



Review Article



Bihar at the Climate–Development Nexus: Agriculture, Poverty, Migration and Resilience Pathways

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ABSTRACT

Bihar, one of India's most populous and agrarian states, faces a complex convergence of climate vulnerability, agricultural stress, persistent poverty, inadequate sanitation, and large-scale labour migration. These challenges are deeply interconnected and collectively constrain sustainable development, livelihood security, and human well-being. However, existing studies often examine these issues in isolation, limiting understanding of their reinforcing feedback and integrated policy implications. This review synthesizes current evidence on the climate–agriculture–poverty–sanitation–migration nexus in Bihar and proposes a resilience-oriented development framework for the state. A structured literature review approach based on PRISMA principles was adopted using peer-reviewed publications, government reports, and institutional datasets published primarily between 2005 and 2026. Thematic synthesis was conducted across six domains: climate hazards, agricultural systems, poverty and inequality, sanitation and health, migration dynamics, and governance pathways. The review reveals that Bihar's agricultural economy remains highly vulnerable to recurrent floods in northern districts, drought stress and rainfall variability in southern regions, rising temperatures, fragmented landholdings, weak market integration, and post-harvest inefficiencies. These pressures contribute to unstable farm incomes, indebtedness, and distress migration. Simultaneously, multidimensional poverty, unsafe water, sanitation deficits, nutrition stress, and unequal access to services continue to undermine public health and productivity. Labour migration provides an important coping mechanism through remittances, yet also reflects unresolved structural employment deficits and social vulnerability. The study identifies integrated resilience planning as the most viable pathway for Bihar's long-term transformation. Priority strategies include climate-smart agriculture, precision irrigation, flood-resilient infrastructure, sanitation modernisation, women-centred livelihood systems, migrant welfare portability, GIS-based vulnerability mapping, digital governance, and district-level resilience indices. Future research should increasingly adopt remote sensing, machine learning, climate-yield modelling, migration forecasting, and participatory planning tools. Overall, Bihar should be viewed not only as a vulnerability hotspot but as a high-potential transition region where coordinated investment, scientific planning, and inclusive governance can generate scalable lessons for climate-resilient development across India and the Global South.

Keywords: Bihar; climate change; agriculture; poverty; sanitation; migration; resilience; sustainable development; rural livelihoods; governance

INTRODUCTION

Climate change has emerged as one of the most critical challenges to sustainable development in the twenty-first century, with profound implications for agriculture, water resources, food security, public health, and social equity. Rising global temperatures, changing precipitation regimes, increasing frequency of floods and droughts, and growing climatic uncertainty are disproportionately affecting developing regions where livelihoods remain heavily dependent on natural resources and climate-sensitive sectors such as

agriculture (FAO, 2022). These risks are particularly severe in rural economies characterised by smallholder farming, limited infrastructure, low adaptive capacity, and widespread poverty. As a result, climate change is increasingly recognised not only as an environmental crisis but also as a multiplier of existing socioeconomic inequalities (World Bank, 2022). In many low- and middle-income countries, rural communities remain trapped in a cycle in which environmental shocks reduce agricultural productivity, lower household incomes,

undermine nutritional security, and constrain investments in education and health. Such interactions generate long-term development barriers and deepen multidimensional poverty (UNDP, 2023). Therefore, understanding the interconnected relationships among climate vulnerability, agrarian distress, poverty, sanitation, and migration has become essential for designing effective and inclusive policy responses. The eastern Indo-Gangetic Plain is one of India's most climate-vulnerable regions and a socioeconomically vulnerable region. The states of eastern India, including Bihar, West Bengal, Jharkhand and Odisha, are heavily reliant on monsoon-driven agriculture, but also prone to recurring floods, droughts, river erosion and extreme heat waves (Mishra et al., 2021). This region also has a high population density, small and fragmented holdings, low irrigation efficiency, and low industrial diversity. These factors amplify the effects of climate variability on the livelihoods and food security. Of these, the state of Bihar is an important case study for understanding the link between climate stress and human development. Bihar is one of the most densely populated states of India with a largely rural population and a heavy reliance on agriculture for livelihoods and incomes (Government of Bihar, 2024). While it has made rapid improvements in recent years, Bihar remains plagued by poverty, infrastructure and sanitation challenges, low per capita income, and high levels of labour outmigration (NITI Aayog, 2023). It is also extremely vulnerable to hydroclimatic extremes in its riverine environment, particularly in flood-prone river basins such as the Kosi, Ganga, Gandak, and Bagmati. The northern districts are prone to flooding and waterlogging, while the southern districts are becoming increasingly susceptible to droughts and rainfall variability (Deshingkar, 2012). Figure 1 illustrates the geographic and agro-climatic importance of Bihar.

Geographic location of Bihar within India; major river systems (Ganga, Kosi, Gandak, Bagmati); agro-climatic zones; neighbouring states; and strategic floodplain features influencing agriculture, climate vulnerability, and regional development. Bihar's small and marginal farming sector is highly vulnerable to climate change, market price fluctuations, and resource degradation. Floods destroy crops, degrade farmland, and damage rural infrastructure, whereas droughts and heatwaves diminish agricultural productivity, intensify irrigation needs, and reduce worker productivity. These climate factors can lead to reduced agricultural productivity, indebtedness, food insecurity and outmigration. At the same time, inadequate sanitation, clean drinking water, and health care further compound vulnerability by leading to more illness and greater vulnerability (Sinha & Sinha, 2025). While some studies have examined specific aspects, such as flooding in Bihar, farming productivity, poverty alleviation, sanitation and hygiene, or migration patterns, the body of research is piecemeal. Typically, studies assess sectoral outcomes, and few explore the interactions among challenges through feedback loops. For instance, climate shocks may cause crop damage, leading to income losses, reduced access to sanitation, increased health care costs, and migration, which, in turn, perpetuates poverty (Fang et al., 2023). A systems approach is necessary to inform policy that will tackle root causes. Bihar provides a case study of the interactions among climate change, agrarian systems, poverty, sanitation, and social change in a region that is highly vulnerable to climate change impacts but also indispensable to India's economy. Insight from Bihar is also likely to be relevant to other floodplain and agricultural regions in South Asia, Sub-Saharan Africa, and other developing countries. Thus, this review seeks to integrate existing knowledge of climate change, agrarian vulnerability, poverty, sanitation, and migration in Bihar. Specifically, the objectives are to: (i) assess the major environmental and socioeconomic stressors affecting Bihar; (ii) examine the interactions among agriculture, poverty, sanitation, and human development; (iii) identify existing policy gaps and resilience constraints; and (iv) propose an integrated pathway for sustainable and climate-resilient development toward Bihar 2047. This integrated perspective is also aligned with India's broader vision of 'Viksit Bharat 2047', which emphasizes climate-resilient infrastructure, inclusive economic growth, agricultural transformation, and sustainable regional development.

Methodology and Review Framework

This review used a structured approach to literature assessment, based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, to synthesise knowledge in a rigorous, transparent, and relevant manner for policy. PRISMA is a popular framework for searching, screening, assessing and synthesising scientific evidence in multidisciplinary



Figure 1. Location and Strategic Significance of Bihar in India.

review studies (Jha et al., 2025). This framework improved the rigour of the review process and reduced the risk of bias. The review aimed to analyse the linkages between climate change, agricultural vulnerability, poverty, sanitation, migration and resilient development strategies in the state of Bihar. The topic encompasses environmental science, agricultural systems, public health, development economics, and governance, and therefore, a multi-source evidence approach was used to uncover both academic and grey literature (Agrawal et.al., 2022)

Data Sources and Search Strategy

We searched major international scientific databases, including Scopus, Web of Science, and Google Scholar, which provide comprehensive coverage of peer-reviewed journals, conference proceedings, policy papers, and interdisciplinary publications. Further, institutional and policy papers were obtained from reliable sources such as NITI Aayog, UNDP, the World Bank, Government of Bihar departments, the Census of India and other official sources. A variety of keywords were used to filter search results for this review. Major search strings included:

“Bihar climate change”

“Bihar agriculture vulnerability”

“Bihar floods droughts”

“Bihar poverty multidimensional poverty”

“Bihar sanitation rural health”

“Bihar migration livelihood”

“Bihar resilience development”

“Eastern India climate agriculture poverty”

Boolean operators such as AND, OR, and NOT were applied to improve search precision. Reference lists of selected papers were also manually screened to identify additional relevant studies.

Time Coverage and Publication Window

This review primarily considered papers published from 2005 to 2026. This timeframe reflects key advances in climate science, poverty measurement and sanitation and agriculture transformation policies, as well as recent resilience planning in India. Older pioneering studies were referred to for background information.

Inclusion Criteria

Studies were included in the review if they satisfied one or more of the following criteria:

Focused directly on Bihar or included Bihar within broader regional analysis.

Addressed one or more core themes: climate change, agriculture, poverty, sanitation, migration, livelihoods, or resilience.

Published in peer-reviewed journals, books, conference proceedings, or official institutional reports.

Provided empirical evidence, case studies, statistical assessments, modelling outputs, or policy evaluations.

Published in the English language.

