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ORIGINAL RESEARCH PAPER

The Climate Economics of Loss and Damage: A Critical Assessment of Financial Architecture, Risk Transfer and Fiscal Justice in Iran and West Asia

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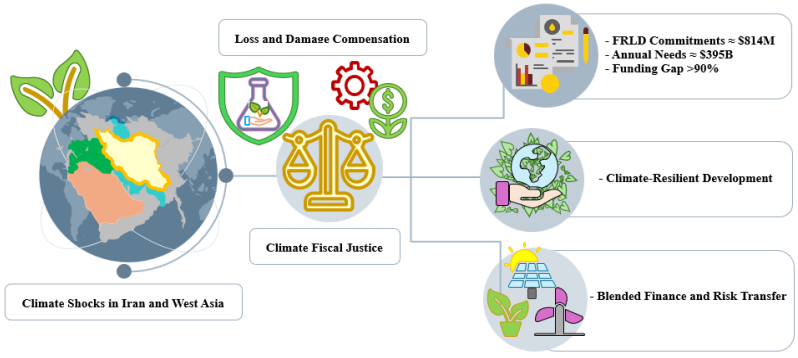
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ABSTRACT

Despite the historic establishment of the Fund for Responding to Loss and Damage (FRLD) at COP27 and its operationalisation at COP30, a fundamental gap persists between normative recognition and effective implementation. This gap is not merely legal or institutional but profoundly economic. This study critically examines the climate economics of loss and damage in Iran and West Asia, a region characterised by sanctions, complex governance structures, and transboundary water politics. It addresses two central questions: how can the global loss and damage regime transition from voluntary humanitarian assistance to mandatory fiscal justice grounded in historical responsibility? And what operational requirements enable economically efficient compensation mechanisms under geopolitical constraint? Employing qualitative systematic documentary analysis of UNFCCC agreements, COP decisions, FRLD governance documents, and peer-reviewed literature, the study applies a tripartite theoretical framework integrating climate justice, multi-layered risk governance, and climate economics. The analysis reveals a structural 'triple failure' in the current financial architecture: allocative, distributive, and sustainability failures. Total FRLD commitments (approximately $814 million) represent less than 0.2% of estimated annual needs ($395 billion), with the funding gap exceeding 90%. Fiscal justice calculations indicate over-emitting countries owe approximately $170 trillion to the Global South by 2050. In Iran and West Asia, institutional weaknesses, transparency deficits, sanctions regimes, and hydro-political secrecy render comprehensive regional insurance schemes infeasible. A contained sub-national pilot in Khuzestan province, with conditional transboundary extension to Maysan (Iraq), constitutes the most viable operational strategy for geopolitically constrained settings, offering a learning-oriented pathway toward climate fiscal justice.



1. Introduction

The climate crisis is no longer a future projection but an immediate and escalating reality, particularly for West Asia; a region identified as one of the world's most climate-vulnerable[1,2]. The resulting losses and damages, both economic and non-economic, frequently exceed what national governments can afford and occur faster than traditional insurance mechanisms can respond. West Asia faces compound climate risks; intensifying droughts, dust storms, biodiversity collapse, and transboundary hydrological disruption, that interact with pre-existing socioeconomic vulnerabilities to produce cascading, often irreversible, harm.

The establishment of the FRLD at COP27 and its operationalization at COP30 mark a historic advance in global climate governance. Yet the recognition of loss and damage as a matter of climate justice has not been matched by the capacity to provide effective, adequate, and timely financial support. This tension is not merely legal or institutional, it is profoundly economic.

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1.1. The Climate Economics Gap

Despite significant progress in climate science and international climate law, a fundamental gap exists in the economic analysis of the loss and damage regime. This gap encompasses three interrelated dimensions.

First, the efficiency gap: the low rate of return on investment in compensation projects compared to foregone opportunity costs. According to the Stern Review [3], the annual costs of inaction could amount to 5–20% of global GDP, whereas the costs of early action were estimated at approximately 1%. The discount rate applied to future climate damages is a key factor underlying this asymmetry. Weitzman [4] demonstrates that conventional positive discount rates systematically undervalue catastrophic tail risks; precisely the risks most relevant for loss and damage. Under low or near-zero social discount rates, the economic case for early investment in loss and damage mechanisms is substantially stronger than conventional cost-benefit analysis suggests.

Second, the fiscal justice gap. Fanning and Hickel [5], in the most rigorous recent quantification published in Nature Sustainability, calculate that over-emitting countries would owe a cumulative total of approximately $192 trillion globally by 2050; of which the Global North is responsible for approximately $170 trillion, representing compensation for the appropriation of the Global South's atmospheric fair shares. This amounts to an annual transfer of nearly $6 trillion, or approximately 7% of global GDP. A contribution of just 0.08% of GDP from developed economies could generate approximately $60 billion annually for loss and damage, approximately 74 times current FRLD commitments.

The relationship between these figures merits an explicit arithmetic bridge, since they operate at different scales and answer different questions. The $6 trillion annual figure is obtained by amortising the Global North's $170 trillion cumulative obligation across the approximately twenty-five-year window remaining to the 2050 horizon used in the underlying fair-shares calculation ($170 trillion ÷ 25 ≈ $6.8 trillion per year, consistent with the figure reported here once rounded to reflect a phased rather than immediate transfer). This is a maximalist figure: it represents full compensation under the Fanning and Hickel [5] methodology, and readers should consult that source directly for the precise annualisation assumptions it applies. The 0.08%-of-GDP, $60 billion figure discussed immediately below is a distinct, minimalist proposal, not a partial instalment toward the $6 trillion maximalist transfer. It is calculated against an assumed developed-economy GDP base of approximately $75 trillion, broadly consistent with aggregate OECD GDP estimates (0.08% × $75 trillion ≈ $60 billion), and is intended as an attainable near-term funding target for the FRLD specifically, rather than as a step toward discharging the full historical obligation.

