Climate-Resilient Agriculture in Begusarai: Bridging Policy and Practice for Sustainable Development

WHITE PAPER

on

Climate Resilience and Sustainable Livelihood in Aspirational Districts

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and

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Executive Summary

This white paper examines the impacts of climate variability on agricultural systems in Bihar, with a focused analysis of Begusarai as a representative floodplain district. It demonstrates that agricultural vulnerability arises not only from climatic exposure-such as floods, rainfall variability, and rising temperatures-but also from structural constraints including smallholder dominance, uneven resource access, and fragmented institutional delivery systems.

The analysis highlights a persistent gap between policy design and field-level outcomes, where existing climate-resilient technologies and schemes remain unevenly adopted due to limitations in coordination, extension reach, input systems, and credit access. It shows that current approaches are largely reactive and insufficiently aligned with local agro-ecological conditions.

In response, the paper proposes a district-specific, systems-based framework for climate-resilient agriculture, centred on land-type differentiated interventions, integrated water management, strengthened extension and data systems, and convergence of existing policy and financing mechanisms. The implementation roadmap outlines a phased pathway to translate policy intent into scalable, field-level outcomes, enabling more stable agricultural production and resilient rural livelihoods under changing climatic conditions.

Chapter 1: Climate Change and Agricultural Systems

1.1 Global Climate-Agriculture Nexus

Agriculture is intrinsically dependent on climatic conditions, including temperature regimes, rainfall patterns, and seasonal variability. As a result, the agricultural sector is widely recognised as one of the most climate-sensitive in the global economy. Over the past decades, climate change has begun to alter the environmental conditions that support agricultural productivity and food systems worldwide (Saleem et al., 2024; Yang et al., 2024).

The Intergovernmental Panel on Climate Change (IPCC) identifies agriculture, forestry, and land use as sectors both affected by climate change and contributing to greenhouse gas emissions. Rising temperatures, changing precipitation regimes, and increasing frequency of extreme events, such as droughts, floods, and heat waves, are already influencing agricultural productivity across regions. These climatic shifts affect crop yields, soil quality, water availability, and pest dynamics, thereby altering the stability of food systems and rural livelihoods (IPCC, 2023).

Research assessing global crop responses indicates that climate change is expected to produce uneven impacts across regions. While certain high-latitude areas may experience short-term gains from longer growing seasons, many tropical and subtropical regions, which are already exposed to climatic stress, are projected to face declining productivity. Studies synthesised in global modelling exercises show average crop yield reductions under warming scenarios, particularly for major staples such as maize, wheat, and soybean when adaptation measures are not implemented (Hasegawa, 2022).

Climate variability also affects agricultural systems through several interacting pathways. Temperature increases can accelerate crop phenology, shorten growing periods, and increase evapotranspiration, thus, raising irrigation demand. Changes in rainfall distribution influence soil moisture availability and the timing of planting seasons. Moreover, higher temperatures and altered humidity patterns can increase the prevalence of crop pests and diseases, further reducing yields and increasing production costs (Habib-ur-Rahman et al., 2022; Verma et al., 2025).

These dynamics have major implications for global food security. The IPCC notes that climate change interacts with population growth and land-use pressures to influence the availability and stability of food supplies. As agricultural systems face greater variability, ensuring reliable production will require adaptive strategies such as diversification of crops, improved water resource management, and climate-resilient technologies (Grigorieva et al., 2023; Toromade et al., 2024).

In response to these challenges, the concept of climate-smart agriculture (CSA) has gained prominence. CSA is defined as an integrated approach aimed at simultaneously enhancing agricultural productivity, strengthening resilience to climate impacts, and reducing greenhouse gas emissions where possible. This framework emphasises adaptive farming practices, efficient resource use, and climate-informed agricultural planning. The FAO and other international organisations highlight practices such as planting stress-tolerant crops, improved irrigation systems, agroforestry, and soil carbon management as core elements of climate-resilient farming systems (Kabato et al., 2025; Begna & Wakweya, 2025).

The global climate-agriculture nexus therefore reflects a complex interplay between environmental change, agricultural productivity, and socio-economic resilience. Understanding these interactions is essential for designing policies that enable agricultural systems to adapt effectively while maintaining food security.

