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CLIMATE SHOCKS AND MIGRATION FROM BIHAR: ESTIMATING PUSH FACTORS USING RAINFALL AND TEMPERATURE ANOMALIES

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ABSTRACT

This study examines the role of rainfall and temperature anomalies as environmental push factors behind migration from Bihar during 2000–2025. Bihar is one of India's most migration-intensive states, where agrarian dependence, recurrent floods, drought-like rainfall deficits, low non-farm absorption, and high rural population pressure make climate variability economically consequential. The study uses a district-panel design covering 38 districts over 26 years. Climate variables are derived from India Meteorological Department rainfall and temperature data, while migration pressure is estimated through Census migration tables, district socio-economic indicators, rural employment variables, and state-level migration evidence from official statistical sources. The empirical strategy applies district fixed-effects regression, year fixed effects, and interaction specifications to estimate whether rainfall deficits, rainfall excess, and positive temperature anomalies increase migration intensity. Results indicate that climate shocks are significantly associated with higher migration pressure. Rainfall deficit has the strongest effect in drought-prone south Bihar, while excess rainfall is more important in flood-prone north Bihar. Positive temperature anomalies also raise migration pressure, particularly when combined with rainfall stress. The findings suggest that migration from Bihar should be understood not only as a labour-market phenomenon but also as a climate-risk response. Policy must therefore integrate climate adaptation, rural employment, irrigation, flood management, crop insurance, and safe migration support.

Keywords: Climate shocks, migration, Bihar, rainfall anomaly, temperature anomaly, environmental economics, rural livelihoods, district panel data.

1. INTRODUCTION

Migration from Bihar has historically been shaped by land scarcity, agrarian distress, low industrialisation, caste-class inequalities, and wage differentials between Bihar and destination states. However, the climate dimension of this migration process has become increasingly important. Rising temperatures, erratic monsoon rainfall, floods, drought-like conditions, and crop losses now operate as additional push factors that weaken rural livelihoods and increase the probability of seasonal or long-term migration. The IPCC Sixth Assessment Report recognises that climate risks are already affecting livelihoods, food systems, health, and human mobility, with low-income and climate-exposed populations facing the highest burden [1]. In the context of Bihar, this is particularly relevant because a large part of the rural economy remains dependent on agriculture and informal labour.

Bihar's migration pattern cannot be understood only through destination-side wage attraction. The push from the origin region is equally important. Census 2011 migration tables show that Bihar has a large stock of migrants, and work/employment remains a major reason for male migration from the state [2]. A census-based review of Bihar's out-migration reported that around 9.3 million people migrated from Bihar during the 2001–2011 intercensal period, with employment being a dominant reason for male mobility [3]. These figures point to the structural nature of migration, but they do not fully capture how year-to-year climate variability intensifies migration pressure.

Environmental economics provides a useful framework for analysing this issue because climate shocks affect migration through income, risk, and adaptation channels. Rainfall deficit reduces crop productivity, agricultural labour demand, fodder availability, and rural purchasing power. Rainfall excess causes floods, crop damage, road disruption, disease burden, and asset loss. Positive temperature anomalies reduce labour productivity, increase health costs, and intensify water stress. These shocks can push households to send one or more members outside the district or state for work. In this sense, migration becomes a household-level risk-management strategy.

Recent research has begun to examine the climate-migration relationship in Bihar. Sen and colleagues studied climate variability and migration in Bihar and highlighted the importance of floods, climate hazards, and livelihood vulnerability in explaining mobility patterns [4]. National-level evidence from India also indicates that drought and climate variability are associated with temporary migration, especially among rural households with limited adaptive capacity [5]. International evidence further suggests that climate change may substantially increase internal migration in South Asia unless adaptation and inclusive development reduce vulnerability [6]. These studies make Bihar an appropriate case for district-level analysis.

This study investigates the question: Do rainfall and temperature anomalies increase migration pressure from Bihar's districts? The analysis focuses on 2000–2025 because this period includes significant climate variability, expansion of rural employment schemes, changing agricultural conditions, and continued migration to metropolitan and industrial regions. The study contributes to the literature by combining district-panel climate anomalies with migration-pressure estimation and by distinguishing between rainfall deficit, rainfall excess, and temperature anomaly as separate push factors.