Third, the sustainability gap: the dependence on voluntary, unpredictable, and inadequate financial flows. Total FRLD commitments of approximately $814 million represent less than 0.2% of estimated annual needs of $395 billion [6]. In the Iranian context, the opportunity cost of inaction is particularly acute. The 2019 Khuzestan floods caused substantial direct damages; estimated variously between $2 and $3 billion by provincial and national damage assessment surveys [7], requiring emergency fiscal reallocation that diverted resources from long-term development investments. This illustrates a fundamental economic reality: reactive disaster response not only costs more than proactive risk management but also imposes a 'development penalty' that compounds over time.

1.2. Conceptual Boundary: Loss and Damage Versus Adaptation

A critical clarification is necessary before proceeding. Loss and damage refers to the residual harms that occur despite; or because there was insufficient capacity for, mitigation and adaptation. Mechler and Schinko [8] articulate this boundary explicitly: avoided damages are the province of adaptation; unavoidable or residual damages constitute the territory of loss and damage. This distinction is analytically essential because it determines which financial instruments are appropriate. Adaptation finance addresses risks that can be managed; loss and damage finance addresses harms that are already occurring or are effectively locked in. For Iran and West Asia, where adaptation capacity is constrained by fiscal, institutional, and geopolitical factors, the residual loss and damage frontier is substantially larger than in better-resourced contexts.

A further conceptual distinction concerns the scope of damages. Economic losses; to infrastructure, agricultural output, and productive capacity, are measurable and have dominated climate finance discourse. But the UNFCCC Warsaw International Mechanism and the FRLD explicitly encompass non-economic loss and damage (NELD): cultural heritage loss, displacement, loss of identity and place, biodiversity collapse, and reduced psychosocial wellbeing. For communities such as the Ahwazi Arab populations and the Ma'dan marsh dwellers of the Hor al-Azim wetland, NELD is arguably the most severe dimension of climate harm, and the most thoroughly excluded from existing compensation frameworks [9].

1.3. Research Questions and Paper Structure

This study addresses a fundamental question: how can the international loss and damage regime be transformed from a paradigm of voluntary humanitarian assistance to one of mandatory fiscal justice grounded in historical responsibility? This question is particularly acute for Iran and West Asia; a region characterised by international sanctions, complex governance structures, transboundary water politics, and domestic structural factors that render conventional approaches infeasible.

The paper proceeds as follows: Section 2 outlines the tripartite theoretical framework. Section 3 reviews existing literature. Section 4 describes the qualitative research methodology. Section 5 examines systemic barriers confronting any climate insurance mechanism in Iran. Section 6 proposes a sub-national pilot approach. Section 7 diagnoses the triple failure of the current global architecture. Section 8 concludes with policy recommendations.

1.4. Climate Justice: A Tripartite Framework

Climate justice scholarship provides a normative foundation for evaluating financial architecture. Schlosberg [10] develops a three-dimensional framework comprising distributive justice, which concerns the equitable allocation of benefits and burdens; procedural justice, which requires meaningful participation by affected communities; and recognition justice, which acknowledges the distinct vulnerabilities and identities of those most affected. These dimensions are mutually reinforcing rather than competing alternatives. Financial solutions that address distribution while overlooking participation and recognition are therefore fundamentally incomplete.

Caney [11] reinforces this tripartite approach through his analysis of intergenerational justice and the moral obligation to address unavoidable harms. His distinction between 'avoiding harm' and 'sharing burdens' provides a conceptual bridge between the climate justice literature and the technical design of loss and damage instruments: avoiding harm requires preventing climate impacts where possible, while sharing burdens requires equitably distributing the costs of unavoidable impacts. Both duties, Caney argues, fall primarily on those who have historically contributed most to the problem.

1.5. Multi-Layered Risk Governance

Linnerooth-Bayer and Mechler [12] proposed a multi-layered approach to climate risk governance that has become foundational in the field. Layer one, covering high-frequency, low-severity risks, is managed through community-based adaptation and micro-insurance. Layer two, covering moderate risks, is managed through market-based insurance and regional risk pooling. Layer three, covering catastrophic and slow-onset risks, is managed through state guarantees or international support arrangements such as the FRLD.

This framework allows for systematic examination of how innovative insurance solutions; which primarily operate at layer two, can be integrated with public layer three instruments to provide a comprehensive safety net. It also highlights the importance of institutional design: instruments that span layers require governance mechanisms that can coordinate across multiple scales and actors, which is precisely where Iran's institutional landscape exhibits its most acute deficiencies.

1.6. Climate Economics Framework

This study introduces a climate economics framework synthesising three analytical dimensions.

First, cost-benefit analysis incorporating discount rate debate. Building on the Stern Review [3] and integrated assessment models (IAMs) including DICE and PAGE, this framework evaluates the economic efficiency of different loss and damage interventions. Fankhauser [13], in the earliest systematic quantification of the social costs of greenhouse gas emissions, estimated approximately 1.3% of GDP loss for the United States under a 3°C warming scenario. More recent scholarship has substantially revised these estimates upward, with Burke et al. [14] and Hsiang et al. [15] demonstrating significantly larger macroeconomic damages, particularly in tropical and subtropical regions. A crucial methodological issue is the social discount rate. Weitzman [4] demonstrates that under uncertainty about extreme outcomes, the appropriate discount rate approaches zero; making catastrophic long-term climate damages as economically compelling as near-term costs. This finding strongly supports investment in loss and damage mechanisms now rather than deferring to future compensation.

Second, fiscal justice and climate debt analysis. Fanning and Hickel [5] provide the most rigorous recent framework, calculating that over-emitting countries owe approximately $192 trillion globally by 2050 in compensation for atmospheric appropriation, with the Global North responsible for approximately $170 trillion. This represents not merely a political aspiration but a quantifiable consequence of the occupation of atmospheric commons without permission or compensation.