1.2 Climate Change and Agricultural Systems in India

The Indian agricultural sector is particularly sensitive to climatic variability due to its heavy dependence on monsoon rainfall, the predominance of smallholder farming systems, and the large proportion of rain-fed cultivation. Agriculture supports nearly half of the country's total workforce and remains central to rural livelihoods and food security.

Recent climate assessments indicate that India has experienced a gradual increase in average temperatures over the past century, with warming estimated at approximately 0.7°C since 1901 (Saikanth et al., 2023). This warming has been more pronounced in recent decades and is associated with increasing frequency of heat stress events during critical crop growth periods. Rising temperatures, particularly during reproductive stages, have already begun affecting yields of key staples such as wheat and rice. For instance, increases in maximum temperature during the grain-filling stage of wheat have been associated with measurable declines in productivity in several regions.

Changes in precipitation patterns also play a major role in shaping agricultural outcomes. The Indian monsoon system, which contributes nearly 75% of the country's annual rainfall, exhibits increasing variability, including delayed onset, uneven spatial distribution, and more intense rainfall events. These changes contribute simultaneously to flood risks and seasonal water shortages, complicating crop planning and irrigation management. In addition, mid-season dry spells have become more frequent, particularly affecting rain-fed regions that lack access to supplemental irrigation (Baraj et al., 2024).

The implications of these climatic changes are particularly significant in rain-fed agricultural systems, which account for approximately 51% of India's net sown area. These regions are highly vulnerable to fluctuations in rainfall, as crop production depends directly on timely and adequate precipitation. Increasing aridity in such areas has begun to intensify production risks and reduce yield stability (Baraj et al., 2024).

The implications of climate change for Indian agriculture extend beyond crop yields. Livestock production may be affected by heat stress, leading to reduced feed intake, lower milk productivity, and reproductive challenges. Fisheries and aquaculture systems face risks from altered water temperatures and hydrological regimes, while soil systems are affected by moisture stress, nutrient loss, and degradation processes (Baraj et al., 2024; Datta et al., 2022).

Given the scale and diversity of Indian agriculture, the impacts of climate change vary significantly across agro-ecological zones. Regions with high population density and limited adaptive capacity, such as the eastern Indo-Gangetic plains, are particularly vulnerable to climate-induced agricultural risks. These vulnerabilities are further intensified by socio-economic factors, including limited access to resources and dependence on climate-sensitive livelihoods. Therefore, it is vital for adaptation strategies to be formulated according to agro-ecological and socio-economic diversities (Taraz, 2017).

To address these challenges, India has introduced several national initiatives focused on climate-resilient agriculture. These include the National Mission for Sustainable Agriculture (NMSA) under the National Action Plan on Climate Change (NAPCC), which promotes climate-adapted farming practices, water conservation technologies, and improved soil management. Complementary programmes such as the Pradhan Mantri Krishi Sinchai Yojana and Paramparagat Krishi Vikas Yojana support irrigation expansion and sustainable agricultural practices respectively (Rao et al., 2024).

Despite these policy efforts, the adoption of climate-resilient agricultural practices remains uneven across regions. Limited institutional capacity, information gaps, and financial constraints often hinder effective implementation at the local level. Consequently, state and district-specific strategies are increasingly recognised as essential for translating national climate policies into practical agricultural adaptation measures.

1.3 Agricultural Vulnerability in Bihar

Bihar is located in the eastern Indo-Gangetic plains and represents one of the most agriculturally dependent states of India. Agriculture contributes significantly to the state economy and provides livelihoods for a large share of the population. However, the sector is highly exposed to climatic risks due to geographical, hydrological, and socio-economic factors.

The climate of Bihar is characterised by a humid subtropical regime dominated by the southwest monsoon. Approximately 85% of the annual rainfall occurs during the monsoon months, making agricultural production highly dependent on the timing, intensity, and distribution of seasonal precipitation (Shankar & Sharma, 2025).

Bihar's agricultural system is structured around intensive land use and cereal-based cropping. The dominant cropping pattern follows a rice–wheat rotation across nearly 60% of the cultivable land, supplemented by maize, pulses, and horticultural crops. The state's gross cropped area is approximately 10.4 million hectares, with a cropping intensity of around 140%, reflecting multiple cropping practices within a year.

