provided comprehensive coverage for the specialized and growing risks associated with water scarcity and climate variability. Nevertheless, an emerging body of domestic research underscores the urgent need to develop climate-resilient and infrastructure-related insurance schemes. Ghafory-Ashtiany and Motamed (2024), in their examination of the challenges facing the insurance industry in covering natural disasters such as earthquakes, shed light on the regulatory, financial, and cultural obstacles that are also relevant to water-related risks. At the same time, these and other studies emphasize the considerable untapped opportunities for expanding insurance activities into environmental risk management and climate adaptation in Iran, suggesting a potentially large and socially beneficial market for innovative products.

The theoretical literature further underscores the close interdependence among insurance, effective risk governance, and socio-ecological resilience. Kousky

et al. (2024) conceptualize insurance as an integral component of a modern climate-risk-governance system, capable of reducing systemic vulnerability and enhancing resilience through financial pooling and risk-spreading functions. From this broader perspective, insurance is not merely a technical financial instrument but also a potential mechanism for promoting intergenerational equity, encouraging proactive adaptation, and strengthening collective resilience in the face of complex climate challenges (Clarke & Dercon, 2009). A comprehensive review of the international literature indicates that insurance is increasingly recognized as a key policy instrument in managing water-related crises and adapting to anthropogenic climate change. In Iran, although the physical dimensions of water scarcity and climate change have been extensively examined by hydrologists and climatologists, the specific role of insurance as a mitigation and adaptation tool in this domain has received comparatively limited scholarly and policy attention. This significant research gap underscores the necessity and potential contribution of the present study, which seeks to bridge hydrology, climate science, and risk finance in proposing actionable solutions for Iran.

Literature Review

Scholarly investigation into the role of insurance in water-resource management and climate-change adaptation has expanded considerably over the past two decades. Clarke and Dercon (2009), in their influential review, demonstrated that insurance can function not only as a reactive mechanism for compensating losses after a disaster but also as a proactive tool for facilitating climate-change adaptation and building long-term societal resilience. Their foundational analysis emphasizes that insurance should be regarded as an integral component of comprehensive, multi-pronged climate-adaptation strategies rather than as a standalone financial product.

The study by Kellett et al. (2024) marked a significant advancement by formally introducing and elaborating the concept of index-based insurance for managing climate risks in agriculture and other water-dependent sectors. Their empirical findings showed that insurance products based on objective and transparent climate indicators can provide an efficient, low-cost, and scalable solution for compensating losses caused by covariate risks such as widespread droughts and catastrophic floods, particularly in data-scarce environments.

The Global Water Partnership (2020), in its technical report on the intersection of climate insurance and water-related disaster-risk management, highlighted the strategic importance of insurance as part of a holistic water-governance toolkit. The report identified insurance as a crucial element of comprehensive national and regional strategies for addressing escalating water crises and explicitly emphasized its potential role in creating positive economic incentives for the adoption of sustainable water-management practices among diverse stakeholders.

In the specialized field of insurance economics and public policy, Ghafory-Ashtiany and Motamed (2024) examined the role of insurance in managing large-scale systemic risks. They argued that well-designed insurance systems can significantly enhance a nation's economic resilience to natural disasters by distributing risk across space and time, thereby preventing localized shocks from cascading into broader economic crises. Similarly, their study investigated the theoretical and empirical role of insurance in reducing the macroeconomic impacts of disasters, suggesting that insurance can serve as a powerful mechanism for mitigating both direct and indirect losses and for strengthening the underlying resilience of the economy.

Focusing on developing countries, Clarke and Dercon (2009) provided a critical analysis of public-private disaster-insurance systems and extracted valuable lessons for countries such as Iran in designing, implementing, and scaling effective and affordable insurance systems that serve both public and private objectives. In a related vein, Ghafory-Ashtiany and Motamed (2024) emphasized the importance of strategic disaster-risk financing in developing countries, showing through empirical modeling that well-designed financial protection mechanisms can substantially reduce fiscal vulnerability and human suffering associated with natural hazards.

Clarke and Dercon (2009) also introduced a critical social-equity dimension by focusing on the role of insurance in protecting economically vulnerable groups. They argued that insurance, when appropriately designed and subsidized, can function as a practical tool for promoting social justice and establishing reliable financial safety nets for low-income populations, who are typically the most exposed and least resilient to climate risks and water shortages.