Third, political economy of climate finance. Drawing on public choice theory [16], this framework explains why rational self-interest of key actors; donor governments facing electoral pressures, international financial institutions prioritising risk-aversion, and domestic political elites preferring visible patronage projects, systematically produces suboptimal outcomes in loss and damage finance, even when collectively irrational.

1.7. Complementary Synergy and Blended Finance

The complementary synergy paradigm suggests that public finance and private insurance can work together without crowding out private investment [12,17]. Blended finance operationalizes this approach by using public or philanthropic capital to mobilize additional private investment for development purposes [18]. In the loss and damage context, blended finance instruments; including first-loss capital tranches, premium subsidies, and technical assistance facilities, can catalyse private insurance engagement in contexts where pure market solutions are insufficient. For Iran, where sanctions prevent engagement with Western reinsurers, blended finance structures channelled through FRLD

grants offer the most viable pathway for attracting domestic insurance capital into the climate risk transfer market.

1.8. Literature Review

1.8.1. The Legal Stream: A Legacy of Broken Promises

The journey of loss and damage in international law is a textbook case of political delay and diluted ambition. In Phase I (1992–2009), the UNFCCC paid lip service to the concept but deliberately sidestepped any operational teeth, refusing to create funding or clear pathways for action [19]. Wealthy, high-emitting nations actively blocked every attempt to hold them accountable for their historical emissions, even torpedoing AOSIS's modest 1991 proposal for an insurance pool [20].

Phase II (2010–2021) offered more rhetoric but little relief. While Cancun and the Warsaw Mechanism (COP19) finally created a home for the issue, the WIM was deliberately handicapped as a mere talking-shop for technical advice. The Paris Agreement's Article 8 at COP21 was a symbolic victory, but the fine print was a devastating betrayal, explicitly ruling out liability and compensation. This caveat rendered the recognition largely performative, ensuring that vulnerable nations got a mention in the treaty but not a penny in reparations [20].

Phase III (2022–present) marked the establishment of the FRLD at COP27, a long-awaited institutional breakthrough that finally translated decades of political advocacy into a dedicated funding vehicle. Yet this breakthrough arrived only after thirty years of delay, a delay during which climate impacts had already escalated beyond the adaptive capacity of many vulnerable nations. While the fund's governance structure began taking shape, and pledges surpassed $700 million by COP28, this aggregate figure obscures a critical caveat: the mix of grants and concessional loans signals that the principle of grant-based, non-debt-creating reparation, so central to AOSIS's original vision, remains only partially realized [21]. At COP30 in Belém, the adoption of the Barbados Implementation Modalities (BIM) and the launch of the first funding call (December 2025 – June 2026) suggested operational momentum. However, the modest $250 million initial allocation, dispersed as $5–20 million project grants, is starkly disproportionate to the escalating, irreversible losses already overwhelming frontline communities [22]. The legal stream has thus entered a new chapter, one of institutional existence rather than mere recognition, yet the underlying tensions that constrained Phases I and II persist: liability remains excluded, compensation remains taboo, and the financial resources committed remain far removed from the scale of actual need.

1.8.2. The Technical-Financial Stream

Climate-related loss and damage can be understood economically as a classic market failure. Emissions impose costs that are not fully reflected in prices, investment in climate resilience remains insufficient, and the global climate system is treated as a resource that can be overexploited. The result is inadequate investment in mitigation and adaptation and, ultimately, no effective market mechanism for compensating unavoidable damages. Instruments such as parametric insurance, catastrophe bonds, and weather derivatives can help address parts of this problem, but they operate within the same market structures that created it. They can therefore complement, but not replace, public finance grounded in justice and historical responsibility [3,5].

Parametric and Index-Based Insurance: Parametric insurance pays out based on the confirmation of pre-defined physical or meteorological parameters, rather than post-event damage assessment. Carter et al. [23] provide a comprehensive review documenting both the potential; particularly rapid payout mechanisms (24-72 hours post-trigger) that prevent distress sales of productive assets, and the principal limitation: basis risk (the gap between what the index measures and actual farm-level losses).

Catastrophe Bonds: Catastrophe bonds offer a mechanism for transferring major risks from insurers or governments to capital market investors [24]. Biffis and Blake [25] demonstrate their efficiency for high-impact, low-probability risks. According to Swiss Re Institute (2023), the global catastrophe bond market exceeded $45 billion in outstanding issuance by end-2023; a record level driven partly by growing recognition of climate tail risks.

Weather Derivatives: Weather derivatives enable firms and governments to manage risks associated with income variability due to unpredictable weather patterns [27]. Unlike traditional insurance, weather derivatives pay out for deviations from normal meteorological conditions irrespective of demonstrable physical damage; making them particularly relevant for agricultural systems exposed to rainfall variability.

1.9. Comparative Cases

1.9.1. The Nagaland Model (India): Sub-National Sovereignty and Adaptive Learning

The Nagaland case presents the most directly transferable institutional framework for the Khuzestan pilot, precisely because it embodies the principles of sub-national sovereignty and iterative learning. The initial iteration, a parametric insurance scheme operational between 2018 and 2020, proved entirely ineffective due to improperly calibrated triggers and deficient meteorological data, resulting in zero payouts even as farm-level losses mounted. In response, the Nagaland State Disaster Management Authority (NSDMA) executed a comprehensive overhaul, central to which was the reclamation of sovereign authority over trigger design, a critical institutional innovation [28]. The resultant Disaster Risk Transfer Parametric Insurance Solution (DRTPS) integrates gridded rainfall data from the India Meteorological Department (IMD) alongside a dense network of 34 automated weather stations. This redesigned system demonstrated its viability in March 2025, disbursing its inaugural payout of ₹1.06 crore (approx. $117,000) for the 2024 monsoon season, against an annual premium of ₹4.5 crore covering up to ₹50 crore [28]. The Nagaland experience underscores that institutional failure is not terminal but can be transformed into a strategic asset where adaptive management frameworks are institutionally embedded.