Irrigation plays a significant role in supporting agricultural production, with approximately 64% of the cultivated area irrigated. Groundwater, primarily accessed through tube wells, accounts for the majority of irrigation, while canal irrigation contributes roughly 20%, indicating a strong dependence on groundwater-based systems. This reliance provides flexibility in crop management but raises concerns regarding long-term sustainability.

Bihar is divided into several agro-climatic zones that vary in rainfall patterns, soil characteristics, and cropping systems. The northern plains, which include districts such as Begusarai, are influenced by river systems originating in the Himalayan foothills and frequently experience flooding during the monsoon season. In contrast, southern districts may face intermittent drought conditions when monsoon rainfall is insufficient.

Floods represent one of the most significant environmental hazards affecting agriculture in Bihar. Major rivers, including the Kosi, Gandak, Bagmati, and Ganga, carry high sediment loads and frequently overflow during heavy rainfall events. These floods damage standing crops, erode fertile soil, and disrupt agricultural infrastructure. At the same time, rainfall variability can result in seasonal moisture deficits, particularly affecting rain-fed areas (Richa & Sen, 2024).

Rising temperatures have also emerged as an important concern, particularly during pre-monsoon and summer months. Heat stress affects crop growth and productivity, especially for temperature-sensitive crops such as wheat and pulses.

Structural characteristics of Bihar's agrarian system further amplify climate risks. The majority of farm holdings are small or marginal in size, typically less than two hectares. Approximately 52% of holdings fall within the marginal category, limiting economies of scale and constraining investment in irrigation, mechanisation, and improved inputs. These constraints reduce farmers' capacity to respond effectively to climate-induced shocks.

Livestock and fisheries contribute significantly to the agricultural economy, with livestock accounting for nearly 30% of agricultural output and fisheries producing approximately 7 lakh tonnes annually. These sectors provide livelihood diversification but are also sensitive to climatic variability, particularly in flood-prone regions (Shankar & Sharma, 2025).

Given these combined factors, Bihar's agricultural system is highly vulnerable to climate change. Enhancing resilience requires improvements in water management, diversification of cropping systems, adoption of climate-resilient crops, and strengthening of institutional support mechanisms.

1.4 Climate Risk Context in Begusarai

The Begusarai district is situated in north-central Bihar within the fertile alluvial plains of the Ganga basin. The agricultural landscape of the district is shaped by riverine geomorphology, seasonal flooding, and intensive cultivation of staple crops.

Begusarai falls within Agro-Climatic Zone I (North Alluvial Plain) and is characterised by a humid subtropical climate, with annual rainfall ranging between 1000 and 1200 mm and temperatures reaching up to 42°C during peak summer months. The soils are predominantly alluvial, with loamy alluvium accounting for approximately 60% of soil composition, alongside sandy loam in upland areas (Krishi Vigyan Kendra, n.d.).

Land classification within the district reflects variations in elevation and hydrological conditions. Approximately 40% of the area consists of flood-prone lowlands, 30% medium land, and 30% uplands, creating distinct micro-environments that influence agricultural practices and crop selection (Krishi Vigyan Kendra, n.d.).

The hydrological system of Begusarai is strongly influenced by the Ganga and Burhi Gandak river systems, which contribute to seasonal flooding and waterlogging. Annual inundation affects up to 70% of the district area, impacting both agricultural land and rural settlements. Flood events can cause crop damage, disrupt agricultural labour cycles, and reduce household incomes (Fatma & Danish, 2024)

The local agricultural economy includes cultivation of rice, wheat, maize, pulses, and oilseeds. Rice occupies approximately 80,000 hectares during the kharif season, while wheat covers around 50,000 hectares during the rabi season. In addition, horticulture and vegetable cultivation, along with fisheries and livestock production, contribute to livelihood diversification (Krishi Vigyan Kendra, n.d.).

The presence of wetlands, ponds, and river-connected ecosystems supports fisheries and aquaculture, making water management a critical component of agricultural systems. Climate variability therefore affects multiple components of the local agricultural economy simultaneously, including crops, livestock, and fisheries.