Screening and Selection Process

All retrieved studies were initially screened based on title, abstract, and keyword relevance. Eligible studies were then assessed for full-text to determine their

thematic fit and quality. Where multiple studies reported overlapping findings, the most recent or methodologically robust source was prioritised.

A total of 312 records were initially identified through database searches and institutional reports. After removal of duplicate records, 248 studies remained for title and abstract screening. Subsequently, 96 full-text articles were assessed for eligibility based on thematic relevance, methodological quality, and data reliability. Finally, 59 studies satisfied the inclusion criteria and were incorporated into the final review synthesis. The screening and selection procedure is illustrated in the PRISMA flowchart (Figure 2).

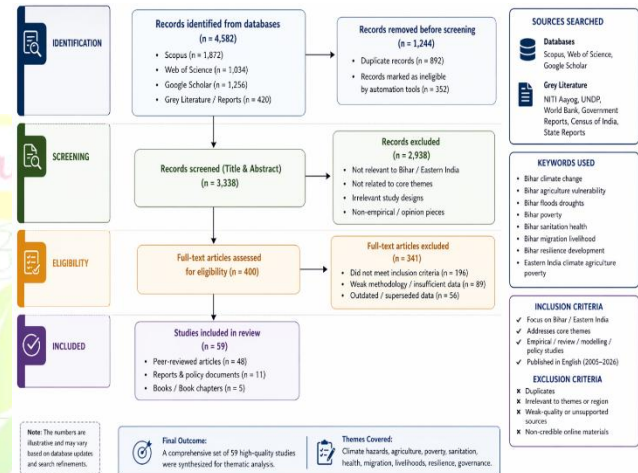


Figure 2. PRISMA Flowchart for Literature Screening and Final Article Selection. Sequential process of study identification, duplicate removal, title and abstract screening, full-text eligibility assessment, and final inclusion of relevant literature used in the review.

Thematic Coding and Synthesis

Selected studies were systematically coded into thematic clusters to enable cross-sectoral synthesis. Six major themes were developed:

Climate hazards and environmental change

Agricultural productivity and rural livelihoods

Poverty and inequality dynamics

Sanitation, water, and public health

Migration and demographic shifts

Policy pathways and resilience strategies

A narrative synthesis approach was then applied to identify recurring trends, causal linkages, evidence gaps, and emerging solutions. This thematic integration was particularly important because Bihar’s development challenges are multidimensional and cannot be understood through a single-sector lens. Shown in Table 1, the thematic organisation of selected literature.

Table 1. Thematic Classification of Literature Included in the Review

Theme	Focus Area	Typical Sources
Climate Hazards	Floods, droughts, heatwaves	Climate journals
Agriculture	Yield, irrigation, landholding	Agricultural journals
Poverty	MPI, livelihoods, inequality	Development journals
Sanitation	Water, hygiene, health	Public health journals
Migration	Labour movement, remittance	Social science journals
Governance	Policy, resilience planning	Policy reports

Quality Assurance and Reliability

To enhance reliability, preference was given to recent peer-reviewed articles, government statistical documentation, and data from internationally recognised organisations. Where possible, we triangulated findings from different sources. Competing data was critically analysed, not excluded.

The chosen review approach enhances the rigour of this manuscript by integrating evidence gathering with interpretation. It allows a comprehensive assessment of the interplay between climate change, agricultural vulnerability, poverty, sanitation issues and migration in Bihar. Additionally, the approach offers a template for conducting reviews of other developing areas.

Socioeconomic and Environmental Profile of Bihar

Bihar is situated in the eastern Indo-Gangetic Plain and is one of India's most populous but also least developed socioeconomically. It is densely populated, largely rural, heavily agriculture-dependent, frequently environmentally challenged, and relatively under-industrialised. These structural factors have contributed to the path of development in Bihar, and continue to determine priorities for poverty reduction, livelihoods and regional development (Kumar et al., 2026)

Demographic Pressure and Population Dynamics

Bihar is one of the most densely populated regions in India, with an estimated population of over 130 million. The pressure on scarce land resources affects housing, job creation, agricultural land fragmentation, the utilisation of natural resources, and the provision of public services. High population growth and a young population are mixed blessings. On the one hand, Bihar has a large labour force that can be tapped for future economic development; on the other hand, limited industrial growth and employment generation have limited the productive use of this labour force (Census of India, 2011; Government of Bihar, 2024). Demographic characteristics are also characterised by a continued reliance on rural economies, where the main sources of

household income are agricultural production, wage and informal labour and migratory work. This means that economic crises, crop loss or extreme climatic events can quickly lead to household vulnerability. Table 2 provides key demographic and environmental indicators.

Table 2. Key Socioeconomic and Environmental Indicators of Bihar

Indicator	Current Status	Development Implication
Population Size	Very High	Pressure on land, jobs, and services
Rural Population Share	High	Strong agrarian dependence
Farm Dependency	High	Climate-sensitive livelihoods
Industrialization Level	Low to Moderate	Limited formal employment
Flood Exposure	Severe in North Bihar	Recurrent disaster losses
Drought Risk	Moderate in South Bihar	Water stress and yield variability
Poverty Burden	Significant	Human development challenge
Migration Intensity	High	Remittance-based resilience
Youth Workforce	Large	Potential demographic dividend

Predominantly Rural Economy and Agricultural Dependence

Bihar is one of India's most rural states, with almost 80% of the population living in rural settings. Farmers play a pivotal role in livelihoods, food security and social life. Rice, wheat, maize, pulses, sugarcane, and vegetables are the major crops, and livestock and allied activities provide complementary earnings (Rigg et al., 2015). Yet the rural economy faces challenges of small and fragmented farms, a lack of mechanisation, market infrastructure, storage, and sensitivity to monsoon. Many farmers are small and marginal farmers with limited economies of scale and capitalisation. As a result, rural welfare continues to be highly dependent on climate, irrigation and agricultural markets (Sahoo & Moharaj, 2024).

Low Industrialization and Structural Transformation Constraints

Though infrastructure and connectivity have improved in recent years, Bihar remains relatively under-industrialised compared to many other states. Manufacturing contributes relatively low to state GDP, and there is a lack of large-scale formal jobs. The legacy of past investment, limited industrial agglomeration, energy shortages, and poor connectivity have all contributed to limited structural shifts (Sathe et al., 2025). The small industrial sector puts greater pressure on the agricultural and informal service sectors to generate employment. It also drives migration flows, as people move to urban areas such as Delhi, Mumbai,

Surat, and Ludhiana. So, by building on agricultural processing, rural industries, food value chains, and labour-intensive manufacturing, Bihar's economy could become a major driver of resilient and inclusive regional growth.

Riverine Floodplain Geography and Environmental Exposure

Bihar is heavily affected by its geophysical characteristics, both in food production and in its vulnerability to natural disasters. It is part of the fertile Ganga alluvial plain and is criss-crossed by major rivers descending from the Himalayas and the northern catchments. These include the Ganga, Kosi, Gandak, Bagmati, and Kamla Rivers. These river systems provide fertile soils, groundwater, and irrigation for agriculture, but also cause seasonal flooding, embankment breaches, silting, riverbed shifts, and waterlogging, particularly in northern Bihar districts. In contrast, southern districts face occasional drought-like situations. This "flood problem in the north and water scarcity in the south" leads to high spatial variability in vulnerability (Sinha & Jain, 2020).

Poverty Concentration and Development Deficits

While Bihar has made headway in reducing poverty over the past decade, it continues to have relatively high levels of multidimensional poverty. Poverty in Bihar is not just a problem of income; it is also connected to nutritional deficits, housing conditions, access to sanitation, educational levels, access to health care, and asset ownership (Gavali et al., 2023).

Districts with poor infrastructure, limited irrigation, high levels of landlessness, and vulnerability to natural disasters tend to be more deprived. Landless labourers, women-headed households, socially marginalised groups and areas vulnerable to climate change are more prone to poverty. Lack of access to roads, digital infrastructure, quality education and health care compounds the district-level inequalities. Figure 3 depicts the district-level inequalities in Bihar.

Youth Migration and Labour Mobility

Bihar households increasingly rely on migration for livelihood. Temporary and permanent inter-state migration offers livelihood diversification via remittances, particularly in situations where local jobs are limited. Many young people migrate for work in construction, manufacturing, transport, hospitality and services outside of Bihar (Diwakar et al., 2019; Sharma et al., 2025). Although migration can ease short-term economic pressures, it may also entail social costs, including separated families, agricultural labour shortages, precarious informal work, and vulnerability to economic shocks. The massive return migration during the COVID-19 crisis revealed the vulnerability of many families in Bihar to shocks in the external labour markets (Kumar et al., 2025).