1.9.2. The CCRIF Model (Caribbean): Regional Risk Pooling

Beyond its technical apparatus, the CCRIF's longevity reveals a complex governance compromise among 22 sovereign states, each ceding a degree of fiscal autonomy to a centralized pooling facility. This political cooperation, cultivated over 17 years since the fund's 2007 establishment, enabled the coordinated response to Hurricane Beryl in July 2024, with $85.4 million disbursed across five jurisdictions to offset damages that reached $230 million in Saint Vincent and the Grenadines and $219 million in Grenada [29,30]. The fund's governance model demonstrates that regional risk pooling can transcend national boundaries when institutional trust is built. However, this governance architecture is underwritten by external patronage from the World Bank and operational integration with Western reinsurers. For Iran, the absence of such geopolitical intermediaries and the impossibility of similar financial integration make the CCRIF's governance model instructive in principle but institutionally unattainable in practice.

1.9.3. The African Risk Capacity Model: Transferability Under Constraints

The African Risk Capacity (ARC), established under African Union auspices in 2012 and operational since 2014, offers a more directly relevant comparator for Iran's institutional context. Unlike CCRIF, ARC was designed explicitly for lower-capacity national settings where Western reinsurer engagement is limited and institutional trust is fragile. ARC uses the Africa RiskView satellite model; based on CHIRPS precipitation data, to trigger drought payouts within 30 days of a qualifying event, without post-event loss assessments. As of 2023, ARC covered 22 member states and had paid out over $112 million to seven countries [31,32]. The ARC model demonstrates that the CHIRPS-based satellite trigger approach proposed for Khuzestan has a proven track record in analogous institutional contexts, and that regional risk pooling is achievable without dependence on Western financial infrastructure.

The preceding review reveals a significant synthesis gap in the existing literature. The political-legal stream has developed sophisticated normative frameworks but has largely neglected the economic and operational dimensions of financial architecture. The technical-financial stream has produced valuable innovation in instrument design but has insufficiently engaged with the political economy constraints; particularly geopolitical factors such as sanctions and data nationalism, that determine feasibility in specific contexts. This study addresses this gap by integrating economic analysis (including the discount rate debate), justice theory, non-economic loss and damage, blended finance, and geopolitical realism into a unified framework.

2. Method

The research design is qualitative, employing systematic documentary analysis in accordance [33]. The evidence base is divided into primary and secondary sources. Primary sources comprise UNFCCC agreements and COP decisions from COP16 to COP30, FRLD governance documents (including Board decisions, the Barbados Implementation Modalities, and funding guidelines), and policy reports from the World Bank, UNDP, UNEP, and OCHA. Secondary sources consist of peer-reviewed academic literature covering climate policy, parametric insurance, political economy, and hydropolitics. All documents are analyzed for their substantive content, institutional context, and inter-textual relationships.

The comparative analysis follows the 'most similar systems' design [34], selecting cases that share key characteristics (climate vulnerability, developing country status, exposure to extreme events) but differ on the independent variable of interest; institutional enabling conditions for parametric insurance. By comparing Nagaland (strong sub-national enabling conditions), CCRIF (very strong regional enabling conditions), and ARC (moderate enabling conditions in lower-capacity contexts), the analysis identifies which institutional factors are necessary for successful implementation in Iran's constrained environment. The ARC case replaces the Iran/West Asia context as a comparator column in Table 1 to sharpen the analytical contrast.

Document coding was executed as a two-cycle analytical process. The first cycle was descriptive in nature, with codes assigned against a pre-structured frame corresponding to the study's three analytical objects: the legal-historical trajectory of loss and damage governance; the multi-layered barriers to parametric insurance (macroeconomic, institutional/data, and geopolitical); and the design specifications for a sub-national pilot. This initial coding phase produced a granular inventory of discrete observations across all source materials. The second cycle involved a higher-order consolidation, wherein the descriptive codes were synthesized into pattern-level categories, which are presented in Sections 5 and 7. For instance, the institutional and data barriers category in Section 5.2 was constructed by aggregating codes related to inter-ministerial data fragmentation, meteorological infrastructure decay, and

resistance to transparency, with each code independently corroborated by Hamzeh et al. [35], and Bilgen [36], Kardan Moghaddam et al. [37]. In instances of scholarly disagreement, such as divergent assessments of satellite-based trigger feasibility in data-poor environments, the conservative estimate was adopted and the interpretive tension is noted in the text. The same coding protocol was deployed across the three comparative cases to generate Table 1, with all six comparative criteria extracted via an identical analytical routine to ensure cross-case comparability.

The research analysis proceeds in three phases. First, it traces the historical development of the loss and damage regime. Second, it critically evaluates systemic barriers to implementation. Third, it synthesises these findings to propose a context-specific pilot design validated against international models.

A key methodological limitation is the unavailability of comprehensive, disaggregated data on climate losses in Iran. A secondary limitation is the qualitative nature of the study, which does not permit causal inference in a strict econometric sense. Where quantitative estimates are used, their sources and limitations are clearly identified, and ranges are provided where available.

2.1. Systemic Barriers to Operationalising Climate Insurance in Iran and West Asia

Despite the technical promise of innovative insurance instruments and the demonstrated success of models such as Nagaland, CCRIF, and ARC, their operationalisation in Iran and West Asia confronts formidable barriers. Table 1 provides a comparative analysis of enabling conditions. The ARC model is included as the most institutionally analogous international comparator.

