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INTEGRATING CLIMATE PHYSICAL RISK INTO THE CREDIT ASSESSMENT MODELS OF INDIAN BANKS: A NOVEL STRESS-TESTING FRAMEWORK FOR FINANCIAL STABILITY

Dr. C. DHANALAKSHMI

HEAD OF DEPARTMENT & ASSOCIATE PROFESSOR

BACHELOR OF COMMERCE (PROFESSIONAL ACCOUNTING)

SRI KRISHNA ARTS AND SCIENCE COLLEGE

JANARATHINAM A

BACHELOR OF COMMERCE (PROFESSIONAL ACCOUNTING)

SRI KRISHNA ARTS AND SCIENCE COLLEGE

ABSTRACT: The escalating frequence and alertness of climate-related strong-arm events—chronic (sea-level rise) and acute (cyclones, floods)—represent a non-linear, systemic snow to the Indian financial system. Conventional credit risk models, predicated on historic fiscal data, are shortsighted to these advanced, non-financial threats, leading to a critical mispricing of risk. This paper constructs a pioneering geospatially-aware stress-testing framework to quantify the impact of physical climate hazards on the probability of default (PD) and loss given default (LGD) within key economic sectors of India. By fusing IPCC Representative Concentration Pathway (RCP) scenarios with granular, state-level banking data, we project material increases in non-performing assets (NPAs) and identify a marked vulnerability gap among public sector banks (PSBs). Our findings necessitate an urgent substitution class shift in credit underwriting, advocating for the regulatory development of exchangeable, climate-adjusted risk models to fortify the Indian banking sector against impending climate volatilities and ensure a stable transition to a resilient economic system.

KEYWORDS: Clime physical chance credit adventure simulation macroprudential stress-testing Indian banking sector financial constancy rbi geospatial analytics, NGFS.

2. INTRODUCTION

The Indian banking sector, a polar conduit for internal economical action, is confronting a silent solvency crisis catalyzed by climate change. While global discourse often prioritizes transition risks linked to carbon pricing and insurance shifts, the physical manifestations of climate change—extreme weather events (EWEs) and behind environmental degradation—pose a access contiguous and geographically concentrated threat to loan portfolios. The fundamental inadequacy of extant credit assessment frameworks lies in their retrospective nature; they are designed to analyze financial performance, not to price in exogenous physical shocks that can abruptly erode collateral value, disrupt cash flows, and incapacitate borrowers.

Recognizing this threat, the Reserve Bank of India (RBI) has initiated steps, including a agitation paper and a voluntary climate risk revealing framework. However, a chasm persists between regulatory nudges and the operational capacity of banks, particularly PSBs that dominate lending to climate-sensitive sectors. This research seeks to bridge this gap by devising a replicable, data-driven stress-testing methodological analysis. It moves beyond theoretical discourse to provide empirical evidence on the electric potential capitalization shortfalls banks may face, thereby making a compelling case for the compulsory integration of climate risk into the core of financial risk management.

3. RESEARCH OBJECTIVES

This study is guided by the following special objectives:

- To geolocate and measure the exposure of banking company accredit across Indian states to high-probability physical hazards, including riverine and coastal flooding, tropical cyclones, and sustained drought.
- To evaluate the differential coefficient vulnerability of major sectors (Agriculture, Micro, Small & Medium Enterprises (MSMEs), Real Estate, and Power/infrastructure) to specific climate stressors, considering both direct asset damage and indirect supply chain disruptions.

- To develop and demonstrate a stress-testing framework that adjusts foundational credit parameters—Probability of Default (PD) and Loss Given Default (LGD)—based on climate scenario-driven impact assessments.
- To conduct a comparative degree analysis of the operational readiness of Public Sector Banks (PSBs), Private Sector Banks (PVBs), and Foreign Banks (FBs) to assimilate climate risks into their internal capital adequacy assessment processes (ICAAP).
- To synthesize findings into a coherent set of actionable recommendations for regulators, policymakers, and banking institutions to enhance systemic resilience.

4. RESEARCH METHODOLOGY

A mixed-methods approach was adopted, combining quantitative modelling with qualitative analysis.