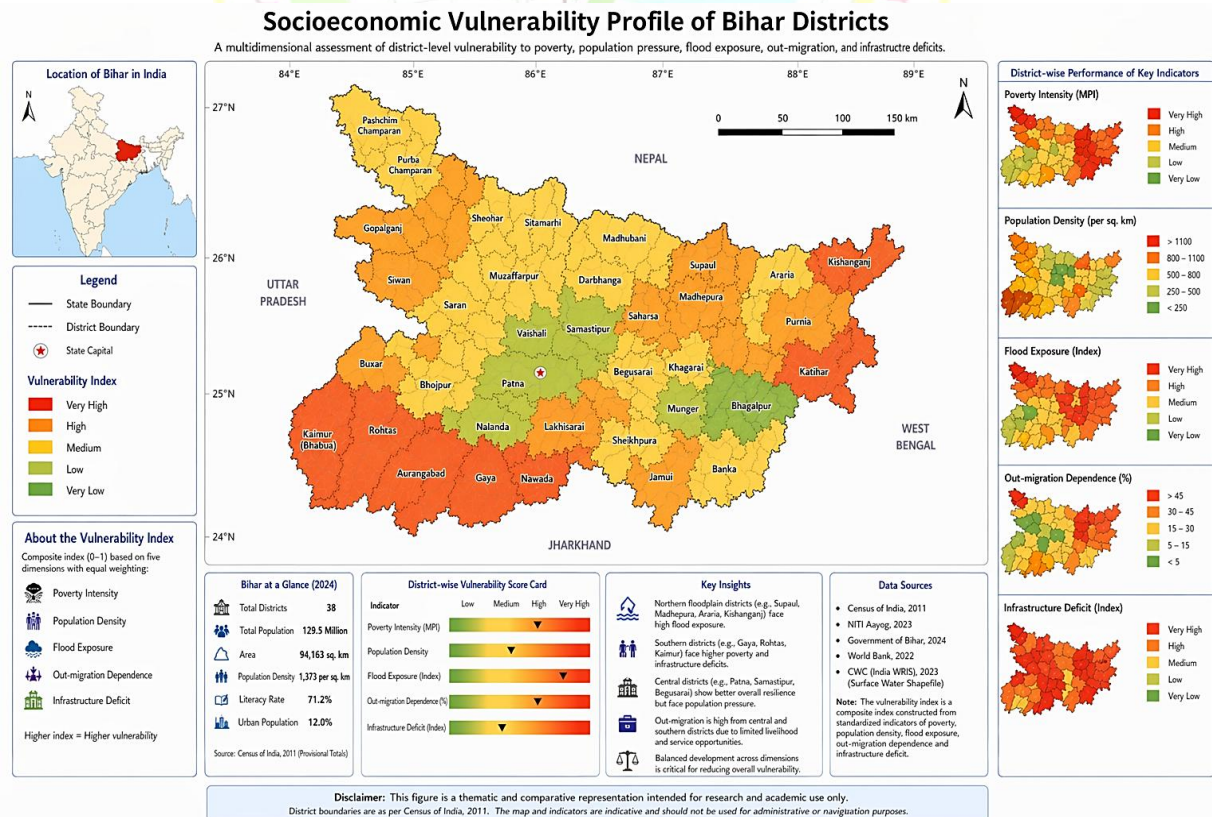


Figure 3. Socioeconomic Vulnerability Profile of Bihar Districts.

Regional Development Significance

While these limitations exist, Bihar has significant long-term development prospects in terms of its fertile land, labour endowments, geographic location between northern and eastern India, road infrastructure, and urbanisation and agricultural potential (Sinha et al., 2021). Through climate-proofing, modern irrigation, education and skill enhancement, sanitation and agro-industrialisation, Bihar could become a significant centre of growth in eastern India. Thus, a socioeconomic and environmental assessment of Bihar is crucial to understanding the complex interplay between climate risk, agricultural vulnerability, poverty, sanitation, and migration, as discussed in the following sections of this report.

Agriculture under Stress: Production Constraints and Climate Impacts

Bihar's rural economy continues to be heavily dependent on agriculture for livelihoods, food security and employment for a large proportion of people. While the state economy has been undergoing a transition, agriculture still remains a major socio-economic activity, especially in rural areas where there is a shortage of non-agricultural employment (Government of Bihar, 2024). Bihar plays a crucial role in the country's rice, corn, pulse, vegetable, fruit and nut production, and has a robust livestock economy (Bhardwaj et al., 2022). Yet agricultural productivity and profitability in the state are being threatened by structural inefficiencies, climate variability and change, land fragmentation, and poor market integration. Consequently, the agricultural sector in Bihar is a paradox of high productivity potential given fertile alluvial soils and ample labour supply and vulnerability, owing to production constraints and environmental risks. These multiple factors need to be understood in order to build climate-resilient and income-generating agricultural practices.

Structural Constraints in Bihar's Agricultural System

Small and Fragmented Landholdings: A major obstacle for agricultural development in Bihar is the widespread presence of small, fragmented plots. Many farms are classified as small or marginal and are often cultivated in scattered patches, which limit economies of scale, reduce the efficient use of machinery, increase transaction costs, and discourage investments in irrigation, soil health, and modern technology (Agricultural Census of India, 2021). While mechanisation has progressed in some areas, many farmers still rely on traditional, labour-intensive methods and lack access to modern machinery. Factors such as limited credit, high machinery costs, small landholdings, and irregular availability of custom services hinder the adoption of tractors, precision seeders, laser levellers, and post-harvest tools (Sinha et al., 2021). As a result, low mechanisation leads to delayed planting, labour-intensive farming, reduced efficiency, and greater vulnerability to climate risks such as untimely rains and heat waves.

Weak Market Chains and Price Volatility: Agricultural marketing systems in Bihar continue to face constraints, including fragmented supply chains, inadequate aggregation platforms, weak cold chain infrastructure, variable road connectivity in some rural areas, and dependence on intermediaries. These limitations reduce farmers' bargaining power and often lead to price realisation below market potential (Bhardwaj et al., 2022; Ahmed et al., 2024). Perishable crops, such as vegetables and fruits, are particularly vulnerable to market fluctuations. Seasonal gluts, transport bottlenecks, and a lack of processing facilities frequently result in post-harvest income losses.

Storage and Post-Harvest Losses: Insufficient storage infrastructure remains a significant challenge. Losses from grain storage, the perishability of horticultural products, pest damage, and inadequate packaging reduce net farm income. Bihar's expanding horticulture sector could greatly benefit from decentralised cold storage facilities, pack houses, grading systems, and agro-processing clusters (Kumar et al., 2025). Table 3 summarises the main production constraints and their related climate risks.

Table 3. Major Agricultural Constraints and Associated Climate Risks in Bihar

Constraint	Agricultural Impact	Climate Linkage
Small fragmented holdings	Low scale efficiency, low investment	Reduced adaptation capacity
Low mechanization	Delayed operations, high labour costs	Higher sensitivity to weather windows
Weak markets	Poor price realization	Post-disaster market disruption
Storage losses	Income erosion	Heat and humidity losses
Flooding	Crop destruction, soil erosion	Intense monsoon / river overflow
Drought	Yield decline, failed sowing	Rainfall deficit / dry spells
Heat stress	Reduced grain filling, labour stress	Rising temperature
Waterlogging	Root damage, disease spread	Prolonged inundation

Climate Risks and Environmental Hazards

Bihar is highly vulnerable to flooding because of rivers originating in the Himalayas and draining into the Ganges plain. Flooding of the Kosi, Gandak, and Bagmati Rivers and their tributaries regularly affects the districts of northern Bihar. Floods damage standing crops, delay sowing, damage rural infrastructure, remove topsoil, and cause waterlogging (Sinha & Jain, 2020). Waterlogging is particularly damaging to pulses, vegetables, and wheat during critical stages of crop development, while frequent floods reduce rural households' capacity to cope (Swargiary et al., 2025). In

contrast to the headline-grabber floods, southern and central Bihar experience occasional rain deficits and drought. Late monsoon onset, persistent dry spells and rainfall variability limit soil moisture and irrigation (Dasgupta et al., 2025).

Rising temperatures and heatwave events are emerging challenges for Bihar's agriculture. Heatwaves can impact wheat grain development during the reproductive period, hasten crop maturity, hinder maize pollination and diminish vegetable quality. Prolonged heat also impacts livestock and milk production, as well as human productivity. Monsoon irregularity is a major production risk factor (Zakaria et al., 2025). Rather than regular rainfall, farmers are now exposed to short, intense bursts of rainfall and dry periods. This makes it difficult for farmers to time planting, apply fertilisers, control weeds, and schedule irrigation. Major Crops and Sensitivity to Climate Stress: Rice, Wheat, Maize, Vegetables and Horticulture.