Table 1. Comparative Enabling Conditions for Parametric Insurance; Nagaland, CCRIF, and ARC vs. Iran/West Asia

Criterion	Nagaland, India	CCRIF SPC	African Risk Capacity (ARC)
Institutional Capacity	High: NSDMA redesigned after failed 2018–2020 pilot; full sovereign control over triggers	High: Independent non-profit governance; professional committees; transparent audit	Moderate: African Union political backing; calibrated to lower-capacity contexts; 22 member states as of 2023
Data Quality & Transparency	High: IMD gridded rainfall; 34 automated stations; third-party validation	High: Transparent catastrophe models; satellite + local data fusion	Moderate-High: CHIRPS + satellite-based triggers; independent model validation by WFP; some data gaps in Sahel
Insurance Market Access	High: Competitive bidding; Munich Re reinsurance; SBI General Insurance	High: World Bank technical/financial support since 2007; global reinsurance access	Moderate: AU backstop capital; reinsurance via African market; not dependent on Western reinsurers
Risk Profile Homogeneity	N/A (single-state, locally calibrated)	High: Similar cyclone/earthquake/excess-rainfall risk across 22 SIDS	Moderate: Drought-focused; some regional variance; sovereign pooling enables diversification
Political Alignment & Trust	High: State-controlled digital payments; demonstrated payout in 2025	High: Payments linked to national response plans; 17-year track record	Moderate: AU integration reduces donor dependency; WFP co-management provides credibility; slower payouts than CCRIF (30 days)
Iran/West Asia Transferability	High for sub-national pilot design; requires adaptation for sanctions context	Low: Requires Western reinsurer access; blocked by sanctions	Moderate: Model for AU-like regional pooling; template for non-Western institutional anchoring

Source: Refs [28,30-32,35,37,38]

2.2. Macroeconomic Barriers

Structural Deficiencies in Climate Risk Underwriting: Hamzeh et al. (2024), in a rigorous survey of 35 insurance professionals in Iran, conclude that while some firms recognise climate risk in their operations, none have formal strategies for evaluating and reducing greenhouse gas emissions, assessing climate risks systematically, providing climate-aligned incentives, or deploying actuarial climate risk models. The industry's overall strategy remains one of annual re-pricing; a reactive approach wholly inadequate for the non-stationary risk profiles that characterise a changing climate.

Inflation and Currency Volatility: High inflation rates in Iran (exceeding 40% in recent years) and severe currency depreciation have exponentially increased reconstruction costs and created fundamental challenges for insurance contract valuation denominated in domestic currency. This macroeconomic instability creates a fundamental mismatch between the long-term risk horizons that effective parametric insurance requires and the short-term financial planning horizons that Iran's economic environment imposes.

Sanctions and Financial Isolation: International sanctions severely restrict Iran's access to global insurance and reinsurance markets. Major international reinsurers including Munich Re and Swiss Re cannot conduct business in USD or EUR with Iranian entities under applicable sanctions regimes. This effectively prevents Iran from accessing the reinsurance backstops that underpin successful parametric insurance models in Nagaland and the Caribbean. The ARC model; which uses African Union institutional anchoring and CHIRPS-based satellite triggers rather than Western reinsurance relationships; offers the most viable institutional template for Iran.

2.3. Institutional and Data Barriers

The institutional and data barriers confronting parametric insurance in Iran stand in sharp contrast to the conditions observed in the comparative cases, particularly Nagaland and CCRIF. At the infrastructural level, Kardan Moghaddam et al. [37] document a meteorological observation system in advanced decay, characterized by aging equipment, irregular maintenance, and inadequate highland monitoring. This physical deficit is compounded by a pronounced institutional fragmentation, with hydrological data siloed across the Ministry of Energy, the Iran Meteorological Organization, and the Ministry of Agriculture, none of which operates a standardised or integrated data platform.

This fragmentation mirrors the institutional competition observed in Nagaland's first insurance failure, though the Indian state ultimately reclaimed sovereign control over trigger design. In Iran, however, information asymmetries serve entrenched bureaucratic interests, creating political resistance to the transparency that parametric insurance requires. The 'transparency paradox' identified here, where satellite data offers a technical solution yet generates state resistance, finds a parallel in Bilgen's [36] analysis of the Euphrates-Tigris basin, where open-source data challenged official narratives. Unlike the CCRIF context, where data sharing is institutionalised across Caribbean member states, Iran's fragmented data landscape constitutes a fundamental barrier to the operationalisation of parametric insurance.

2.4. Geopolitical Barriers

Parametric insurance delivers value only when beneficiaries trust that disbursements will arrive automatically upon trigger confirmation, without political interference or bureaucratic delay. In Iran's economic landscape, marked by unfulfilled policy commitments, subsidy removals, currency collapse, and pervasive institutional scepticism, such confidence is conspicuously absent.

On the regional front, Hasan et al. [39], in their study of transboundary water cooperation in the Tigris-Euphrates and Indus basins, identify 'data nationalism'; the strategic withholding of hydrological information, as a persistent barrier to cooperation. Bilgen [36] similarly demonstrates that even where open-source satellite data provides an alternative to disputed official data, riparian states resist the political implications of transparent hydrological accounting. This resistance is particularly acute in the Karkheh basin, whose hydrological data is classified at the national security level in both Iran and Iraq.

2.5. A Realistic Pathway: The Climate Economics of a Sub-National Pilot

The preceding analysis establishes, with empirical grounding, the significant institutional, technical, political, and financial obstacles that render large-scale national or regional insurance architectures infeasible in Iran in the near term. This section therefore proposes a contained and manageable sub-national pilot in Khuzestan province, conceptualised as a 'reality laboratory'; a small-scale, learning-intensive intervention designed to test technical feasibility, build institutional capacity, and generate evidence under real-world constraints.

3. Results and Discussion

3.1. The Economic Case for a Pilot Approach

Learning-by-doing and adaptive management. As Linnerooth-Bayer and Mechler [8] demonstrate, effective climate risk management at scale must be built on validated local-level interventions. Hamzeh et al. [35] document the Iranian insurance sector's systematic absence of climate risk expertise, which means any large-scale scheme would be built on untested assumptions. The Nagaland case powerfully illustrates the principle: the successful 2025 scheme was the direct product of a failed 2018–2020 pilot that generated the learning necessary for redesign.