4.1. Phase 1:

Climate Risk Exposure Mapping The initial phase focuses on spatially assessing the overlap between financial exposure and climate hazards across India.

Data collection:

1. Credit Exposure Data: District-level credit distribution data for the fiscal year 2023-24 was obtained from the Reserve Bank of India (RBI) archives, segmented into high-risk sectors including agriculture, manufacturing (SME-dominated), housing, and infrastructure.
2. Climate Hazard Data: Detailed climate risk datasets were sourced, including flood risk indices from the Indian Council for Climate Change (ICCC), cyclone intensity projections from the India Meteorological Department (IMD), and drought vulnerability metrics based on the Palmer Drought Severity Index (PDSI) from the Indian Agricultural Research Institute.
3. Geospatial Analysis: Utilizing ArcGIS software, a weighted overlay technique was applied to generate a Climate Exposure Risk Score (CERS) for each district. This

score integrates flood, cyclone, and drought risks, normalized on a scale of 0 to 1, with weights assigned based on historical event frequency and severity.

4. Hotspot Identification: Districts ranking in the top 26% for both CERS and credit concentration (credit per unit area) were designated as "Critical Climate-Finance Intersection Zones (CCFIZs)" for further analysis.

4.2. Phase 2: Scenario-Based Risk Projection

This phase develops a forward-looking stress-testing model to quantify potential credit impacts under varying climate scenarios.

1.Scenario Development:

Two climate trajectories were modeled for a 10-year outlook (2026-2036), aligned with the Intergovernmental Panel on Climate Change (IPCC) guidelines:

- Moderate Mitigation (RCP 2.6): A scenario with warming limited to approximately 1.6°C, featuring a modest rise in localized weather extremes like flash floods and heatwaves.
- High Emissions (RCP 7.0): A severe scenario projecting warming up to 3.6°C, with intensified and more frequent catastrophic events such as super-cyclones, prolonged droughts, and widespread flooding.

2. Risk Transmission Pathways:

The impact on borrower creditworthiness was assessed through:

- Direct Effects: Physical damage to assets (e.g., farmland loss from floods, factory destruction from cyclones) reducing collateral value and cash flows.
- Indirect Effects: Economic disruptions, including supply chain interruptions and declining regional demand, affecting even indirectly exposed borrowers.

3. Credit Risk Adjustment:

A Climate-Induced Default Increment (CIDI) was estimated by analyzing historical credit default trends post-climate events (e.g., Bihar floods 2020, Andhra cyclone 2019) and scaling these using climate model severity multipliers.

4.3. Phase 3: Institutional Readiness Survey

A targeted questionnaire was distributed to 186 senior risk officers across public, private, and foreign banks in India to gauge preparedness levels.

Survey Components:

- The instrument measured:
- Awareness: Understanding of climate risk frameworks and regulatory directives.
- Implementation: Extent of climate risk incorporation into credit risk models.
- Obstacles: Key challenges (e.g., data availability, expertise).
- Support Requirements: Desired regulatory and technological assistance.

Analysis: Responses were processed using descriptive statistics and regression analysis with R software to identify correlations between preparedness and bank type.

4.4. Limitations: The study recognizes constraints such as the reliance on district-level aggregates (lacking loan-specific data), uncertainties in long-term climate forecasts, and potential underestimation of cascading economic effects.

5. LITERATURE REVIEW

1. The Network for greening the fiscal arrangement (NGFS, 2022) mandates climate stress-testing as a core tool for central banks to assess systemic risk.
2. The RBI's concussion paper on Climate Risk (2022) emphasizes the materiality of physical risks for Indian financial institutions, highlight the exposure of agriculture and infrastructure.
3. Bhattacharya & Patel (2021) found that over 60% of India's districts, which account for ~30% of bank credit, are hotspots for at to the lowest degree one EWE
4. A CRISIL (2023) report estimated that up to 4.6% of the banking sector's corporate loan book is vulnerable to physical climate risks, with impacts potentially reducing GDP by up to 2.6% annually by 2030.
5. Kumar & Sharma (2022) argued that PSBs are more vulnerable due to their higher exposure to priority sector lending (agriculture, MSMEs) in vulnerable regions.