In the specific Iranian context, Ahmadi et al. (2021) conducted a rigorous study of the effects of climate change on water resources in southeastern Iran, showing through hydrological modeling that climate change has already significantly reduced water availability in this arid region, thereby threatening rural livelihoods and regional stability. Complementing this analysis, Ghafory-Ashtiany and Motamed (2024), in their study of earthquake-insurance challenges in Iran, showed that the country's insurance industry faces serious structural obstacles in providing coverage for natural disasters, including limited reinsurance capacity, regulatory constraints, and low public risk awareness.

Table 2. Chronological analysis of key literature on water-related insurance

Year	Author(s)	Primary Focus	Geographical Context	Relevance to Iran
2009	(Clarke & Dercon, 2009)	Social protection and safety nets	Developing countries	Equity considerations
2020	(Global Water Partnership, 2020)	Water-related disaster risk management	International	Policy approaches
2021	(Ahmadi et al., 2021)	Climate impacts on water resources	Iran	Problem identification
2024	(Kellett et al., 2024)	Index-based agricultural insurance	Global/Developing countries	Theoretical foundation
2024	(Kousky et al., 2024)	Climate risk insurance scenarios	International	Scenario planning
2024	(Ghafory-Ashtiany & Motamed, 2024)	Natural disaster insurance challenges	Iran	Barrier analysis
2024	(Payandeh & Rahmani., 2024)	Climate risk and insurance industry	Iran	General assessment

These constraints are also directly relevant to water-related risks (Payandeh & Rahmani, 2024). Table 2 provides a systematic overview of this literature and highlights the limited focus on Iran-specific water-insurance solutions.

To illustrate the market potential for water-related insurance in Iran, it is important to consider industry-specific data, including the current size of the natural-disaster insurance market, the volume of premiums underwritten, and the capacity of domestic insurers to expand coverage. Recent reports indicate that, although natural-disaster insurance currently covers less than 2% of potential losses, the total premiums written and the insured asset base suggest that water-related products could realistically account for 15-20% of the national insurance market, provided that appropriate regulatory support, risk modeling, and reinsurance arrangements are put in place. Incorporating such data-based estimates strengthens the case for both the economic feasibility and the strategic relevance of introducing water-insurance mechanisms tailored to Iran's context.

Research Implementation Method

This study employed a rigorously designed mixed-methods approach to investigate the potential integration of insurance mechanisms into Iran's water-resource management and climate-adaptation strategies. The methodology was specifically structured to address the complex, multidimensional nature of water risks, which simultaneously encompass technical, economic, social, and institutional dimensions that cannot be adequately captured through a single methodological approach (Kellett et al., 2024). The research was executed in three interconnected phases, each building upon the findings of the previous one to ensure a comprehensive analysis.

First Phase: Comprehensive Literature Review and Analysis of Existing Data

The initial phase established the theoretical and empirical foundation through a systematic review of the international literature and documented practices relating to water- and climate-insurance schemes. This involved qualitative content analysis of peer-reviewed publications, policy documents, and case studies from various geographical contexts. The review critically examined successful implementations such as the U.S. National Flood Insurance Program and innovative index-based agricultural-insurance systems in developing countries with climatic conditions comparable to Iran, analyzing their structural designs, implementation challenges, compensation mechanisms, and overall effectiveness in enhancing water security (Kousky et al., 2024). Concurrently, quantitative data on Iran's insurance industry were collected from official sources, including statistical yearbooks and the annual performance reports of major domestic insurance companies. These datasets were instrumental in calculating key metrics such as the penetration rate of natural-disaster insurance, the share of flood and drought losses in the country's total insurance portfolio, and the five-year trends of these indicators, thereby establishing a baseline understanding of the current insurance landscape. To ensure accuracy and comparability over time, all financial data were adjusted using official inflation rates to reflect real economic values.