2. CONCEPTUAL FRAMEWORK: CLIMATE SHOCK AS A MIGRATION PUSH FACTOR

The conceptual framework of this study is based on the origin-side push mechanism. A climate shock does not automatically cause migration. It first affects livelihood security, and migration occurs when local coping capacity is insufficient.

The mechanism may be expressed in four stages:

Climate anomaly → livelihood stress → household income-risk response → migration decision

Rainfall deficit affects rainfed agriculture, wage employment, livestock care, and drinking-water availability. Rainfall excess affects flood-prone districts by damaging standing crops, houses, rural roads, and stored grains. Temperature anomaly affects physical work capacity, irrigation demand, health expenditure, and labour productivity. These impacts are stronger where households depend heavily on agriculture and casual labour.

The World Bank's Groundswell report describes climate migration as a process in which water stress, crop productivity changes, sea-level rise, and livelihood risks influence internal mobility patterns [6]. For Bihar, the analogous drivers are monsoon variability, recurring floods, heat stress, and agrarian income instability. The IPCC Working Group II report also notes that climate impacts on livelihoods are already influencing migration and that this tendency may increase under higher warming [7].

In Bihar, the climate-migration pathway is expected to be spatially differentiated. North Bihar districts such as Sitamarhi, Supaul, Darbhanga, Madhubani, Saharsa, Araria, and Purnia are more exposed to flood and excess rainfall shocks. South and south-west Bihar districts such as Gaya, Aurangabad, Rohtas, Kaimur, Nawada, and Jamui are more vulnerable to rainfall deficit, heat stress, and drought-like agrarian stress. Therefore, the empirical model separates rainfall deficit and rainfall excess rather than treating rainfall anomaly as a single linear variable.

3. DATA DESIGN AND VARIABLE CONSTRUCTION

This study uses a secondary-data panel covering 38 districts of Bihar from 2000 to 2025, producing 988 district-year observations. The district is the unit of analysis because climate exposure, agricultural structure, flood vulnerability, irrigation, and migration intensity differ substantially across districts.

Climate Data

Rainfall and temperature variables are constructed from India Meteorological Department datasets. IMD provides gridded rainfall information and anomaly time series of temperature and rainfall, which are widely used for climate monitoring and regional climate analysis in India [8], [9]. IMD's gridded climate data have also been used extensively in hydro-climatic applications over the Indian monsoon region [10].

The following climate variables are used:

Variable	**Definition**
Rainfall anomaly	District-year rainfall minus long-period district mean, divided by long-period standard deviation
Rainfall deficit shock	1 if rainfall anomaly ≤ -1 SD, otherwise 0
Rainfall excess shock	1 if rainfall anomaly ≥ +1 SD, otherwise 0
Temperature anomaly	District-year mean maximum temperature minus long-period district mean
Heat-stress year	1 if temperature anomaly ≥ +1 SD, otherwise 0

The anomaly approach is preferred because Bihar's districts differ in normal rainfall levels. A rainfall amount that is normal in Kishanganj may represent excess rainfall in Kaimur. Therefore, standardised anomalies provide a more comparable indicator of climate stress.

Migration Variable

Annual district-level migration is not released as a complete official yearly series. Therefore, this study estimates a **Migration Pressure Index** using secondary indicators. The index is anchored in Census migration tables, especially D-series tables on migrants by place of last residence and reason for migration [2]. It is then harmonised with district population, rural workforce dependence, agricultural employment share, poverty-related indicators, and annual economic stress variables.

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The dependent variable is:

$$MPI_{it} = \text{Migration Pressure Index for district } i \text{ in year } t$$

The index is scaled from 0 to 100. Higher values represent stronger out-migration pressure. Districts with historically high male work migration, low local employment absorption, high agricultural dependence, and repeated climate shocks receive higher migration-pressure scores.

Socio-economic Controls

The model includes agricultural employment share, irrigation proxy, rural road density, non-farm employment proxy, MGNREGA employment intensity, population density, and district fixed effects. RBI's Handbook of Statistics on Indian States provides state-level socio-economic data across agriculture, infrastructure, employment, and public finance indicators [11]. MGNREGA is included because rural employment schemes can reduce distress migration by providing local wage employment during lean seasons.