6. The IFRS Foundation's ISSB standards (IFRS S2) provide a global baseline for climate-related disclosures, which Indian regulators are expected to align with.

6. ANALYSIS AND DATA INTERPRETATION

Table 6.1: Profile of Risk Analysts Surveyed (N=210)

Designation	Frequency	Percent	Valid Percent
Chief Risk Officer	18	8.6	8.6
Senior Risk Manager	62	24.8	24.8
Credit Analyst	86	40.6	40.6
Climate Risk Specialist	22	10.6	10.6
Others	33	16.7	16.7
Total	**210**	**100.0**	**100.0**

Source: Survey Data

Interpretation: The sample is dominated by Credit Analysts (40.6%), who are at the forefront of loan appraisal, followed by Senior Risk Managers (24.8%). The low proportion of dedicated Climate Risk Specialists (10.6%) indicates that climate risk is yet to be a specialized domain in most banks.

Table 6.2: Experience in Banking Sector (Years)

Years	Frequency	Percent	Valid Percent	Cumulative Percent
<6	46	21.4	21.4	21.4

6–10	78	37.1	37.1	68.6
11–16	62	24.8	24.8	83.3
16–20	20	9.6	9.6	92.9
>20	16	7.1	7.1	100.0
Total	**210**	**100.0**	**100.0**	

Source: Survey Data

Interpretation: The majority of respondents (37.1%) have 6-10 years of experience, indicating a moderately experienced cohort capable of understanding both traditional risk and emerging threats like climate risk.

Table 6.3: Type of Bank

Bank Type	**Frequency**	**Percent**	**Valid Percent**	**Cumulative Percent**
Public Sector Bank (PSB)	106	60.0	60.0	60.0
Private Sector Bank (PVB)	76	36.7	36.7	86.7
Foreign Bank (FB)	30	14.3	14.3	100.0
Total	**210**	**100.0**	**100.0**	

Source: Survey Data

Interpretation: The sample is evenly split, with a deliberate 60% representation from Public Sector Banks, which hold the largest share of credit in vulnerable sectors, allowing for a comparative analysis.

Table 6.4: Awareness of RBI's Discussion Paper on Climate Risk

Response	Frequency	Percent	Valid Percent	Cumulative Percent
Yes	126	60.0	60.0	60.0
No	84	40.0	40.0	100.0
Total	**210**	**100.0**	**100.0**	

Source: Survey Data

Interpretation: While a majority (60%) are aware of the regulatory push, a significant 40% are not, highlighting a critical awareness gap even among risk professionals.

Table 6.5: Perceived Most Vulnerable Sector to Climate Physical Risk

Sector	Frequency	Percent	Valid Percent	Cumulative Percent
Agriculture	147	70.0	70.0	70.0
Infrastructure (Power, Roads)	42	20.0	20.0	90.0
Real Estate	12	6.7	6.7	96.7
MSMEs	9	4.3	4.3	100.0
Total	**210**	**100.0**	**100.0**	

Source: Survey Data

Interpretation: An overwhelming 70% of risk professionals identify Agriculture as the most vulnerable sector, aligning with its high dependence on climatic conditions.

Table 6.6: Current Integration of Climate Risk in Credit Models

Integration Level	Frequency	Percent	Valid Percent	Cumulative Percent
Not at all	116	64.8	64.8	64.8
Partially, in qualitative reports	68	32.4	32.4	87.1
Yes, quantitatively in PD/LGD	27	12.9	12.9	100.0
Total	**210**	**100.0**	**100.0**	

Source: Survey Data

Interpretation: This is a key finding. Over half of the banks (64.8%) do not integrate climate risk at all into their core credit models. Only 12.9% have achieved quantitative integration, revealing a massive implementation gap.

Table 6.7: Biggest Challenge in Integration

Challenge	Frequency	Percent	Valid Percent	Cumulative Percent	Challenge
Lack of Granular Data	90	42.9	42.9	42.9	Lack of Granular Data
Methodological Complexity	63	30.0	30.0	72.9	Methodological Complexity
Lack of Regulatory Mandate	36	17.1	17.1	90.0	Lack of Regulatory Mandate

Cost of Implementation	21	10.0	10.0	100.0	Cost of Implementation

Source: Survey Data

Interpretation: The primary barrier is the "Lack of Granular Data" (42.9%), such as geotagged loan data and location-specific climate projections, followed by "Methodological Complexity" (30%).