Second Phase: In-depth Field Study and Primary Data Collection

This phase was dedicated to gathering and analyzing primary data through multiple complementary approaches in order to ground the research in Iran's specific contextual realities. To quantitatively assess climate-related water risks, sophisticated modeling based on multiple climate scenarios was employed, drawing methodological inspiration from Ahmadi et al. (2021), who examined climate-change impacts on water resources in southeastern Iran. Specifically, the modeling process incorporated regional climate projections, including multiple General Circulation Models (GCMs) and Representative Concentration Pathways (RCPs),

to capture a range of potential temperature and precipitation trajectories over a 20-year future period. Hydrological models were then calibrated using historical observations from national meteorological stations and river-flow measurements to ensure internal consistency and to validate model outputs. Model accuracy and reliability were assessed through cross-validation techniques, sensitivity analyses, and comparison with observed extreme events such as past droughts and floods, thereby enhancing confidence in the derived quantitative risk metrics. These metrics included the probability of severe drought occurrences and the frequency of devastating flood events across different regions of Iran (Damavandi, 2022).

Complementing the quantitative analysis, semi-structured interviews were conducted with 20 key stakeholders selected through purposive sampling to ensure representation of relevant expertise and direct experience. The participant pool comprised technical managers from insurance companies active in property and agricultural insurance segments, senior water-sector experts from the Ministry of Energy and regional water authorities, academic specialists in environmental-risk management, and representatives of environmental-protection organizations. The interview protocol was organized around several core thematic areas: operational definitions of water-related risks that are potentially insurable within the Iranian context; identification of technical and institutional barriers to designing and pricing such specialized insurance products; assessment of the existing capacity of Iran's insurance market and domestic reinsurance capabilities to absorb these risks; exploration of possible mechanisms to incentivize risk-reducing behavior among policyholders; and clarification of the requirements for effective cross-sectoral collaboration between government institutions and private-sector insurers. All interviews were recorded and transcribed with participants' explicit consent, and the resulting qualitative data were analyzed using systematic thematic analysis to identify patterns, challenges, and opportunities.

Third Phase: Integration of Findings and Development of Proposed Solutions

The final phase focused on synthesizing and integrating the quantitative and qualitative findings from the preceding stages within a cohesive analytical framework. To this end, mixed-methods analytical tools were employed, including Multi-Criteria Decision Analysis (MCDA), to weigh and combine stakeholder inputs with quantitative risk metrics derived from the climate and hydrological models. The integration process also involved thematic coding of the qualitative interview data, which was then mapped against region-specific water-risk indices to ensure that contextual insights informed model parameters. Key integration criteria included risk magnitude, frequency, potential economic loss, and stakeholder sensitivity to water scarcity, enabling a transparent and systematic approach to developing actionable recommendations.

Drawing on evidence-based design methodologies, preliminary concepts for specialized insurance instruments tailored to Iran's water sector were developed. This phase was particularly informed by the theoretical framework of index-based insurance while pragmatically accounting for the limitations of Iran's climate-data infrastructure, as repeatedly emphasized during the stakeholder interviews.

The proposed insurance products were conceptualized at three distinct levels, each accompanied by a sample premium-calculation approach to demonstrate practical applicability:

- Micro-level products: Designed for individual farmers and agricultural cooperatives, using simplified parametric triggers such as rainfall thresholds at local meteorological stations. For example, a drought trigger could be defined as cumulative rainfall below 250 mm over a growing season, with the premium calculated as:

$$\left(\frac{\text{Expected Loss Probability}}{100}+1\right)+\text{Base Rate}=\text{Premium}$$

This approach enables farmers to understand and anticipate costs while linking payouts directly to measurable climate indicators.

- Mid-level products: Targeting water-intensive industries and manufacturing sectors, incorporating risk-based premium structures linked to water-efficiency metrics such as cubic meters of water used per unit of output. A sample scenario considered a factory achieving a 15% reduction in water consumption over a fiscal year and thus eligible for a 10% premium discount, demonstrating how incentives can be operationalized.
- Macro-level products: Intended for major national water-infrastructure assets, requiring complex probabilistic risk modeling through Monte Carlo simulations and parametric indices for drought and flood events. Premiums could involve shared-risk structures with conditional government guarantees. For example, a water reservoir with a replacement cost of USD 50 million could have a premium calculated as:

(Government Share – 1) X Expected Loss = Premiun

where the government share is set at 30%, illustrating how public-private partnerships can render coverage feasible while maintaining risk sensitivity.