Socioeconomic Impacts of Agricultural Stress

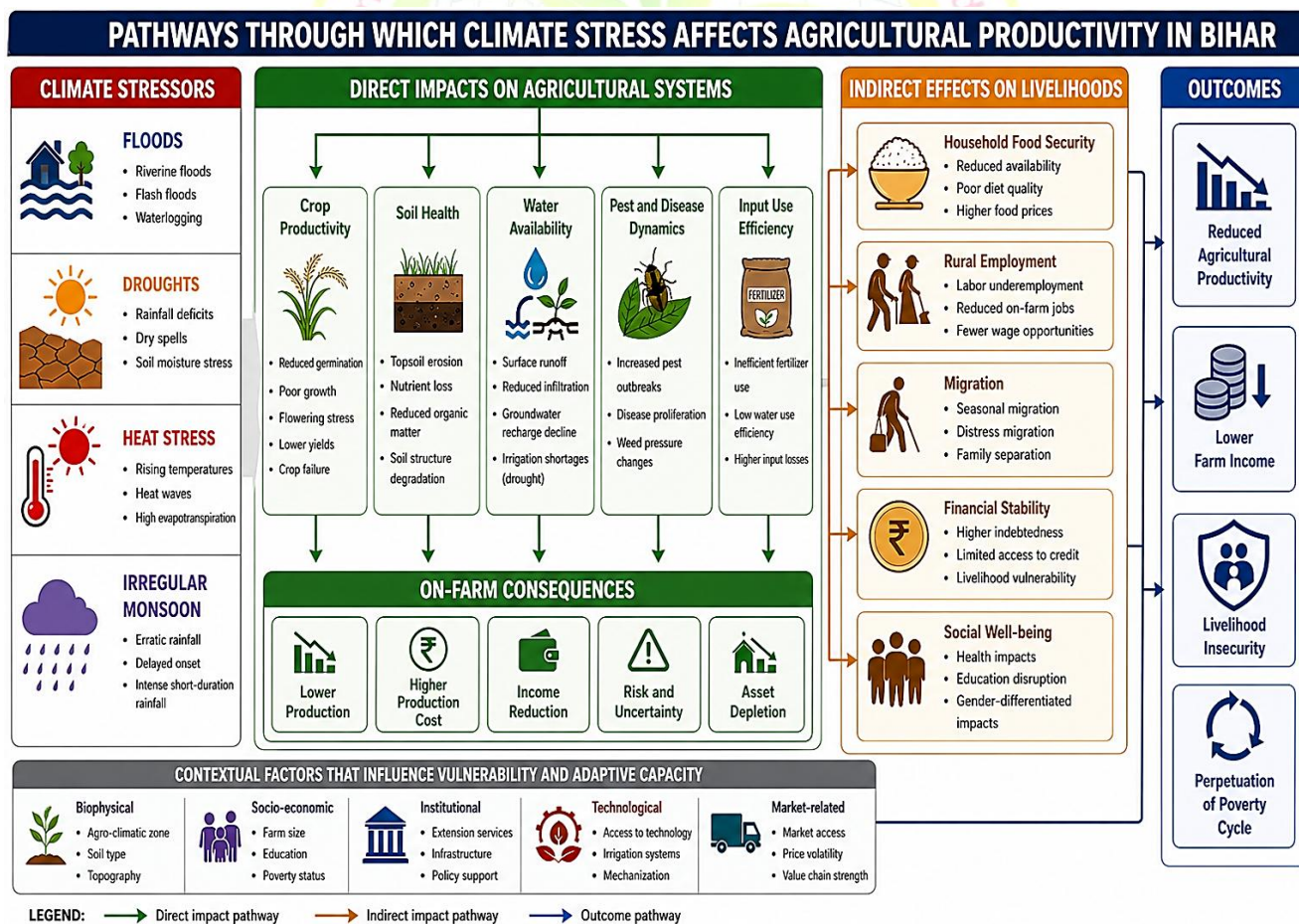
Agricultural vulnerability to climate change often has broader impacts on rural development. Agricultural failures decrease farmers' income, induce indebtedness, compromise food security and trigger seasonal labour migration. Women, tenant farmers, and landless labourers are also more vulnerable due to lower assets

and institutional support (Solomon et al., 2024). Between Figure 4, repeated production shocks may also discourage youth participation in farming, thereby accelerating agrarian transition without adequate alternatives.

Figure 4. Pathways through Which Climate Stress Affects Agricultural Productivity. Conceptual representation of direct and indirect impacts of floods, droughts, heat stress, and irregular monsoon behaviour on crop yield, soil health, labour productivity, input efficiency, farm income, and rural livelihood security in Bihar.

Poverty, Sanitation and Public Health Nexus

Poverty, inadequate sanitation, and poor public health outcomes remain deeply interconnected development challenges in Bihar. Although Bihar has recorded measurable progress in income growth, infrastructure expansion, and multidimensional poverty reduction over the past decade, a substantial proportion of households—particularly in rural and socially vulnerable districts—continue to experience overlapping deprivations related to housing quality, nutrition, water access, healthcare availability, and livelihood security (Behera et al., 2025). These conditions often reinforce one another, creating a cycle in which poverty limits access to safe living



environments, while disease burdens and productivity losses further deepen economic vulnerability.

The relationship between poverty and sanitation is especially significant in Bihar due to the state's high rural population density, flood-prone settlements, reliance on informal employment, and uneven infrastructure delivery. In such contexts, sanitation is not merely an engineering issue; it is closely linked with nutrition, child development, labour productivity, women's dignity and safety, educational continuity, and household resilience.

Multidimensional Nature of Poverty in Bihar

Poverty in Bihar extends beyond low household income and is more accurately understood through a multidimensional lens. Households may face simultaneous disadvantages in housing, nutrition, schooling, sanitation, healthcare access, and productive assets. Rural family's dependent on seasonal agriculture or casual labour often experience fluctuating incomes, making them highly sensitive to climate shocks, illness, or food price inflation (Rana et al., 2025).

Income Deprivation: Low and unstable incomes remain a key driver of vulnerability. Households with limited landholdings, irregular wage opportunities, or dependence on migration often struggle to invest in sanitation facilities, clean fuels, education, or preventive healthcare. Even short-term shocks such as crop failure or medical expenses can push vulnerable families into debt traps (Behera et al., 2025).

Housing Quality: Many economically weaker households reside in semi-permanent or poorly serviced settlements with inadequate drainage, overcrowding, weak roofing, and unsafe water storage conditions. Such environments increase exposure to vector-borne diseases, heat stress, indoor pollution, and flood damage (Rana et al., 2025).

Nutrition Insecurity: Nutrition deprivation remains a major concern, particularly among women and children. Low dietary diversity, periodic food insecurity, poor maternal health, and recurrent infections can lead to stunting, anaemia, and undernutrition. Disease and malnutrition often interact in a two-way cycle in which poor health reduces nutrient absorption, and poor nutrition increases susceptibility to illness (NFHS-5, 2021; Diwakar et al., 2019).

Education Access: Educational deprivation is both a cause and a consequence of poverty. Poor sanitation in schools, household labour burdens, illness-related absenteeism, and economic stress can interrupt learning outcomes, especially among girls and children in vulnerable communities. The principal interconnections among poverty, sanitation deficits, and health burdens are summarised in Table 4.

Table 4. Interconnections among Poverty, Sanitation Deficits, and Health Burdens in Bihar

Dimension	Key Challenge	Likely Consequence
Income Poverty	Low and unstable earnings	Inability to afford sanitation, healthcare, and nutrition
Housing Poverty	Congestion, weak drainage	Higher disease exposure
Water Access	Unsafe or contaminated supply	Diarrhoea, infection burden
Sanitation Gaps	Poor toilets, open wastewater	Environmental contamination
Nutrition Deficit	Low dietary quality	Stunting, anaemia, weak immunity
Illness Burden	Frequent disease episodes	Wage loss, medical debt
Education Disruption	Illness / poor facilities	Lower human capital formation
Climate Exposure	Flood-damaged systems	Repeated vulnerability cycle

Sanitation Issues and Environmental Health Risks

While there have been significant strides in improving sanitation through national programs, Bihar continues to face challenges in maintaining safe sanitation practices, managing wastewater, and providing clean living environments. Simply scaling up infrastructure development does not necessarily lead to sustainable, safe, and quality use. **Open Drains and Stagnant Wastewater:** Open drains, wastewater accumulation and inefficient stormwater drainage systems still plague many rural and peri-urban areas. This leads to mosquito breeding, potential water contamination, and enteric infections (UNICEF India, 2023). **Drinking Water Contamination:** Contaminated drinking water is a problem in some districts due to microbial contamination, inadequate storage, shallow groundwater risks, and local water quality issues (such as arsenic or iron) in some areas of the Gangetic plain. Flooding increases the risk of contamination from overflowing latrines and from surface water contamination of domestic water.

Flood-Damaged Sanitation Systems: Annual flooding often damages toilet systems, septic tanks, drains, handpumps and pathways. Flooding can undermine sanitation progress by destroying safe containment practices and precipitating a temporary return to unsafe practices. **Solid Waste Management Gaps:** Expanding towns and market towns produce ever-increasing solid waste streams, but segregation, collection and scientific disposal systems are not well developed in many small towns and rural growth centres. Poor handling leads to blocked drains, pollution and disease.

Health Consequences of Poverty and Mal-Sanitation

Contaminated water, poor hygiene and poor sanitation are associated with risks of diarrhoea, gastroenteritis,

typhoid and parasitic diseases. Infants and young children (aged less than five) are particularly at risk of recurrent infections that can affect growth and development (WHO, 2023). Frequent infections decrease nutrient absorption and improve appetite, exacerbating vulnerable nutritional status. Iron deficiency anaemia is common among women and adolescent girls, with children suffering from chronic undernutrition. Poor sanitation, unsafe drinking water and limited healthcare services result in poor maternal and infant outcomes (Sinha et al., 2021). And illness increases women's caregiving burden. Impacts on labour productivity. For casual labourers, farmers, and migrants, illness results in a loss of daily earnings. Frequent health costs also compete with resources for education, agricultural and productive investments.