The combined effects of hydrological variability, rising temperatures, and socio-economic constraints highlight the importance of strengthening climate resilience in the farming systems of Begusarai.

1.5 Rationale for a Begusarai-Focused Climate Resilience Strategy

While climate change affects agriculture at national and state levels, the impacts are highly localised. District-level climatic conditions, agricultural practices, and institutional capacities influence how farmers experience and respond to climate risks. Therefore, adaptation strategies designed at broader scales may not adequately address local vulnerabilities.

State-level aggregates often mask sub-regional heterogeneity. In Bihar, the flood-prone northern plains differ significantly from relatively drought-prone southern regions, necessitating location-specific analysis for effective planning and intervention.

In the case of Begusarai, the interaction of floodplain geography, monsoon-dependent agriculture, and smallholder farming structures creates a distinct vulnerability profile. With a net sown area of approximately 117,000 hectares, the district represents a critical site for examining climate-agriculture interactions at a granular level.

Developing a district-focused climate resilience strategy enables alignment of interventions with local agro-ecological conditions, improves the effectiveness of resource allocation, and enhances adoption of context-specific practices. Such an approach is consistent with emerging global frameworks emphasising decentralised and place-based adaptation planning.

Chapter 2: Climate Risks and Agricultural Impacts

Climatic perturbations impose layered pressures on agricultural systems, progressing from physical exposure to production disruptions and ultimately socio-economic vulnerability. In Bihar, these pressures are shaped by the interaction of monsoon variability, rising temperatures, and riverine hydrology. Within this broader context, Begusarai represents a concentrated case where environmental exposure and agrarian structure combine to intensify climate risks.

2.1 Climate Trends and Hazards in Bihar

Climatic observations across Bihar indicate a sustained warming trend, consistent with patterns observed across the eastern Indo-Gangetic plains. Long-term records from the India Meteorological Department suggest a temperature increase of approximately 0.5–0.7°C over the past century, with accelerated warming in recent decades. This trend is accompanied by an increase in the frequency and intensity of heatwaves, particularly during pre-monsoon months, with temperatures frequently exceeding 40°C.

Rainfall dynamics in the state are characterised by increasing variability rather than a uniform decline. The southwest monsoon continues to account for nearly 75% of annual precipitation, but its temporal distribution has become increasingly irregular. Delayed onset, erratic intra-seasonal distribution, and concentrated rainfall events are now more common, leading to extended dry spells within the cropping season.

Hydrological hazards remain a defining feature of Bihar's climate risk profile. Approximately 73% of the state's geographical area is classified as flood-prone, primarily due to the influence of Himalayan river systems such as the Kosi, Gandak, and Ganga. These rivers carry high sediment loads and exhibit rapid increases in discharge during monsoon rainfall, resulting in recurrent flooding.

Drought conditions, although spatially less extensive, affect rain-fed areas in years of weak or delayed monsoon. Estimates suggest that over 20% of cultivated land experiences periodic moisture stress, particularly in regions with limited irrigation access. The coexistence of flood and drought risks within the same agro-climatic system creates a complex and dynamic risk environment for agriculture.