The development process specifically incorporated innovative approaches for integrating traditional

water systems, with particular attention to designing feasible insurance mechanisms for qanat preservation and maintenance, acknowledging their critical role in Iran's hydrological heritage and sustainable water management. This included scenario-based maintenance subsidies, triggered by verified completion of qanat repair activities, to ensure alignment of incentives with conservation goals.

The phase culminated in the formulation of a comprehensive set of policy recommendations and a preliminary implementation roadmap for integrating insurance into Iran's national water-management framework, strategically designed to leverage international technical cooperation while addressing the identified regulatory, financial, and cultural barriers through targeted interventions. By including detailed example calculations and scenarios at all three levels, the study demonstrates that the proposed model is not purely conceptual but also operationally implementable within Iran's current institutional and technical constraints.

RESULTS AND DISCUSSION

Current Insurance Landscape and Identified Gaps

The comprehensive analysis of Iran's insurance market reveals a substantial disparity between existing coverage and the significant risks associated with water scarcity and climate extremes. Quantitative data reported by Schwarze and Wagner (2009) indicate that insurance products specifically addressing water-related risks account for less than 2% of the total insurance-market portfolio. This level of coverage contrasts sharply with that of developed countries with advanced climate-risk-management systems, where water-related insurance often represents 15–20% of the insurance sector, as documented in European flood-insurance markets (Schwarze & Wagner, 2009). This protection gap highlights both the vulnerability of Iran's economy to water-related shocks and the potential market for innovative insurance products tailored to local hydrological conditions (Damavandi, 2022). The *disparity between current coverage and* the estimated *potential market share is* illustrated *in Fig. 2.*

As illustrated in Fig. 2, water-related insurance currently accounts for less than 2% of Iran's total insurance portfolio, compared with an estimated potential market share of 15–20%. This difference represents a potential 7.5- to 10-fold expansion of the domestic insurance market while addressing critical national water-security challenges.

Climate-Risk Projections and Insurance Implications

Scenario-based climate modeling, building on the foundational work of Ahmadi et al. (2021), projects concerning trends for Iran's water security. Under moderate climate-change scenarios, accessible water resources in critical southeastern basins could decline by up to 20% over the next two decades. These hydrological changes not only increase the probability of widespread agricultural droughts but also, paradoxically, heighten the risk of destructive flash floods during intense precipitation events. This pattern was observed during the severe 2019 floods in Golestan and Lorestan, which caused damage estimated at several trillion tomans. The absence of comprehensive insurance coverage significantly hampered reconstruction efforts following these events, demonstrating the need for pre-arranged financial-protection mechanisms that

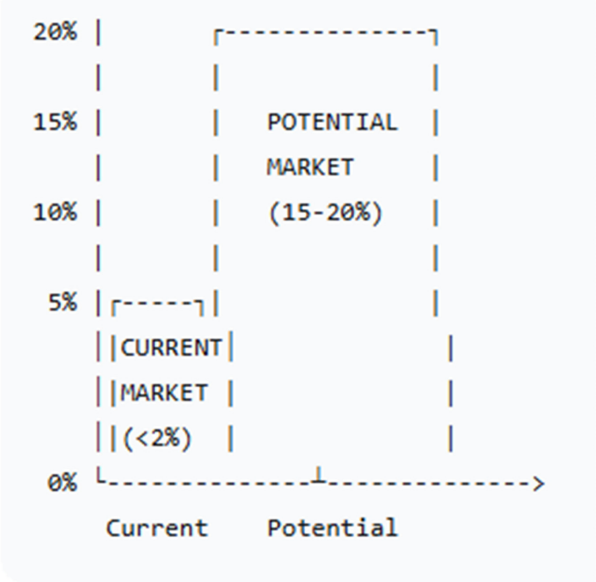


Fig. 2. Water-related insurance gap in Iran›s market

can facilitate rapid recovery and reduce fiscal pressure on government budgets and affected communities (Ahmadi et al., 2021).