5.4 Social and Gendered Aspects of Sanitation Poverty
Sanitation inequality can disproportionately impact women and girls, the elderly, and the disabled. Privacy concerns, insecurity of toilet facilities, constraints on menstrual hygiene, and water collection can lower dignity, safety, and time to participate in education and livelihoods. Disparities in infrastructure access and service delivery may also affect socially marginalised groups.

Climate Change, Sanitation and Health

Climate variability intensifies existing vulnerabilities. Floods harm sanitation infrastructure and water supply, and droughts diminish water for hygiene and cleaning.

Heatwaves may aggravate water scarcity and health risks in overcrowded settlements. So, in Bihar, climate adaptation strategies need to consider the resilience of sanitation and public health, not as silos (Tang et al., 2023; Fang et al., 2020; Diwakar et al., 2019). Figure 5 shows how a vicious cycle is perpetuated

Figure 5. Poverty–Sanitation–Health Cycle in Vulnerable Rural Households.

This conceptual feedback loop illustrates how low income, poor housing, unsafe water, weak sanitation, disease burden, medical expenditure, reduced labour productivity, and child undernutrition interact to perpetuate multidimensional poverty among vulnerable households across Bihar.

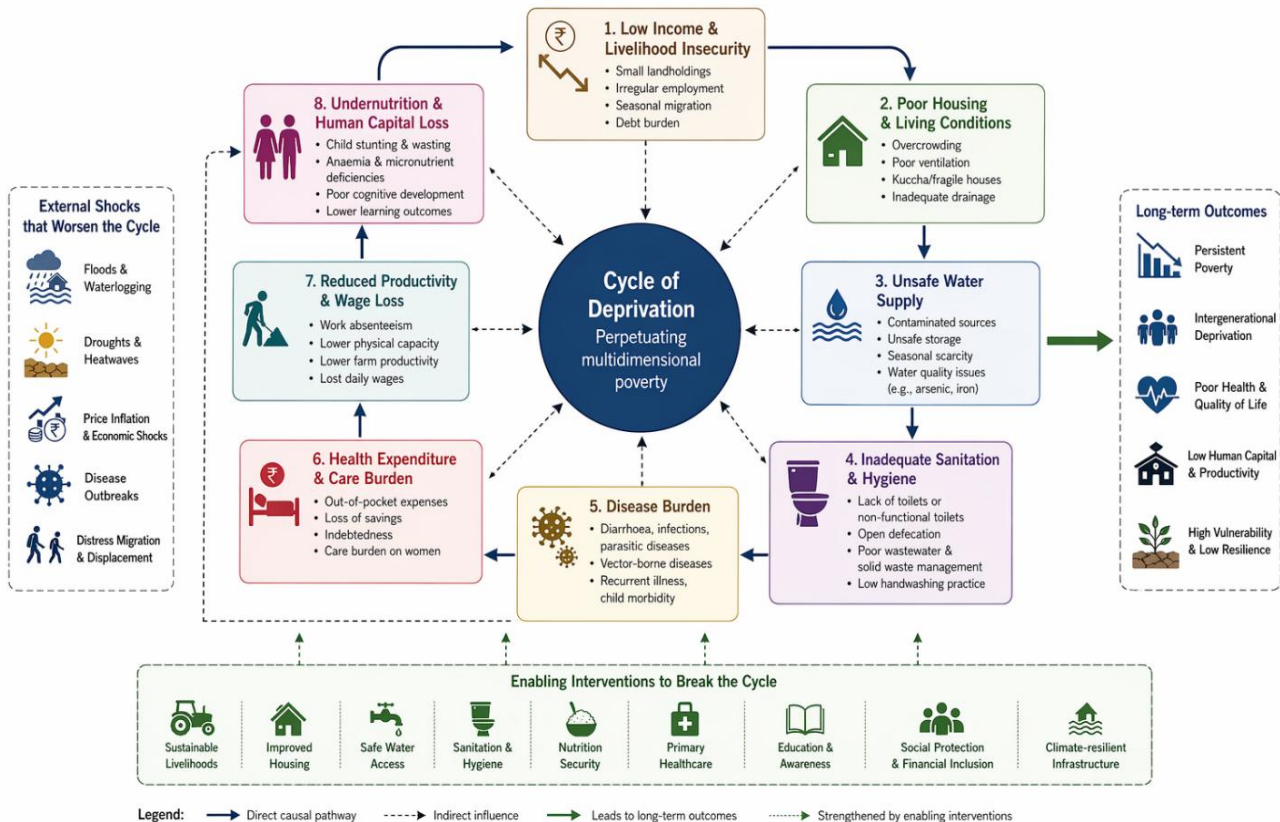
These overlapping sanitation and health vulnerabilities frequently extend beyond immediate public health impacts and increasingly influence labour mobility decisions. Repeated disease outbreaks, medical debt, and declining livelihood security often contribute to seasonal and long-term migration among vulnerable rural households.

Integrated avenues for improvement

Bihar's approach to climate change must promote parallel initiatives to reduce poverty, provide sanitation and safe water, and improve nutrition and health. Priority interventions include:

- climate-proof toilets and drains
- safely piped water with quality checks
- decentralised wastewater management

Poverty–Sanitation–Health Cycle in Vulnerable Rural Households (Bihar)



Source: WHO (2023); UNICEF (2022); World Bank (2022); NITI Aayog (2023); MoHUA (2023); NFHS-5 (2021); CGWB (2022); Secondary literature and field reports.

- nutrition-sensitive social protection
- school WASH programmes
- women's groups for community sanitation
- digital disease surveillance
- flood-resilient village infrastructure
- living conditions for vulnerable families
- Multidomain investments can yield benefits in health, productivity, education, and poverty reduction.

Mobility, Livelihoods and Social Vulnerability

Bihar has a long history of migration. For generations, out-migration has served as a survival and livelihood strategy for households grappling with a shortage of local employment, agricultural crises, frequent flooding, seasonal wage uncertainties and poverty. For many districts, migration is not just an economic choice for individuals but a survival mechanism for households and rural social structures (Deshingkar & Akter, 2009).

Continuing migration in Bihar is a result of a combination of push factors, such as underemployment, small landholdings, climate change, and reduced demand for rural industries, and pull factors, such as wage opportunities, urbanisation, urban labour markets, construction, and the service sector in other states. As a result, migration has transformed livelihoods, family life, labour dynamics, gender relations and social dynamics in rural Bihar.

Rural Coping through Seasonal Labour Migration

For many low-income households in Bihar, seasonal labour migration is a popular livelihood strategy. In the off-season or after droughts and floods, labourers frequently migrate seasonally to cities and industrial hubs such as Delhi, Mumbai, Surat, Ludhiana, and Bengaluru to find work in construction, transport, hospitality, manufacturing, and informal services (Keshri & Bhagat, 2012; Ahmed et al., 2024).

Seasonal migration offers rural households a critical additional source of income to meet consumption needs. Remittances are often spent on food, loan repayments, education fees, home repairs, and agricultural inputs. But such migration is often associated with precarious working conditions, low remuneration, lack of social protection and health care. The key causes and impacts of migration in Bihar are outlined in Table 5.

Youth Migration and Human Capital Flight

Bihar has a high proportion of young adults among its migrants. The lack of industrial jobs, weak local enterprise ecosystems, and low-wage employment in rural districts incentivise young people to migrate. Even if migration offers opportunities for skills exposure and income mobility, young migrants' departure may undermine local economic activity and produce long-term demographic consequences (Rajan & Saxena, 2020).

Dependence on Remittances and Household Livelihoods

Remittances are important to the rural economy of Bihar. Remittances serve as a buffer for many

households, facilitating consumption smoothing, health care expenditures, education, household improvement, weddings and investments in agriculture. In some households, remittances have become a more secure source of income than farming, especially in climate-vulnerable regions (Tumbe, 2018). But over-reliance on remittances also poses risks. Economic and labour-market shocks, pandemics, or construction booms and busts in host cities can significantly affect households' incomes. The exodus of returning migrants during the COVID-19 pandemic underlines the vulnerability of migration dependence.

Table 5. Drivers and Development Implications of Seasonal Labour Migration in Bihar

Dimension	Key Factors	Development Implication
Economic Push	Underemployment, low wages	Seasonal labour outflow
Agrarian Stress	Small holdings, crop losses	Distress migration
Climate Risk	Floods, droughts, heat stress	Temporary and repeated migration
Urban Pull	Higher wages, labour demand	Inter-state migration flows
Remittances	Income transfers to households	Consumption smoothing
Gender Change	Male migration	Feminisation of agriculture
Social Cost	Family separation, insecurity	Reduced resilience
Opportunity	Skills, savings, networks	Potential upward mobility

Agriculture Feminisation and Gender Transformations

Outmigration of men has led to the feminisation of agriculture in many regions of Bihar. With men leaving for employment, women increasingly take on the roles of managing crops, livestock, household income, agricultural inputs, and resource management in the community. Such a shift can offer opportunities for women to exercise their agency and lead, but it can also exacerbate underpaid work (Agarwal, 2018). Women farmers face limitations in landholdings, credit, extension, machinery, irrigation assets, and market opportunities. Building women-focused agricultural institutions, self-help groups, and training is not only key to inclusive rural development.