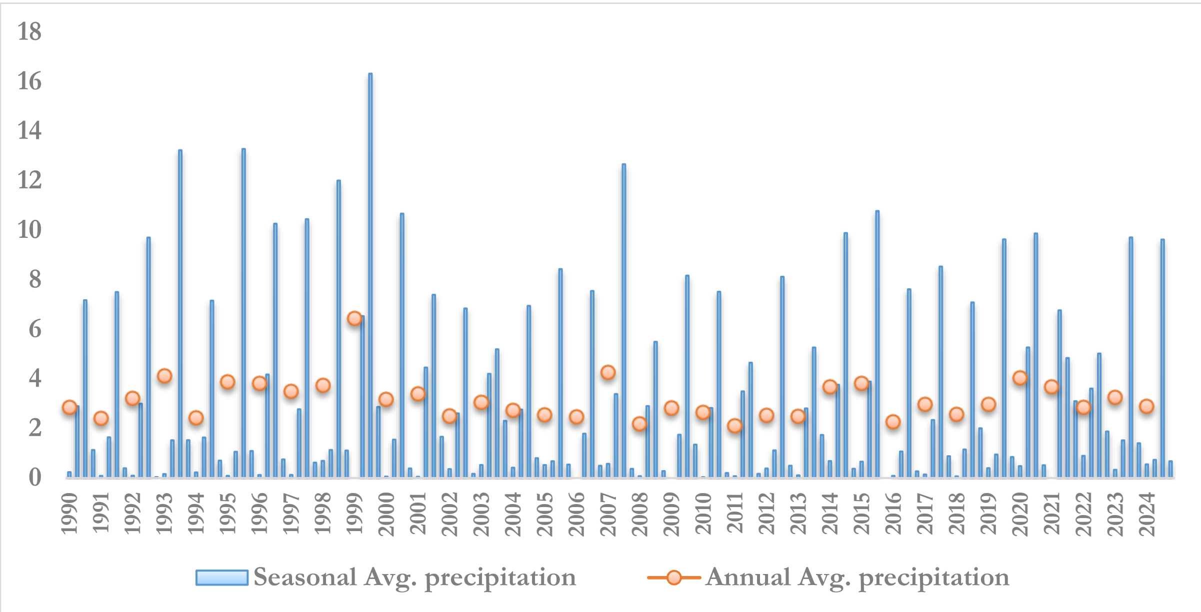

Figure 1: Average annual precipitation and seasonal average precipitation of Begusarai, Bihar from 1990 to 2024

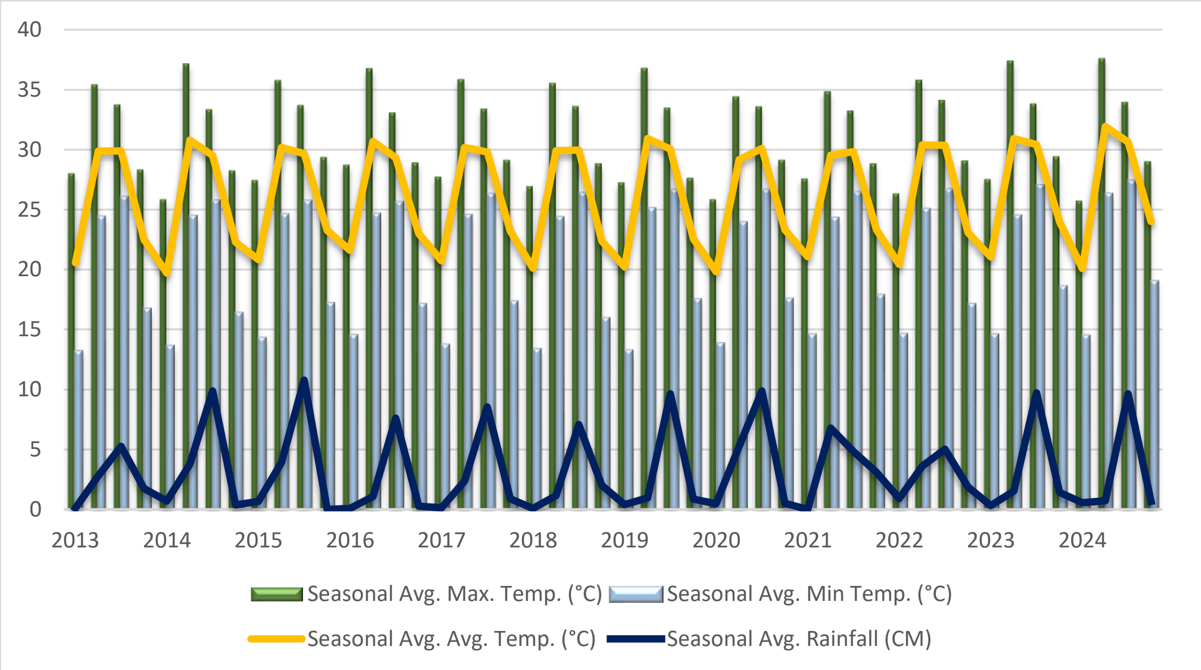

Figure 2: Seasonal average, maximum and minimum temperature of Begusarai Bihar

2.2 Agricultural Impacts of Climate Variability in Bihar

The primary manifestation of climate variability in the agriculture of Bihar is increasing instability in production systems. Rather than a consistent decline in output, agricultural performance exhibits significant inter-annual fluctuations. Empirical observations indicate yield variability in the range of 20–30%, particularly in cereal crops such as rice and wheat.