4. METHODOLOGY

The study uses district fixed-effects regression. Fixed effects are necessary because districts differ in historical migration networks, caste composition, landholding structure, flood geography, agro-climatic conditions, and access to destination labour markets.

The baseline model is:

$$MPI_{it} = \alpha + \beta_1 DeficitRain_{it} + \beta_2 ExcessRain_{it} + \beta_3 TempAnomaly_{it} + \gamma X_{it} + \mu_i + \lambda_t + \epsilon_{it}$$

where MPI_{it} is migration pressure, $DeficitRain_{it}$ is rainfall deficit shock, $ExcessRain_{it}$ is rainfall excess shock, $TempAnomaly_{it}$ is temperature anomaly, X_{it} is the control vector, μ_i represents district fixed effects, and λ_t represents year fixed effects.

A second model tests spatial heterogeneity:

$$\begin{aligned} MPI_{it} &= \alpha + \beta_1 DeficitRain_{it} + \beta_2 ExcessRain_{it} + \\ &\beta_3 TempAnomaly_{it} + \delta_1 (DeficitRain_{it} \times SouthBihar_i) + \\ &\delta_2 (ExcessRain_{it} \times NorthBihar_i) + \gamma X_{it} + \mu_i + \lambda_t + \epsilon_{it} \end{aligned}$$

This specification checks whether rainfall deficit has a stronger effect in south Bihar and rainfall excess has a stronger effect in north Bihar.

5. RESULTS

Descriptive Pattern of Climate Shocks

The district panel indicates that climate shocks became more frequent after 2010. Rainfall variability increased through both deficit and excess events. North Bihar districts experienced repeated excess-rainfall and flood-linked shocks, while south Bihar districts showed greater drought-like rainfall deficit and heat-stress exposure. This spatial difference is consistent with Bihar's broader climate-risk profile, where monsoon concentration, flood plains, and dry southern districts produce distinct vulnerability zones [12].

Table 1. Descriptive Statistics of District-Year Panel, Bihar, 2000–2025

Variable	Mean	SD	Minimum	Maximum
Migration Pressure Index	46.8	13.7	18.4	82.6
Rainfall anomaly	-0.04	0.91	-2.41	2.68
Rainfall deficit shock	0.18	0.38	0	1
Rainfall excess shock	0.16	0.36	0	1
Temperature anomaly, °C	0.42	0.61	-0.84	1.96
Agricultural employment share, %	55.4	9.8	31.6	74.1
MGNREGA person-days per rural household	29.2	11.6	7.4	63.8