Cost-effectiveness and risk reduction. The Stern Review [3] established that early investment in climate risk management is far more cost-effective than delayed response. Weitzman's [4] discount rate analysis reinforces this finding: under realistic uncertainty about extreme outcomes, the near-zero effective discount rate for catastrophic risks makes even expensive early interventions economically rational. A pilot approach allows for testing and refinement at relatively low cost before large-scale rollout.

Building trust through demonstrated performance. Trust in institutional performance is built through track records of delivery, not through promises. Even one or two triggered payouts made transparently and on time would generate more institutional trust than any communication campaign. This principle; central to the ARC model's success in analogous African institutional contexts, is directly applicable to Khuzestan's trust-deficient environment.

3.2. Khuzestan as the Optimal Pilot Location

Drawing on the lessons from Nagaland, CCRIF, and ARC, Khuzestan emerges as the most analytically appropriate site for a parametric insurance pilot within Iran. The province's compound climate risk profile, including the 2019 floods, persistent drought, and escalating sand and dust storms [40], mirrors the climate vulnerabilities that motivated the Nagaland redesign and the Caribbean pooling model.

The predominance of climate-sensitive smallholder agriculture, dependent on the Karkheh and Karun river basins for sugarcane, wheat, rice, and date production [41], establishes a clear demand signal for risk transfer instruments. Institutionally, Khuzestan offers assets that parallel the Nagaland case, including local universities (Shahid Chamran University, Jundishapur University) and international partnerships forged through wetland restoration. These provide the academic and institutional partnerships necessary for rigorous implementation and evaluation.

The implementation challenges identified in Khuzestan, limited financial literacy, low institutional trust, and restricted digital access, are consistent with those encountered in Nagaland's first insurance failure, and the pilot design draws directly on Nagaland's adaptive learning by prioritising trust-building through local intermediaries, simplified communications, and diversified disbursement channels. The grievance mechanism, with escalation to an independent university audit unit, adds a layer of accountability that addresses concerns identified in the ARC and CCRIF governance models. Khuzestan thus represents a demanding but instructive site for applying the comparative lessons.

3.3. Pilot Design: Parameters and Architecture

Table 2. Khuzestan Parametric Insurance Pilot, Design Specifications

Component	Design Specification
Target Population	Smallholder farmers and agro-pastoral households in high-vulnerability Khuzestan districts (Ahvaz, Shadegan, Hoveyzeh sub-basins)
Parametric Triggers	Primary: CHIRPS satellite rainfall anomaly index (≥1.5 SD below 30-year mean); Secondary: MODIS-derived NDVI vegetation stress indicator; Tertiary: local WMO-standard station data where available
Premium Structure	Years 1–2 (Testing Phase): 100% premium subsidy via FRLD grant; Years 3–4 (Transboundary Phase): 50% subsidy with co-financing from Iran's National Disaster Risk Management Organisation (NDRMO) and Iraqi counterpart
Validation & Audit	Demonstration payments; digital + offline disbursement channels; public trigger logs; independent annual audit (Shahid Chamran University of Ahvaz, accessible grievance mechanism through agricultural cooperatives
Implementation Partners	Lead: Central Insurance of Iran (Bimeh Markazi); Co-implementers: provincial agricultural cooperatives, Shahid Chamran University; Technical Oversight: UNDP Iran Country Office
FRLD Alignment	Qualifies under BIM Grant Window ($5–20 million); addresses FRLD priorities: data deficit reduction, national response plan strengthening, direct access capacity-building; gender-disaggregated beneficiary registration required
NELD Integration	Pilot explicitly tracks non-economic loss and damage (NELD) indicators: cultural heritage loss, identity displacement of Ahwazi Arab and Ma'dan communities, biodiversity loss indicators in Hor al-Azim wetland (Serdeczny 2019)

Source: Refs [22,28,30,31]

Table 3. Phased Implementation Timeline, Khuzestan Pilot (Years 1–4)

Year	Phase	Activities	Key Outputs
1	**Launch & Feasibility**	Trigger calibration workshops; farmer registration; data infrastructure audit; gender-disaggregated baseline survey; community awareness through local intermediaries	Calibrated CHIRPS/MODIS triggers; enrolled beneficiary registry; data quality report; NELD baseline; first independent audit
2	**Consolidation & Testing**	Refine trigger design; quantify basis risk; real-time payout test (if triggered); beneficiary satisfaction survey disaggregated by gender; blended finance mobilisation assessment	Basis risk assessment report; payout demonstration (if event occurs); trust and uptake evidence base; blended finance feasibility report
3	**Transboundary Preparation**	Bilateral protocol with Iraq (Maysan); harmonise trigger definitions; cross-border academic collaboration; historical trigger validation; ARC institutional benchmarking mission	Iran–Iraq Governance MOU; joint trigger calibration report; Khuzestan–Maysan historical loss dataset; ARC comparison report
4	**Bilateral Coverage & Evaluation**	Real-time bilateral coverage; joint payout operations; comprehensive M&E; NELD final assessment; scaling evidence package for FRLD Board	Cross-border payout records; cost-effectiveness analysis; FRLD scaling proposal; gender equity assessment; policy brief for COP31

3.4. The Transboundary Extension: Khuzestan–Maysan

The geographical proximity of Khuzestan (Iran) and Maysan (Iraq) along the Hor al-Azim / Hawizeh shared wetland creates a unique opportunity for piloting bilateral parametric insurance cooperation; potentially the first such scheme in the Tigris-Euphrates-Karkheh basin. The shared environmental challenges, drought, wetland degradation, biodiversity loss, and dust storms, create an objective basis for cooperation that transcends political differences.