Rural Households with Elderly or Women

Female-headed or elderly-headed households remain in the source regions of migration. Remittances may boost household incomes, but caregiving responsibilities, labour shortages and decision-making pressures increase. Older family members might experience difficulties in health care, mobility and farm labour, particularly during climatic shocks and disasters. Female-headed households may also experience empowerment, but also face social stigma, labour pressures and institutional marginalisation. These trends show that migration is not a universally positive outcome (Jana et al., 2022).

Climate and Agrarian Drivers of Migration

Environmental stress has become an increasingly important contributor to migration decisions in Bihar. Recurrent floods in northern districts damage crops, housing, roads, and local employment opportunities. In southern and central districts, rainfall variability, groundwater stress, and declining farm profitability can

also encourage labour mobility. Migration is therefore often linked not only to poverty but to climate-sensitive livelihood insecurity (Black et al., 2011). Figure 6 illustrates the interconnected pathways that link climate stress, agrarian change, migration flows, and livelihood outcomes.

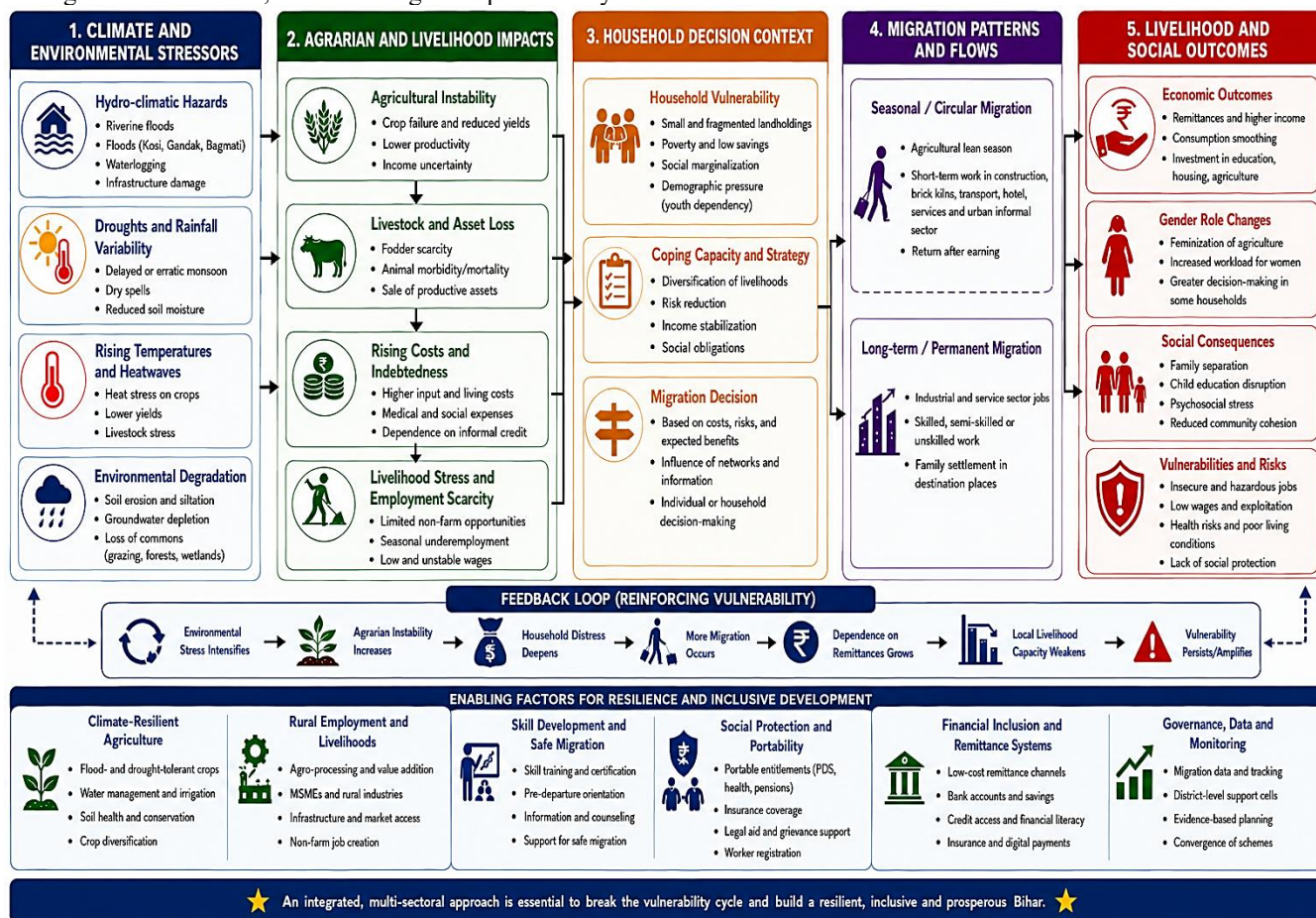


Figure 6. Climate and Agrarian Drivers of Migration in Bihar: A Conceptual Framework

This Conceptual framework illustrates how climate shocks, agricultural instability, household vulnerability, and labour demand stimulate seasonal and long-term migration from Bihar, while remittances, social change, and policy interventions influence long-term resilience outcomes. The interaction can be summarised as:

Climate Shock → Crop Loss → Income Stress → Debt → Labour Migration → Remittance Dependence → Social Restructuring

This pathway suggests that migration in Bihar should be viewed within a broader resilience framework rather than solely as a labour-market phenomenon.

Social Resilience Challenges

Although migration can reduce short-term poverty, it also creates several resilience challenges: family separation and Psychosocial Stress: School Discontinuity among children in mobile households Insecure housing and health risks for migrants in destination cities

Reduced agricultural labour availability in villages dependence on volatile urban labour markets unequal benefits across caste, class, and gender groups These factors became especially visible during the COVID-19 crisis, when reverse migration exposed the fragility of informal labour systems.

Pathways for Inclusive and Resilient Mobility

A forward-looking strategy for Bihar should not aim to eliminate migration, but to make mobility safer, more productive, and less distress-driven. Priority measures include:

- rural job creation through agro-processing and MSMEs
- climate-resilient agriculture to reduce distress migration
- portable social protection for migrant workers
- skill development linked to formal labour markets
- women farmer support programmes
- digital remittance and financial inclusion systems

- district migration monitoring cells
- returnee entrepreneurship schemes

Such measures can transform migration from a survival necessity into a pathway for dignified economic mobility.

Integrated Resilience Pathways: Technology, Governance and Policy

The multidimensional challenges facing Bihar—including climate risk, agricultural fragility, poverty, sanitation deficits, labour migration, and uneven infrastructure—cannot be resolved through isolated sectoral policies. These pressures interact across households, landscapes, and institutions, requiring a coordinated resilience framework that integrates economic opportunity, environmental sustainability, human development, and governance capacity. In this context, resilience refers not only to recovery from floods, droughts, disease outbreaks, and market shocks, but also to the long-term transformation of vulnerable systems into adaptive and inclusive development pathways (UNDRR, 2022). With fertile alluvial resources, a large labour force, expanding connectivity, and rising digital penetration, Bihar possesses significant potential to emerge as a resilient growth hub in eastern India. Realizing this opportunity, however, requires targeted investment, institutional coordination, and technology-enabled governance.

Climate-Smart Agricultural Transformation

Agriculture remains central to Bihar's economy and employment structure. Strengthening farm resilience can generate broad benefits for food security, rural income stability, and poverty reduction.

Adaptive Production Systems: Future agricultural policy should promote stress-tolerant crop varieties, climate-adjusted sowing calendars, integrated nutrient management, conservation agriculture, and agroforestry. Flood-tolerant rice, drought-resilient maize, and heat-tolerant wheat varieties can reduce production volatility under changing climate conditions (FAO, 2022).

Efficient Water Management: Given rising rainfall uncertainty, irrigation modernisation is essential. Solar pumps, drip systems, sprinkler irrigation, laser land levelling, and sensor-guided scheduling can improve water productivity while lowering energy costs (ICAR, 2023).

Diversification and Value Addition: Overdependence on cereal systems increases vulnerability. Diversification toward pulses, oilseeds, vegetables, fruits, fisheries, dairy, and fodder systems can strengthen nutrition security and income resilience. Parallel investments in storage, cold chains, grading centres, agro-processing, and farmer-producer organisations (FPOs) can reduce post-harvest losses and increase farm profitability. Priority cross-sector interventions are summarised in Table 6.