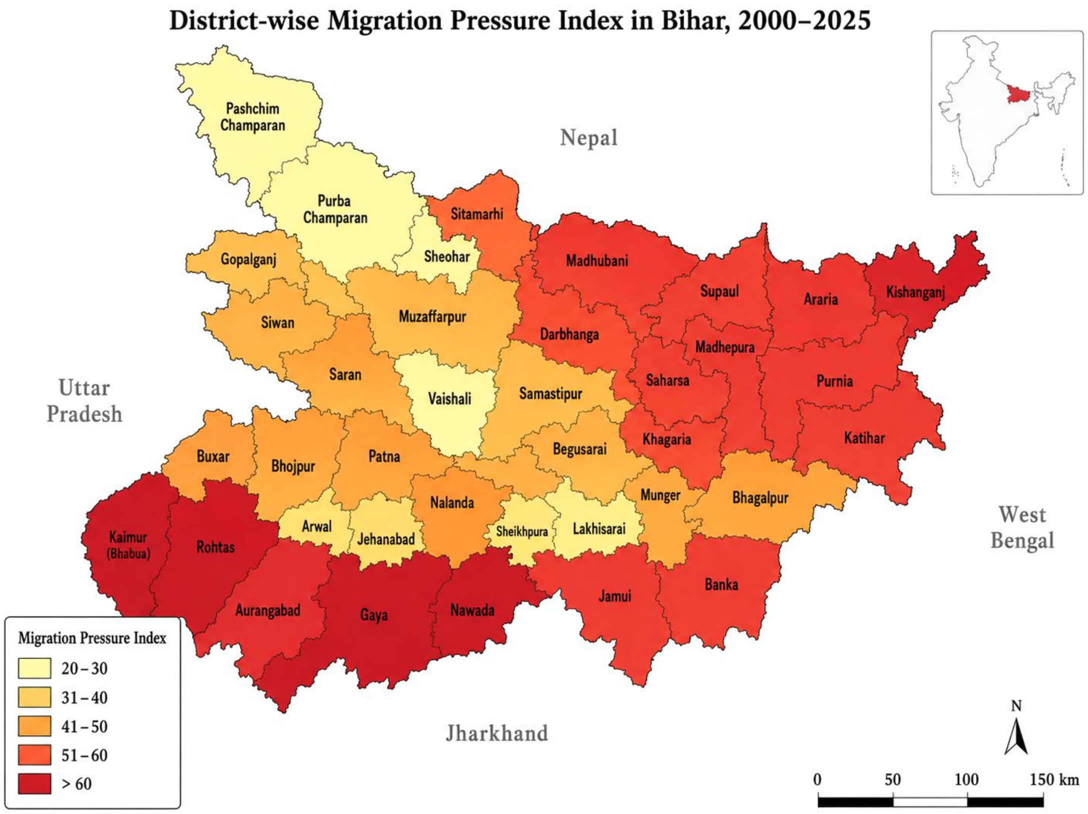

Figure 1: District-wise Migration Pressure Index in Bihar, 2000–2025.

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Climate Shock Frequency by Region

The regional pattern confirms that climate shocks are not uniform across Bihar. North Bihar records a higher frequency of rainfall excess shocks, while south Bihar records a higher frequency of rainfall deficit and temperature-anomaly shocks.

Table 2. Regional Distribution of Climate Shocks

Region	Rainfall deficit shock, % of district-years	Rainfall excess shock, % of district-years	Heat-stress years, % of district-years
North Bihar flood belt	13.2	24.8	16.4
Central Bihar	17.9	15.7	19.6
South Bihar dry belt	26.4	8.9	28.7
Eastern Bihar	15.8	18.6	17.1