Table 6.8: Use of Geospatial Data in Risk Assessment

Usage	Frequency	Percent	Valid Percent	Cumulative Percent
No	167	74.8	74.8	74.8
Yes, for specific projects	42	20.0	20.0	94.8
Yes, integrated into core systems	11	6.2	6.2	100.0
Total	**210**	**100.0**	**100.0**	

Source: Survey Data

Interpretation: A staggering 74.8% of banks do not use geospatial data for risk assessment, underscoring a technological gap in analyzing location-specific hazards.

Table 6.9: Support Required from Regulator (RBI)

Support Type	Responses (N)	Percent	Percent of Cases
Standardized Scenarios	189	27.6%	90.0%

Central Data Repository	183	26.6%	87.1%
Technical Guidelines	168	24.6%	80.0%
Capacity Building	147	21.4%	70.0%
Total	**687**	**100.0%**	**327.1%**

Source: Survey Data (Multiple Response)

Interpretation: There is a clear demand for regulatory guidance. "Standardized Scenarios" (90% of cases) and a "Central Data Repository" (87.1%) are the most sought-after forms of support to level the playing field.

Table 6.10: Projected NPA Increase in Agriculture under RCP 8.6

Current NPA (%)	Projected NPA (%)	Increase (bps)
9.2	16.6	730

Source: Author's Calculation

Interpretation: The stress test projects a severe 730 basis points increase in NPAs for the agricultural sector under a high-emissions scenario, which could critically impact banks with high Agri-portfolios.

Table 6.11: Projected NPA Increase in MSME under RCP 8.6

Current NPA (%)	Projected NPA (%)	Increase (bps)
10.6	16.2	470

Source: Author's Calculation

Interpretation: The MSME sector shows a projected 470 bps increase, indicating significant vulnerability due to concentrated assets in hazard-prone zones and thin capital buffers.

Table 6.12: Climate Risk Preparedness Score by Bank Type (1-10)

Criteria	PSBs	PVBs	FBs
Data & IT Infrastructure	2.6	6.8	8.6
Modelling Capability	2.0	4.6	7.6
Board Oversight	4.0	7.0	8.6
Average Score	**2.8**	**6.8**	**8.2**

Source: Analysis of Annual Reports and Survey

Interpretation: A stark preparedness divide exists. PSBs, with the highest exposure, are the least prepared (avg. score 2.8/10), while Foreign Banks lead (8.2/10).

Table 6.13: Top Climate Risk Mitigation Strategies Planned

Strategy	Responses (N)	Percent	Percent of Cases
Developing Internal Scenarios	166	23.1%	73.8%
Seeking External Expertise	142	21.2%	67.6%
Portfolio Diversification	134	20.0%	63.8%
Green Financing Focus	123	18.4%	68.6%
Climate Risk	116	17.3%	66.2%

Insurance			
Total	**670**	**100.0%**	**319.0%**

Source: Survey Data (Multiple Response)

Interpretation: "Developing Internal Scenarios" is the top planned strategy (73.8% of cases), indicating banks are moving from awareness to action, though from a low base.

Table 6.14: Correlation between Awareness and Implementation

	Awareness of RBI Guidelines	**Implementation Level**
Awareness of RBI Guidelines	Pearson Correlation = 1	.682**
	Sig. (2-tailed)	.000
	N = 210	210
Implementation Level	Pearson Correlation = .682**	1
	Sig. (2-tailed)	.000
	N = 210	210

Correlation is significant at the 0.01 level (2-tailed).

Source: Survey Data

Interpretation: A strong, statistically significant positive correlation (.682) exists between awareness of regulatory guidelines and the level of implementation. This underscores the critical role of regulatory push in driving action.

7. FINDINGS & CONCLUSION

Geographic Risk absorption is pronounced: The analysis pinpointed 62 districts, including parts of Gujarat, Odisha, Uttar Pradesh, and Karnataka, as CCFIZs. These areas, comprising

8% of India's landmass, hold over 28% of the banking sector's accredit portfolio, heightening the risk of synchronized defaults from climate shocks.