Stakeholder Perspectives and Implementation Barriers

The qualitative analysis of stakeholder interviews identified four major structural barriers to the development of effective water-insurance markets in Iran. First, the lack of reliable and integrated climate data constitutes the most fundamental obstacle, particularly for the design of sophisticated index-based insurance products that require robust historical and real-time environmental data. Second, limited technical capacity within domestic insurance companies to model and price complex water-related risks presents a substantial constraint, as most insurers lack specialized expertise in hydrological risk assessment. Third, the restricted financial capacity of Iran's insurance market and the challenges associated with accessing international reinsurance markets limit the ability to cover catastrophic losses resulting from major droughts or floods. Fourth, an underdeveloped insurance culture and limited understanding of insurance as a proactive risk-management tool among potential policyholders, including agricultural producers and industrial water users, create demand-side challenges that require targeted education and awareness initiatives (Abrishamchi & Khazaei, 2021).

Innovative Insurance Solutions and Implementation Pathways

Despite these challenges, the findings identify promising pathways for developing context-appropriate insurance solutions. For the agricultural sector, index-based drought insurance offers a particularly viable approach, as demonstrated by successful implementation in comparable arid and semi-arid regions (Abrishamchi & Khazaei, 2021). By triggering payouts on the basis of objective indicators, such as rainfall measurements or satellite-based vegetation indices, rather than costly individual loss assessments, this model can reduce administrative costs and facilitate rapid compensation. Similar programs in Kenya, for example, have enabled payments to farmers within weeks of drought onset. To address Iran's data limitations, modern technologies, including remote sensing and networks of low-cost automated weather stations, could be deployed to establish the infrastructure required for reliable index-based insurance.

To address capacity constraints in the domestic insurance market, the establishment of public-private risk-pooling facilities represents a promising mechanism. Under this model, multiple insurers would pool their resources to cover catastrophic climate risks, while the government would provide ultimate financial backing as a reinsurer of last resort, following examples from developing countries with comparable market conditions (UNDRR, 2025). This approach would expand aggregate risk-bearing capacity and support the financial sustainability of the insurance system during extreme events that could otherwise overwhelm individual insurers.

Most importantly, the findings suggest that insurance mechanisms can be strategically designed to promote sustainable water-management practices rather than merely providing post-disaster compensation. By directly linking insurance premium levels to policyholders' adoption of verified risk-reduction measures, such as precision-irrigation systems in agriculture, water-recycling technologies in industry, or participation in qanat maintenance and restoration activities, insurers can create meaningful economic incentives for conservation and resilience building. This approach aligns the financial interests of insurers with the broader environmental objectives of sustainable water governance and may transform insurance from a passive risk-transfer mechanism into an active instrument for encouraging behavioral change across water-use sectors (Crawford & Mangalmurti, 2025).

Comparative International Lessons and Adaptation to Iranian Context

The comparative analysis of international experience suggests that the effective integration of insurance into holistic water-governance frameworks can enhance national resilience to water-related hazards, reduce macroeconomic losses, and accelerate societal adaptation to climate change (UNDRR, 2025). However, successful implementation in Iran will require careful adaptation of international models to the country's specific institutional arrangements, regulatory frameworks, and sociocultural factors affecting risk perception and insurance uptake. In particular, proposed initiatives should build on existing community-based water-management traditions, including the historical role of local water associations in maintaining qanat systems, in order to strengthen the cultural acceptability and operational effectiveness of the proposed insurance schemes (Crawford & Mangalmurti, 2025).

CONCLUSION AND RECOMMENDATIONS

Synthesis of Key Findings

This study demonstrates that insurance is a crucial but severely underutilized financial mechanism for addressing Iran's escalating water crisis. The findings indicate that strategically designed insurance products can simultaneously provide financial protection for critical water infrastructure against climate-related

damage, create economic incentives for sustainable water use across sectors, and mobilize private capital for climate-adaptation efforts (Crawford & Mangalmurti, 2025). The substantial gap between the potential of water-related insurance and its limited current implementation in Iran highlights the need for comprehensive policy reform and market-development initiatives to address this protection gap.

Strategic-Level Recommendations

• Develop and formally adopt a national water-insurance strategy that systematically integrates insurance mechanisms into Iran's climate-adaptation policies and integrated water-resource-management framework. The strategy should define clear roles for public and private stakeholders and establish a coordinated implementation roadmap.

• Establish a high-level steering committee comprising representatives of the Central Insurance of Iran, the Ministry of Energy, the Ministry of Agriculture, the Department of Environment, and academic institutions to provide strategic direction and oversee the development of Iran's water-insurance market.