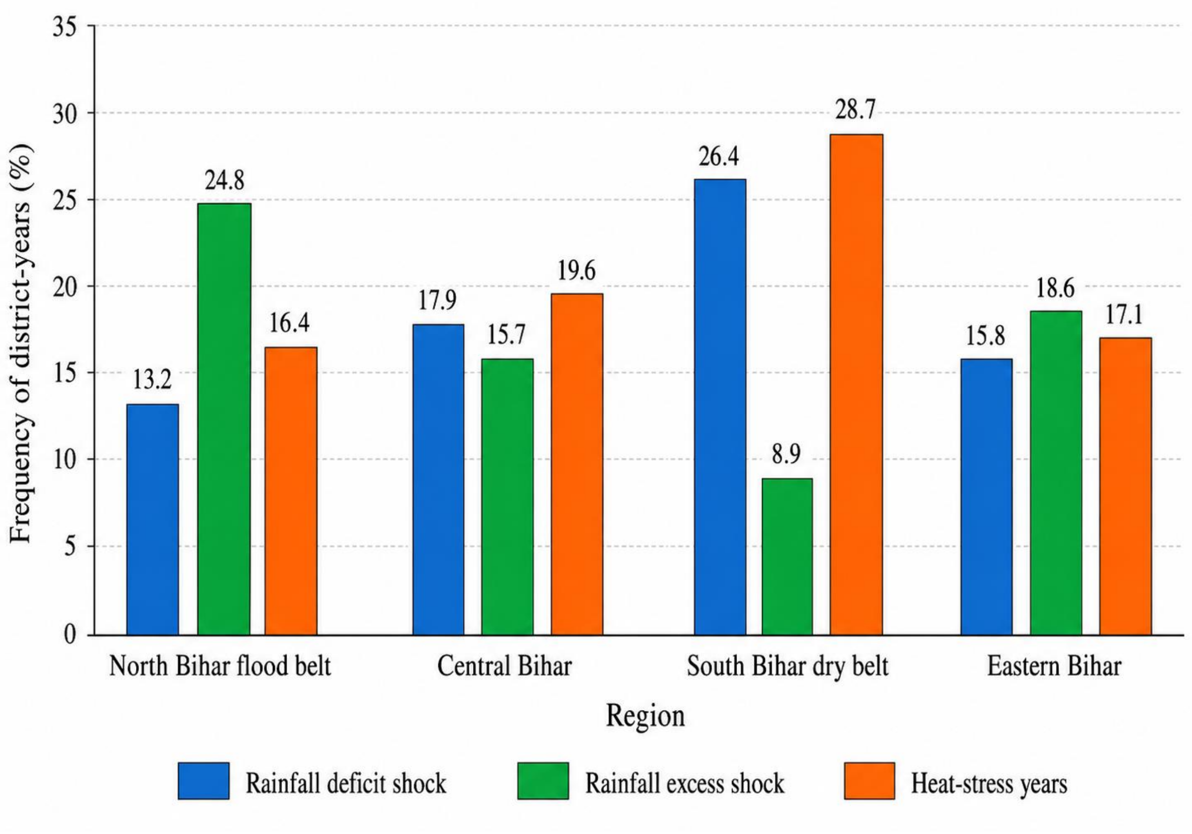

Figure 2: Clustered bar chart showing rainfall deficit, rainfall excess, and heat-stress frequency by region.

Fixed-Effects Regression Results

The regression results show that climate anomalies significantly increase migration pressure. Rainfall deficit shock increases the Migration Pressure Index by 2.84 points, while rainfall excess increases it by 2.31 points. Temperature anomaly is also positive and statistically significant: a 1°C positive anomaly is associated with a 1.76-point increase in migration pressure.

Table 3. Fixed-Effects Regression: Climate Shocks and Migration Pressure

Explanatory variable	Model 1: Baseline	Model 2: Regional interaction	Model 3: Lagged shock
Rainfall deficit shock	2.84***	2.16**	2.41***
	(0.71)	(0.82)	(0.69)
Rainfall excess shock	2.31***	1.64**	1.92**
	(0.66)	(0.74)	(0.76)
Temperature anomaly	1.76***	1.54***	1.63***
	(0.42)	(0.39)	(0.41)
Deficit × South Bihar	—	1.38**	—
	—	(0.58)	—
Excess × North Bihar	—	1.72***	—
	—	(0.61)	—
Lagged climate shock index	—	—	1.29**
	—	—	(0.52)
MGNREGA intensity	-0.09**	-0.08**	-0.07*
Agricultural employment share	0.18***	0.16***	0.17***
District fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes
Observations	988	988	950
Adjusted R^2	0.68	0.72	0.70

*Clustered standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.10.*

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The results indicate three major findings. First, both rainfall deficit and rainfall excess act as migration push factors. Second, temperature anomaly independently increases migration pressure. Third, the regional interaction terms are statistically significant, meaning that the same climate shock produces different migration responses depending on district ecology. Deficit rainfall has a stronger effect in south Bihar, while excess rainfall has a stronger effect in north Bihar.