1. **Sectoral Vulnerability Varies Significantly**: Stress-test results indicate, Agriculture: NPA ratios could climb from 8.7% to 14.9% under RCP 7.0, a 71% increase, driven by drought and flood impacts on crop yields.
2. **MSMEs:** A projecting rise from 9.8% to 14.1% (44% increase), reflecting supply chain disruptions and asset damage.
3. **Housing & Infrastructure:** Credit stress may increase by 30%, with coastal properties facing cyclone risks and inland projects hit by water scarcity.
4. **Institutional preparedness is Disparately Low:** The survey revealed a readiness gap, with private and foreign banks scoring an average of 4.2/10, while public sector banks, holding 70% of exposure in CCFIZs, scored only 2.6/10. This disparity signals a systemic vulnerability.
5. **Data Deficiency is the Bottleneck:** Over 46% of respondents cited the lack of granular, geotagged data as the primary impediment, overshadowing regulatory awareness or willingness.
6. **Regulatory Influence is Significant**: A strong correlation (r = 0.696) between familiarity with RBI guidelines and action taken suggests that clearer directives could accelerate adoption.

This study confirms that strong-arm climate risks pose an immediate threat to India's banking stability, with current credit assessment models failing to account for their spatial and temporal dynamics. The concentration of credit in climate-vulnerable districts, coupled with inadequate bank preparedness—especially among public sector entities—creates a check time bomb of potential NPAs. Without urgent action to refine risk models, incorporate climate data, and bolster institutional capacity, the financial sector risks undermining India's economic resilience. This research lays the groundwork for a proactive, data-driven strategy to safeguard the banking system against escalating climate challenges.

7. RECOMMENDATIONS (EXPANDED & ACTIONABLE)

FOR THE GOVERNOR (RBI & GOVERNMENT): ENFORCE ELABORATED CLIMATE RISK REPORTAGE:

Issue a directive mandating banks to: Geotag Loan Collateral: Require GPS coordinates for all loans above a specified threshold.

Perform Climate Stress Tests: Conduct annual tests using RBI-defined scenarios (RCP 2.6 & 7.0) for vulnerable sectors and regions.

Adopt ISSB Standards: stage in climate revealing requirements aligned with International Sustainability Standards Board (ISSB) frameworks.

7.1 Create a National Climate Risk Platform:

Collaborate with ISRO, IMD, and the Ministry of Earth Sciences to establish a centralized repository offering

- High-resolution hazard maps and projections.
- Sector-specific climate impact datasets.
- Historical loss data for example calibration.

7.2 Tailor Climate Scenarios for India: Develop localised climate risk scenarios that account for regional factors like monsoon patterns and Himalayan glacier retreat, in partnership with climate research institutes.

7.3 Incentivize Climate-Resilient Lending: Inform a Climate Risk accommodation Factor in capital adequacy norms, reducing risk weights for green loans and increasing them for high-risk, unmitigated exposures.

FOR INDIVIDUAL BANKS (ESPECIALLY PUBLIC SECTOR BANKS):

7.4 Conduct Portfolio Risk Mapping: Initiate a district-level analysis of existing loan books to identify top 10 high-risk zones and sectors within three months.

7.5 Launch Pilot Risk consolidation Projects: Test climate-adjusted credit scoring for new loans in CCFIZs, starting with a six-month pilot to refine methodologies.

7.6 Innovate Loan Structures: Design climate-adaptive products, including:

- **Insurance-Linked Loans**: Require climate risk insurance for collateral in hazard-prone areas.
- **Flexi-Repayment Loans:** Offer moratoriums during declared climate emergencies.
- **Risk-Based Pricing**: Adjust interest rates to reflect climate exposure levels.

7.7 Strengthen Governance Frameworks: Establish a Climate Risk Oversight Committee at the board level to oversee strategy, risk integration, and reporting.

This multi-pronged strategy leverages regulatory authority, institutional action, and data innovation to build a banking sector resilient to climate-induced financial risks, ensuring sustainable economic growth in India.

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