Table 6. Priority Interventions for Resilient Development in Bihar

Sector	Priority Intervention	Expected Benefit
Agriculture	Climate-smart farming	Stable yields under climate stress
Water	Precision irrigation	Higher water productivity
Markets	Storage and cold chains	Reduced post-harvest loss
Governance	GIS vulnerability mapping	Better planning and targeting
Disaster Risk	Early warning systems	Reduced hazard losses
Insurance	Crop risk transfer	Income stability
Sanitation	Flood-resilient toilets	Lower contamination risk
Health	Safe drinking water systems	Reduced disease burden
Livelihoods	MSMEs and skill development	Local employment growth
Social Policy	Portable welfare for migrants	Greater household security

Governance Modernisation and Risk Intelligence

Physical infrastructure alone is insufficient without effective institutions. Governance systems must anticipate risks, coordinate responses, and allocate resources efficiently.

Spatial Decision Support: District- and block-level GIS vulnerability mapping should identify hotspots of flooding, drought stress, poverty concentration, migration dependence, and sanitation gaps. Such systems can support evidence-based planning and faster emergency response.

Early Warning Systems: Expansion of weather advisories, river flood forecasting, heatwave alerts, and mobile-based farmer communication networks can significantly reduce human and economic losses, especially among smallholders and vulnerable settlements (WMO, 2023).

Smart Risk Protection: Crop insurance systems should improve transparency, enrollment coverage, and settlement speed. Integration of satellite imagery, weather-index triggers, and digital claims systems can increase credibility and effectiveness.

Integrated Public Dashboards: Linked databases across agriculture, health, water, migration, and disaster management departments can help Bihar transition toward real-time governance and coordinated decision-making.

Water, Sanitation and Public Health Security

Public health resilience is foundational to economic resilience. Poor sanitation and unsafe water rapidly undermine labour productivity, educational continuity, and poverty-reduction gains. Flood-prone districts require raised toilets, sealed containment systems, sludge management services, and drainage-compatible sanitation design. Piped treated water, decentralised purification systems, arsenic-safe supply networks, and

household filtration systems can substantially reduce disease burdens in vulnerable communities (UNICEF, 2023).

Livelihood Diversification and Inclusive Growth

Reducing structural vulnerability requires stronger non-farm employment systems and more diversified household income sources. Agro-processing, dairy, textiles, food services, logistics, renewable energy maintenance, and digital commerce can create jobs closer to home. Targeted skill development linked with formal labour markets, green jobs, construction safety, agri-tech, and entrepreneurship can convert Bihar's youthful population into a productive demographic dividend. Migrant workers require portable access to food entitlements, health insurance, pensions, and emergency assistance across states. Self-help groups, women producer collectives, access to digital finance, and support for land rights can significantly strengthen household resilience and inclusive development. Mechanisms such as the One Nation One Ration Card (ONORC) system, Ayushman Bharat portability, e-Shram registration platforms, and interstate social protection databases can significantly improve welfare continuity and social security for migrant households.

Financing and Institutional Convergence

Long-term resilience requires sustained financing mechanisms and administrative convergence. Public spending should be complemented by private investment, climate finance, development banks, CSR participation, and blended finance instruments.

Integrated framework linking climate-smart agriculture, water security, sanitation, public health, livelihood diversification, digital governance, social protection, disaster risk reduction, and ecosystem restoration to achieve inclusive and climate-resilient development in Bihar by 2047.

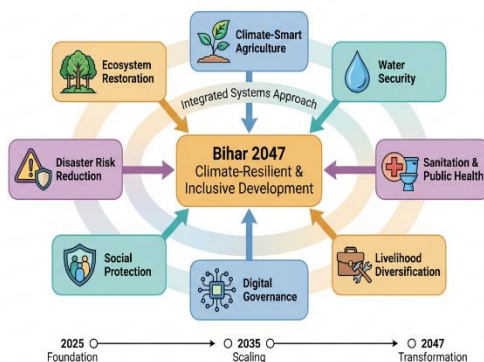


Figure 7. Multi-Sector Resilience Roadmap for Bihar 2047.

Institutional coordination among agriculture, rural development, water resources, health, disaster management, and urban departments can improve implementation efficiency. District-level resilience missions may provide an operational platform for integrated action. In Figure 7, a systems-level roadmap for Bihar's transformation is presented. Establishing district-level resilience missions involving agriculture, water resources, health, rural development, and disaster management departments can help break institutional silos and support coordinated climate adaptation planning across Bihar.

Integrated framework linking climate-smart agriculture, water security, sanitation, public health, livelihood diversification, digital governance, social protection, disaster risk reduction, and ecosystem restoration to achieve inclusive and climate-resilient development in Bihar by 2047.

Bihar 2047: Strategic Transformation Priorities

As India advances toward the vision of *Viksit Bharat 2047*, Bihar can become a major contributor if resilience planning is embedded within a long-term development strategy. Priority goals should include:

- elimination of extreme poverty through livelihood growth
- climate-resilient agriculture at scale
- universal safe water and sanitation
- youth-led enterprise and skills expansion
- data-enabled governance systems
- reduction of distress migration
- resilient infrastructure in hazard-prone districts
- women-led inclusive development
- ecosystem restoration and groundwater security

If pursued consistently, Bihar can transition from a climate-vulnerable state to a resilient economic growth engine for eastern India.

Research Gaps and Future Directions

Despite increasing policy attention and a growing body of literature on agriculture, climate vulnerability, poverty, sanitation, and migration in Bihar, major knowledge gaps remain. Existing studies are often sector-specific, geographically fragmented, or based on short-term datasets, limiting their ability to explain the interconnected nature of Bihar's development challenges. Many district-level disparities are insufficiently documented, and dynamic interactions among climate shocks, livelihoods, health outcomes, and migration are still poorly quantified. Addressing these gaps is essential to designing evidence-based, future-ready development pathways (Aiswarya et al., 2026). Future research should move beyond descriptive assessments toward integrated, predictive, and decision-support approaches that combine geospatial analytics, machine learning, econometrics, climate science, and participatory policy research. Bihar offers a valuable case study for understanding how densely populated agrarian regions can adapt to climate stress while pursuing inclusive growth.

Need for High-Resolution Spatial Intelligence

Most available studies rely on state-level averages or limited district statistics, which often conceal substantial intra-state heterogeneity. Northern flood-prone districts, central agrarian belts, and southern drought-prone regions exhibit distinct risk profiles and development trajectories. Therefore, future work should prioritise block-level and village-level spatial intelligence systems. Summarised in Table 7, the major emerging research priorities for Bihar's sustainability studies.

Table 7. Emerging Research Priorities for Bihar Sustainability Studies

Priority Theme	Key Research Need	Potential Application
Poverty Analytics	AI-based district poverty mapping	Better targeting of welfare schemes
Flood Risk	Satellite inundation and crop loss mapping	Disaster compensation and planning
Agriculture	Climate-yield simulation models	Adaptation strategies for crops
Migration	Forecasting labour mobility systems	Portable welfare and employment planning
Sanitation	Sustainability and resilience models	Long-term WASH investments
Governance	Bihar District Resilience Index	District priority ranking
Water Security	Groundwater and recharge modelling	Irrigation planning
Youth Economy	Skills and entrepreneurship transitions	Employment generation

Machine learning and remote sensing can be used to estimate multidimensional poverty patterns using indicators such as night-time lights, road connectivity, housing materials, vegetation stress, settlement density, and service accessibility. Such approaches can complement conventional survey data and improve real-time poverty targeting (Jean et al., 2016). There is a strong need for a composite Bihar District Resilience Index integrating climate exposure, agricultural productivity, migration intensity, sanitation coverage, infrastructure access, health indicators, and governance readiness. This tool would support priority ranking and resource allocation across districts.

Climate, Agriculture and Geospatial Research Priorities

Bihar's recurrent floods require near-real-time monitoring systems using NASA and European Space Agency satellite datasets (e.g., Sentinel, Landsat, MODIS). Future studies should integrate flood inundation mapping with crop calendars, soil moisture, and yield-loss estimation to more accurately quantify economic damage (Bharadwaj et al., 2022). There is limited district-scale application of crop simulation models such as DSSAT, APSIM, and hybrid AI-model ensembles for Bihar. Future applications of DSSAT and APSIM models should focus on evaluating crop responses under altered monsoon behaviour, heat stress scenarios, irrigation constraints, and adaptation interventions such as altered sowing windows, drought-tolerant cultivars, precision irrigation, and nutrient

optimisation. Integration of remote sensing datasets and machine learning algorithms with crop simulation frameworks can substantially improve district-level yield forecasting and climate-risk assessment.

Migration, Labour and Demographic Forecasting

Migration from Bihar is often analysed descriptively, but predictive systems remain underdeveloped. Future work should build district-level migration forecasting models using employment trends, rainfall anomalies, crop losses, wages, transport connectivity, and urban labour demand. Such systems could help anticipate seasonal labour movement and improve portability of welfare services (Sharna et al., 2024). There is insufficient evidence on changing aspirations of Bihar's youth, digital labour readiness, return migration entrepreneurship, and the transition from low-skilled labour to knowledge-based employment sectors.

Sanitation, Health and Social Infrastructure Research

Rural Sanitation Sustainability Models: While toilet construction has improved access, long-term sustainability, sludge management, water availability, behaviour change, and climate resilience remain understudied. Future studies should evaluate which sanitation models remain functional under flood-prone and water-scarce conditions (Bhaumic & S.K., 2022).