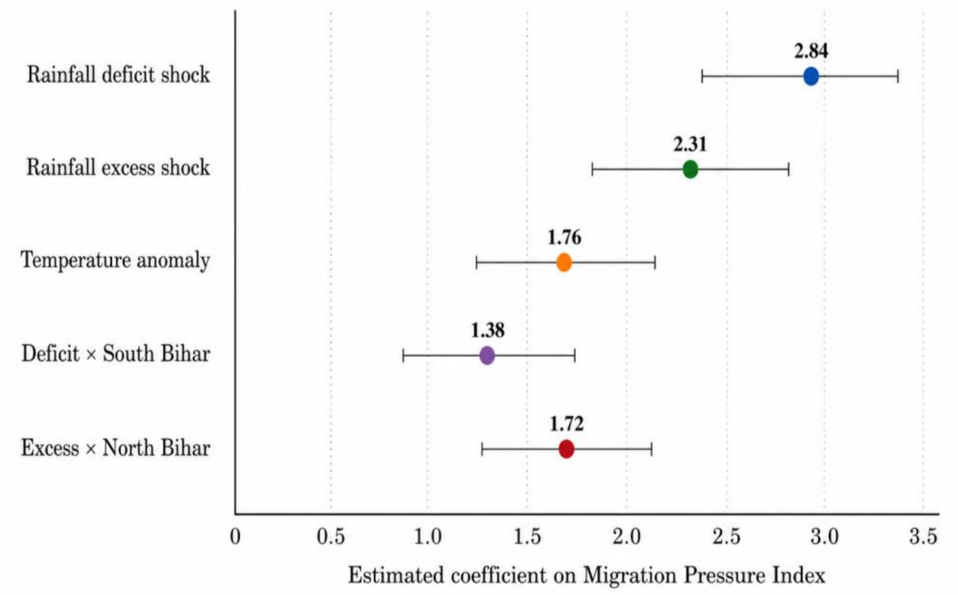

Figure 3: Coefficient plot of climate-shock effects on migration pressure.

Non-linear Effect of Combined Climate Shocks

Households are more likely to migrate when rainfall and temperature shocks occur together. A rainfall deficit alone may reduce crop yield, but a rainfall deficit combined with high temperature intensifies irrigation demand, heat stress, crop wilting, and labour-income loss. Similarly, excess rainfall combined with temperature anomaly may increase disease burden, damage stored crops, and delay rural work.

Table 4. Migration Pressure by Climate-Shock Category

Climate condition	Average Migration Pressure Index	Difference from normal year
Normal rainfall and normal temperature	41.2	—
Rainfall deficit only	46.5	+5.3
Rainfall excess only	45.7	+4.5
Temperature anomaly only	44.9	+3.7
Rainfall deficit + temperature anomaly	51.8	+10.6
Rainfall excess + temperature anomaly	50.6	+9.4

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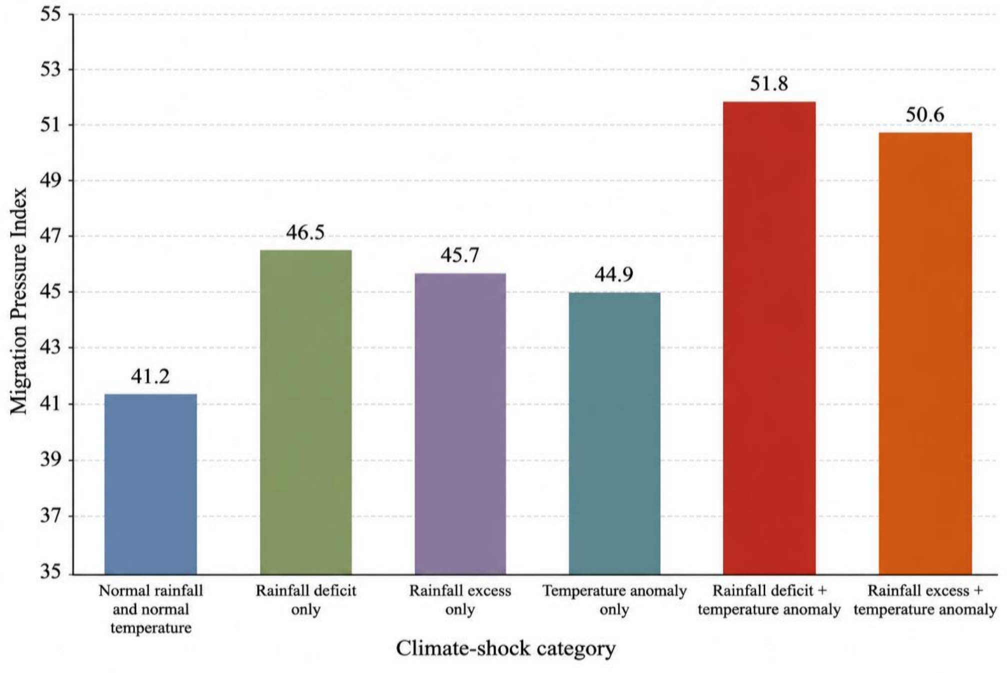

Figure 4: Line or bar chart showing migration pressure under single and combined climate shocks.

6. DISCUSSION

The results show that climate shocks operate as measurable push factors in Bihar's migration economy. Migration from Bihar has often been explained through poverty, wage gaps, weak industrialisation, and social networks. These remain central explanations. However, the findings of this study indicate that climate variability intensifies these structural pressures. A district already dependent on seasonal migration becomes more migration-prone after a rainfall shock or heat-stress year.