From an economic perspective, the transboundary extension offers three advantages: economies of scale and risk pooling consistent with the CCRIF and ARC models; a demonstration effect for regional climate cooperation; and data independence through reliance on CHIRPS and MODIS satellite data that bypasses the data nationalism identified by Hasan et al. [39] and Bilgen [36] as a persistent barrier to transboundary cooperation in this basin.

3.5. Financing the Pilot: The FRLD and Blended Finance Opportunity

The FRLD launched its first call for funding applications in December 2025 under the BIM, with a submission window running to mid-June 2026. The initial allocation of $250 million supports grants of $5–20 million per project [22]. The FRLD's mandate explicitly includes 'addressing insufficient climate information and data' and 'supporting national response plans', both directly relevant to the proposed pilot.

Beyond the FRLD grant, the pilot's design explicitly incorporates a blended finance escalation pathway [18]: Year 1–2 FRLD grant funding builds the evidence base; Year 3–4 co-financing from Iran's NDRMO and Iraqi counterpart introduces domestic public capital; Year 5+ seeks to attract domestic private insurance capital on the basis of the established track record. This blended finance sequencing, public grant to public co-finance to private capital; mirrors the trajectory of the CCRIF model and is consistent with Mechler et al.'s [17] demonstration of how public capital can crowd in private engagement over time.

3.6 Implementation Risks and Mitigation

The pilot design outlined above depends for its credibility on managing risk categories endemic to Khuzestan's institutional environment. Each is addressed explicitly below rather than assumed away, extending the barriers identified in Section 5 into concrete design responses.

Inter-Agency Data Conflict: Section 5.2 documents that hydrological and meteorological data in Iran is fragmented across the Ministry of Energy, the Iran Meteorological Organization, and the Ministry of Agriculture, each maintaining parallel, non-synthesised datasets. Left unaddressed, this fragmentation could allow a competing agency to contest trigger confirmations after the fact, undermining payout legitimacy. The pilot mitigates this risk structurally rather than procedurally: the primary and secondary triggers in Table 2 rely exclusively on independent, third-party-validated satellite indices (CHIRPS rainfall anomaly and MODIS-derived NDVI), not on any single domestic agency's dataset. Domestic agency data is used only as a tertiary, supplementary input, and is explicitly subordinated to the satellite triggers in the governance protocol. Trigger confirmations and payout logs are published publicly and on a fixed schedule, independent of any single ministry, so that no agency can unilaterally delay or dispute a payout after the fact.

Last-Mile Digital Access: Smallholder and agro-pastoral households in Khuzestan's tribal areas, including Ahwazi Arab and Ma'dan marsh-dwelling communities, may lack smartphone connectivity or formal banking access, risking exclusion from a purely digital disbursement channel. The Year 1 baseline survey (Table 3) is designed to identify which households require non-digital channels before disbursement design is finalised, and the pilot combines digital transfers with cash-based disbursement through agricultural cooperatives as a standing parallel channel rather than a fallback. Local intermediaries, cooperative heads, tribal elders, and religious leaders, are engaged as trusted facilitators for both enrolment and disbursement, consistent with the community-based awareness strategy described in Section 6.2.

3.7. Institutional and Political Capture

The risk of politicised delay in trigger confirmation, associated with the concentration of authority in Central Insurance of Iran (Bimeh Markazi), mirrors the governance vulnerabilities observed in Nagaland's first parametric insurance failure, where lack of independent oversight contributed to the scheme's collapse. The Khuzestan pilot addresses this by adopting a separation of powers model. The independent audit function at Shahid Chamran University of Ahvaz parallels the institutional innovation in Nagaland, where the NSDMA reclaimed sovereign control over trigger design. External oversight from the UNDP Iran Country Office provides accountability similar to the multilateral monitoring mechanisms embedded in the CCRIF structure. The grievance escalation pathway to the university audit unit, rather than back to the implementing agency, ensures that no single actor controls both delivery and adjudication, a principle that has been critical to the CCRIF's long-term credibility.

3.8. Currency and Premium-Repricing Risk

The inflation risk confronting the Khuzestan pilot, with rates exceeding 40%, has no direct parallel in the Caribbean or African contexts, but the adaptive management approach adopted here reflects the Nagaland principle of iterative learning. The phased subsidy structure, reassessed annually against inflation

data, mirrors the flexibility that enabled Nagaland's redesign after the initial failure.

3.9. Transboundary Contingency

The transboundary dependency on bilateral political conditions and classified hydrological data introduces a geopolitical vulnerability absent from the CCRIF and ARC cases. The pilot's decision to schedule the transboundary component as Phases 3 and 4 of Table 3, rather than a Year 1 or 2 dependency, ensures that the core Khuzestan pilot remains evaluable on its own terms, following the Nagaland precedent of securing the domestic institutional foundation before pursuing regional integration.

3.10. Triple Failure of the Current Financial Architecture

The foregoing analysis grounds a diagnosis of the global loss and damage financial architecture as exhibiting a 'triple failure', not accidental but structural, not temporary but embedded in the political economy of international climate finance.