• Implement a phased approach beginning with pilot programs in high-priority regions, such as the Urmia Lake and Zayandeh Rud basins, where water stress is acute and institutional capacity is comparatively strong, before scaling successful models nationally.

Qanat-Specific Insurance Recommendations

• Establish a Qanat Conservation Insurance Program that provides premium subsidies and enhanced coverage for communities and agricultural cooperatives that document regular maintenance and restoration activities for traditional water systems. The program should be explicitly linked to Iran's cultural-heritage-preservation policies (UNESCO, 2023).

• Develop parametric insurance products for qanat water supply that trigger automatic payments when predefined water-scarcity indicators are met, thereby providing financial support to qanat-dependent communities during drought periods without requiring complex loss assessments.

• Establish a qanat risk-pooling facility that combines resources across multiple watersheds to distribute the financial risk of qanat-system failure, making coverage more affordable and actuarially sustainable for these critical infrastructure assets.

Agricultural Water Insurance Recommendations

• Design and launch index-based drought-insurance products for major strategic crops in water-stressed regions, using satellite data and weather-station networks to determine payouts on the basis of objective indicators of water scarcity (Abrishamchi & Khazaei, 2021).

• Implement water-efficiency-linked premium structures that provide substantial discounts to farmers who adopt water-saving technologies, such as drip-irrigation systems, soil-moisture-monitoring systems, and drought-resistant crop varieties.

• Create a government-backed reinsurance facility specifically for agricultural water risks to strengthen insurer confidence and underwriting capacity, drawing on relevant models in comparable developing countries (Didier & Tsan, 2024).

Urban and Industrial Water Insurance Recommendations

• Develop comprehensive water-risk insurance for municipalities and industrial water users that covers both flood-related infrastructure damage and business-interruption losses arising from water shortages, with premiums calibrated according to policyholders' water-efficiency performance (Sheehan et al., 2023).

• Introduce water-recycling investment incentives through insurance products that offer reduced premiums to industries implementing certified water-recycling and water-reuse systems, thereby creating financial rewards for circular-water-economy practices.

• Establish risk-based water-pricing integration that aligns insurance premiums with water-utility pricing structures, thereby creating coordinated economic signals for conservation across both policy domains.

Implementation Framework and Institutional Recommendations

• Create a national water-data-infrastructure initiative to address critical data gaps by expanding meteorological monitoring networks, developing satellite-based water-resource-assessment capabilities, and establishing centralized databases for water-risk modeling, in accordance with World Meteorological Organization (WMO, 2024) standards.

• Launch a water-insurance capacity-building program for domestic insurers, reinsurers, and regulatory authorities to develop specialized expertise in hydrological risk assessment, product design, and claims management for water-related perils.

• Establish a public-private water-insurance facility, with initial capitalization from government sources and subsequent private-sector participation, to underwrite early water-insurance products and demonstrate market viability.

• Implement a stakeholder education and awareness campaign to strengthen understanding of water-insurance benefits among potential policyholders. Demonstration projects and documented outcomes from early adopters may be used to encourage market demand.

Future Research Priorities

Future research should investigate hybrid insurance

structures that combine traditional indemnity coverage with parametric triggers for complex water risks, building on the frameworks proposed by Kousky et al. (2024). Further studies are also needed to examine innovative financing mechanisms, including catastrophe bonds for water-related disasters and green bonds for water-infrastructure resilience, while adapting international experience to Iran's specific context. Research should additionally assess the potential contribution of financial-technology solutions, including blockchain-enabled transparent claims settlement and remote sensing for objective loss assessment, to enhancing the efficiency and credibility of water-insurance markets (Kellett et al., 2024).

The implementation of these recommendations through a coherent operational program supported by continuous monitoring and evaluation could transform Iran's approach to water security. Such an approach would enhance economic and social resilience to climate challenges while positioning the insurance industry as a strategic partner in national sustainable development. The proposed water-insurance framework provides a pragmatic pathway for climate adaptation that leverages market mechanisms while promoting equitable protection for vulnerable communities and critical ecosystems.

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The authors' contribution to the writing of the paper is equal.

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CONFLICT OF INTEREST

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