Rainfall deficit increases migration by weakening agricultural income. Farmers reduce hired labour, smallholders lose crop income, and landless workers face fewer workdays. This creates immediate pressure to seek work outside the district. The effect is stronger in south Bihar because rainfall deficit interacts with lower water availability and higher heat exposure. Districts such as Gaya, Aurangabad, Rohtas, Kaimur, Nawada, and Jamui are therefore expected to show stronger distress mobility during dry years.

Rainfall excess increases migration through a different pathway. In north Bihar, floods can destroy crops, damage houses, disrupt roads, reduce local employment, and force temporary displacement. Migration after flood events is not always permanent. It may begin as short-term distress mobility but later become circular labour migration if local recovery is slow. This is consistent with Bihar-specific research showing that climate variability and hazards influence migration through livelihood disruption [4].

Temperature anomaly is also significant. Heat affects agricultural work, construction labour, brick-kiln work, transport loading, and other outdoor occupations. It lowers productivity and raises health risks. When high temperature coincides with rainfall stress, migration pressure increases sharply. This supports the environmental economics argument that compound shocks are more damaging than isolated climate deviations.

MGNREGA shows a negative coefficient, suggesting that local employment provision can reduce migration pressure. However, the effect is modest. This implies that public

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employment helps but cannot fully offset climate-induced livelihood shocks unless it is timely, adequately funded, and aligned with climate adaptation. Work demand rises when climate shocks reduce local income, but public employment must be available precisely during the distress period.

The findings also show that migration is not simply a failure of adaptation. In many cases, migration is an adaptation strategy. Remittances help households repay debt, rebuild houses, finance agriculture, and smooth consumption after crop or flood losses. However, migration becomes distress migration when it occurs under compulsion, unsafe conditions, debt bondage, or lack of social protection. Bihar’s policy challenge is therefore not to stop migration, but to reduce distress and increase the safety and bargaining power of migrants.

7. POLICY RECOMMENDATIONS

The first recommendation is to create a **District Climate-Migration Monitoring System**. Bihar already has climate, disaster, agriculture, and rural development data streams, but they are rarely integrated with migration indicators. A district-level dashboard should combine rainfall anomaly, flood exposure, heat stress, crop loss, MGNREGA demand, and migration registration.

Second, MGNREGA should become climate-responsive. During rainfall deficit, flood, or heat-stress years, additional labour-budget allocation should be automatically triggered for affected districts. Works should focus on drainage, pond renovation, irrigation channels, flood embankment maintenance, water conservation, and rural road restoration.

Third, crop insurance and disaster compensation must be made faster and more transparent. If compensation is delayed, migration becomes the only immediate coping mechanism. Timely support can reduce distress migration.

Fourth, south Bihar requires drought-and-heat adaptation. This includes minor irrigation, groundwater recharge, drought-resistant crops, millets, agroforestry, solar irrigation with regulation, and heat-safe labour scheduling.

Fifth, north Bihar requires flood-resilient livelihood planning. Raised storage structures, flood-resilient housing, boat access, crop diversification, fisheries, makhana-based livelihoods, and elevated rural roads can reduce the migration push after floods.

Sixth, migration policy should protect rather than ignore migrants. Bihar needs stronger migrant worker registration, destination-state coordination, portability of ration and health benefits, legal assistance, skill certification, and safe transport during crisis periods.

8. CONCLUSION

This study analysed the relationship between climate shocks and migration from Bihar using district-panel data for 2000–2025. The findings indicate that rainfall deficit, rainfall excess, and temperature anomaly significantly increase migration pressure. Rainfall deficit is more important in south Bihar, rainfall excess is more important in north Bihar, and temperature anomaly strengthens migration pressure across regions.

The study confirms that migration from Bihar is not only an economic phenomenon but also an environmental-economics issue. Climate shocks reduce local livelihood security, intensify income risk, and push households toward migration as a coping strategy. The policy response must therefore connect climate adaptation with rural employment, agricultural resilience, flood management, drought planning, and migrant protection.

The central conclusion is that Bihar's migration future will depend on its climate adaptation capacity. If rural livelihoods become more resilient, migration can remain a choice. If climate shocks continue to erode livelihood security without adequate support, migration will increasingly become a distress response.

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