Table 4. The Triple Failure, Manifestations and Evidence

Failure Type	Manifestation	Evidence
Allocative Failure	Inability to direct financial resources to areas of greatest need and highest vulnerability	Total FRLD commitments (~$814M) = <0.2% of estimated annual needs ($395B); funding gap exceeds 90% across all vulnerable country categories [6]
Distributive Failure	Imposition of financial burdens on the most vulnerable through loan-dominated structures; systematic neglect of gendered and non-economic losses	Dominance of concessional loans over grants transforms climate compensation into sovereign debt; NELD—including cultural heritage loss, displacement, and gendered time-use burdens—systematically excluded from compensation frameworks [9]
Sustainability Failure	Inability to create stable, predictable, long-term financial flows for climate resilience investment	Current model relies on voluntary annual contributions subject to political cycles; FRLD risks exhausting reserves by 2027 without major replenishment; no mandatory levy mechanism exists [6]

Source: Refs [3,4,9,35,36]

The distributive failure dimension deserves particular attention in the Iranian context. Women in rural Khuzestan and across West Asia bear a disproportionate burden of climate-related tasks; water and fuel collection, agricultural labour, and household food security, roles that make them particularly vulnerable to drought, flood, and extreme heat (UN Women & DESA 2024). Yet existing compensation mechanisms almost exclusively focus on measurable household income losses while entirely neglecting gendered time-use burdens, health impacts, and reduced agency. Any genuinely equitable loss and damage mechanism must disaggregate impact assessments by gender and incorporate women's participation as a conditionality for project approval. The economic case for transformation is clear. Fanning and Hickel [3] demonstrate that the $170 trillion compensation obligation borne by the Global North is a quantifiable consequence of atmospheric appropriation; the occupation of atmospheric commons without permission or compensation. The polluter pays principle, as a foundational economic instrument, provides the theoretical basis for mandatory contribution mechanisms. Just 0.08% of GDP from developed economies, approximately $60 billion annually, would transform the current paradigm of voluntary insufficiency into one of structured, predictable, and adequate support.

4. Conclusion

This study has critically examined the climate economics of loss and damage with particular focus on Iran and West Asia. The analysis yields several interrelated conclusions. First, the current financial architecture suffers from a structural triple failure that is not a resource problem but a political choice. Second, the economic case for transformation is robust: early action is cheaper, compensation obligations are quantifiable, and the barriers are political rather than financial. Third, for Iran and West Asia, the path to transformation must pass through incremental, evidence-generating sub-national pilots. Fourth, the integration of NELD, gender equity, and blended finance into pilot design is not optional, it is required for alignment with FRLD principles and for genuine compliance with Schlosberg's [7] tripartite justice framework.

4.1. Policy Recommendations For the International Community

A transition from voluntary contributions to mandatory assessed contributions; based on historical emissions and current economic capacity, is recommended to operationalise the polluter pays principle, with reference to Fanning and Hickel's [3] quantified compensation obligations.

The establishment of innovative international financing mechanisms is also warranted, including global solidarity levies on shipping, aviation, and fossil fuel extraction, to generate stable, predictable, and adequate flows for the FRLD, consistent with Weitzman's [12] finding that catastrophic climate risks warrant near-zero discount rates.

Reform of FRLD governance structures is further indicated to eliminate effective donor veto power, ensure meaningful participation of recipient countries in fund governance, and prioritise grant-based over loan-based instruments.

Specific provisions for sanctions-affected countries; including FRLD-to-country direct transfer mechanisms that do not pass through sanctioned financial systems, should be developed to prevent political constraints from compounding climate injustice.

Finally, the mandatory tracking of NELD and gender-disaggregated impact assessments is recommended as a condition for all FRLD project approvals, recognising that distributive justice requires addressing non-economic and gendered harms [9]. The development of a National Loss and Damage Strategy integrated into national development planning is recommended, with the establishment of a dedicated institutional unit with the mandate and capacity to access international climate finance.

Investment in meteorological and hydrological data infrastructure; specifically the calibration and maintenance of CHIRPS-compatible ground-truth stations, is identified as a prerequisite for any parametric instrument.

The Khuzestan pilot should be pursued as a strategic institutional priority, leveraging the FRLD's BIM funding window (December 2025–June 2026) and building on existing partnerships with Shahid Chamran University, and UNDP.

Greater transparency in climate risk governance is also recommended, recognising that institutional opacity is not only ethically problematic but economically costly, as it systematically blocks access to international financial instruments that require transparent data.

Finally, gender-sensitive mechanisms should be embedded in pilot design, including women's participation in community awareness campaigns, gender-disaggregated beneficiary registration, and dedicated women's access channels for grievance mechanisms.The Khuzestan–Maysan transboundary pilot is worth exploring as a trust-building mechanism, building on the shared Hor al-Azim / Hawizeh wetland governance framework and the precedent of the FRLD/BIM joint Iran-Iraq funding application.

Shared data protocols using CHIRPS and MODIS satellite data should be developed to bypass data nationalism and the institutional barriers to bilateral hydrological data-sharing documented by Hasan et al. [39] and Bilgen [36].

Engagement with UNDP and UNFCCC regional offices as neutral facilitators for bilateral climate finance cooperation is also recommended.

An ARC-style regional risk pooling architecture for West Asia is suggested as a longer-term institutional goal.

The climate crisis in Iran and West Asia is escalating at an accelerating pace, with compounding hazards including drought, flood, extreme heat, and sand and dust storms imposing mounting costs on vulnerable populations and fragile ecosystems. The technical tools necessary for effective climate risk management exist. The financial instruments, including parametric insurance and regional risk pooling, are proven in diverse contexts. The institutional designs are available for adaptation, as demonstrated by the Nagaland, CCRIF, and ARC case studies. What is lacking is not technical capacity or financial resources globally speaking, but political will. Specifically, what is required is the willingness to acknowledge historical responsibility for greenhouse gas emissions, to redistribute power and financial resources toward those who bear the least responsibility but the greatest burden, and to move from voluntary humanitarian assistance to mandatory fiscal justice as a matter of international obligation.

The Khuzestan pilot represents a practical first step toward this transformation. It constitutes a learning laboratory that can demonstrate whether a different approach is possible, one grounded in economic efficiency, fiscal justice, recognition of non-economic loss, gender equity, and genuine solidarity with the most vulnerable populations on the frontlines of climate change. The analytical and empirical foundations for that transformation exist, as this study has documented across its legal, institutional, and comparative dimensions. The time for their political operationalisation is now, before the window of opportunity closes and the costs of inaction become irreversibly catastrophic.

Author Contributions

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Conflict of Interest

The authors, while observing publication ethics in the referencing, declare the absence of interest of conflict.

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