Disease–Environment Linkages: More integrated epidemiological studies are needed to quantify how flooding, heatwaves, wastewater exposure, and drinking-water quality affect disease burdens across Bihar (Wani & S.P., 2023).

Gendered Infrastructure Access: Research should examine whether women, older adults, and socially marginalised groups have equitable access to sanitation, healthcare, transport, and digital services (Sinha et al., 2022).

Data Systems, Methodological Frontiers and Policy Innovation

A major obstacle to advanced research in Bihar is the fragmented and inconsistent access to data. To make progress, interoperable district databases are needed that encompass agriculture, health, climate, migration, and infrastructure. When used transparently and ethically, artificial intelligence can aid in beneficiary targeting, flood early warning systems, crop insurance verification, and improving service delivery. Future governance research should focus on establishing district innovation labs where communities, universities, and government agencies collaborate to co-create local resilience strategies. These methods can greatly enhance forecasting accuracy and policy relevance. Figure 8 shows the proposed architecture for next-generation interdisciplinary research.

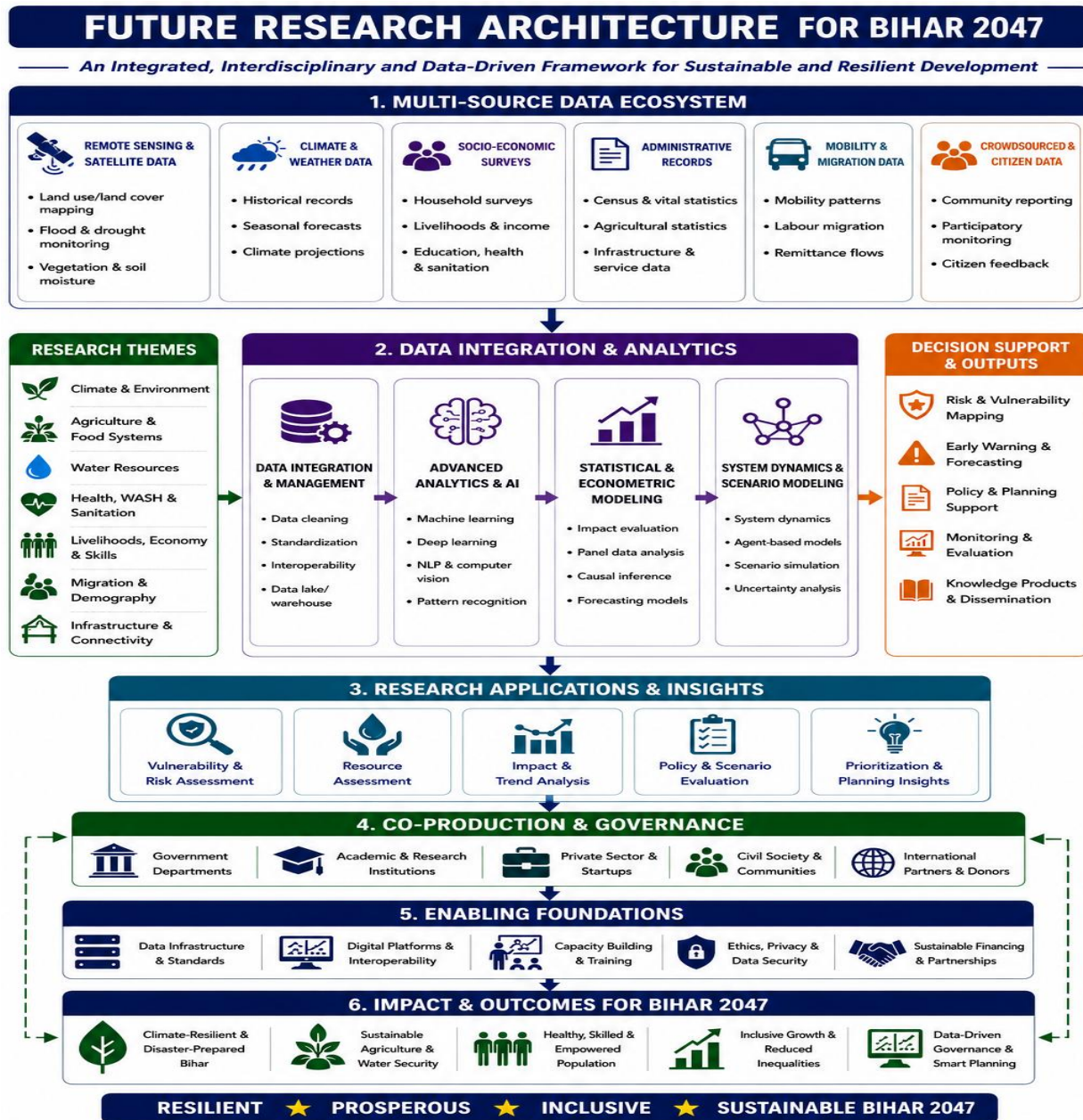


Figure 8. Future Research Architecture for Bihar 2047.

This Conceptual framework linking AI analytics, remote sensing, climate modelling, migration forecasting, sanitation sustainability, governance innovation, and district resilience assessment to guide next-generation sustainability research and evidence-based planning in Bihar.

Strategic Outlook

If these research priorities are systematically pursued, Bihar can become a national laboratory for climate-resilient development, rural transformation, and data-driven governance (Singh et al., 2022). The state's combination of demographic scale, agricultural importance, climate exposure, and development transition makes it uniquely positioned to generate policy lessons relevant not only to India but also to other densely populated agrarian regions of the Global South.

CONCLUSION

Bihar stands at a decisive stage of development where poverty, agricultural vulnerability, climate extremes, inadequate sanitation, livelihood insecurity, and persistent migration pressures interact in mutually reinforcing ways. These challenges do not operate independently; together, they influence household welfare, labour productivity, food systems, public health, and long-term regional transformation. The evidence synthesised in this review demonstrates that Bihar's development trajectory cannot be adequately

understood through single-sector perspectives. Instead, it requires an integrated systems framework that recognises the close interconnections among environment, economy, infrastructure, and social well-being. Agriculture remains central to Bihar's economy and employment base, yet the sector continues to face recurrent floods, drought stress, rising temperatures, fragmented landholdings, weak market integration, and post-harvest inefficiencies. At the same time, multidimensional poverty, sanitation gaps, health burdens, and uneven access to basic services continue to constrain human development across several districts. Migration has become both a coping strategy and an income-support mechanism through remittances, but it also reflects unresolved structural limitations in local employment generation and rural diversification. Despite these constraints, Bihar possesses substantial comparative strengths that can support accelerated progress. Fertile alluvial soils, groundwater and river resources, a large youthful population, improving transport connectivity, expanding digital access, and growing entrepreneurial potential provide a strong foundation for transformation. If effectively leveraged, these assets can reposition Bihar from a vulnerability hotspot to a resilient growth engine of eastern India.

A central finding of this review is that Bihar's future progress depends on integrated resilience planning. Climate-smart agriculture, water security, sanitation modernisation, public health strengthening, livelihood diversification, women-led inclusion, migrant welfare portability, ecosystem restoration, and digital governance should be pursued as mutually reinforcing pillars rather than disconnected policy domains. Spatial targeting through GIS platforms, early warning systems, real-time data dashboards, and district resilience indices can significantly improve planning efficiency and resource allocation. The review also identifies important research opportunities. Bihar offers a valuable living laboratory for interdisciplinary scholarship on climate adaptation, rural transformation, migration systems, geospatial governance, and inclusive development pathways. Future studies should increasingly apply remote sensing, machine learning, crop simulation modelling, econometric forecasting, participatory planning, and scenario-based assessment to support evidence-driven policy under changing climatic and socioeconomic conditions. Looking toward the national vision of *Viksit Bharat 2047*, Bihar's transformation will be nationally significant. Progress in Bihar would contribute substantially to India's goals of food security, poverty reduction, employment generation, climate resilience, and balanced regional development. Conversely, persistent vulnerabilities in Bihar would continue to constrain broader national progress. In conclusion, Bihar should not be viewed solely through the lens of developmental deficits. It should be recognized as a high-potential transition region where strategic investment, scientific planning, institutional convergence, and inclusive governance can generate

large-scale social and economic returns. With sustained commitment and innovation, Bihar can emerge as a leading example of resilient, prosperous, and equitable development across the Global South.

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CRedit Author Statement

Roshan Kumar Mishra: Conceptualization, Methodology, Literature Review, Visualization, Writing – Original Draft. Pashupati Nath Singh: Supervision, Conceptualization, Data Curation, Validation, Writing – Review & Editing, Visualization, Framework Development. Shubha Shivani: Investigation, Literature Compilation, Writing – Review & Editing. Rahul Kumar: Data Interpretation, Policy Analysis, Validation, Writing – Review & Editing. All authors have read and approved the final version of the manuscript.

Data Availability Statement

This study is a review-based synthesis and does not involve the generation of primary experimental datasets. All data and information used in this study were obtained from publicly available peer-reviewed literature, government reports, institutional publications, and open-access databases cited appropriately within the manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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