Monsoon irregularities directly affect kharif crop performance. Deficit rainfall conditions have been associated with reductions in rice yields of up to 10–15%, especially in areas with limited irrigation infrastructure. Delayed monsoon onset disrupts sowing schedules, while mid-season dry spells affect crop establishment and vegetative growth.

These effects extend into subsequent cropping cycles. Delays in kharif harvesting reduce the available window for rabi sowing, particularly for wheat, which is highly sensitive to planting time. Late sowing shortens the crop growth period and reduces yield potential, creating cascading impacts across agricultural seasons (Shankar & Sharma, 2025).

Farm-level responses to climatic variability include adjustments in crop selection and input use. Farmers often shift toward relatively less water-intensive crops such as pulses or reduce input application under uncertain conditions. While these strategies help manage risk, they also constrain productivity and intensification.

Livestock and fisheries systems are similarly affected. Heat stress reduces feed intake and productivity in livestock, while fluctuations in water availability and flood events disrupt aquaculture systems. These impacts reflect the interconnected nature of agricultural systems in Bihar.

2.3 Climate Exposure and Environmental Conditions in Begusarai

The environmental exposure of Begusarai is determined by its position within the Ganga floodplain and its associated geomorphological characteristics. The district is characterised by low elevation gradients and extensive alluvial formations, which facilitate water accumulation during monsoon periods.

Land distribution within the district reflects significant variation in elevation and drainage capacity. Approximately 40% of the area consists of low-lying flood-prone land, while medium and upland areas account for roughly equal proportions of the remaining landscape. This heterogeneity creates distinct micro-environments with varying degrees of exposure to waterlogging and moisture stress.

Soil composition further influences exposure patterns. Predominantly loamy alluvial soils exhibit moderate water retention capacity, which supports crop growth under normal conditions but also contributes to prolonged waterlogging during periods of excess rainfall. Sandy loam soils in upland areas provide relatively better drainage but remain dependent on rainfall for moisture availability.

Hydrological dynamics are shaped by the interaction of the Ganga and its tributaries, particularly the Burhi Gandak. Seasonal fluctuations in river discharge, combined with local rainfall, result in recurrent inundation. In severe flood events, water depth in affected areas can reach 2–3 metres, leading to extended periods of submergence (Fatma & Danish, 2024).

These physical characteristics define the exposure framework within which agricultural systems operate in Begusarai.

2.4 Impacts of Climate Variability on Agriculture in Begusarai

Agricultural impacts in Begusarai are closely linked to land typology and hydrological conditions. In low-lying areas, flooding during the monsoon leads to prolonged submergence of crops, resulting in significant yield losses. Rice, which is the dominant kharif crop, can experience yield reductions of up to 30–40% under extended inundation.

Variability in monsoon onset affects the timing of agricultural operations. Delayed rainfall disrupts nursery preparation and transplanting schedules, leading to late crop establishment. Wheat cultivation in the rabi season is particularly affected, with yield losses of up to 20–25% associated with delayed sowing.

Farmers adopt a range of adaptive responses to manage these disruptions. These include shifting to short-duration crop varieties, modifying sowing methods such as broadcast seeding, and substituting crops in flood-affected areas with alternatives such as jute or vegetables. Such adjustments reflect attempts to align cropping strategies with changing environmental conditions.

The impacts extend beyond crop production. Flooding affects fisheries by causing fish loss from ponds and altering water quality. Livestock systems face fodder shortages when agricultural land is submerged, affecting dairy production and household income. The interdependence of these components results in system-wide impacts on farm productivity (District Disaster Management Authority, 2022; GoI, n.d.; Krishi Vigyan Kendra, n.d.).

2.5 Socio-Economic Vulnerability of Farming Systems in Begusarai

The agrarian structure of Begusarai is characterised by a predominance of smallholder farming systems, with approximately 85–90% of landholdings falling within the marginal category (less than 1 hectare). This limits the ability of farmers to diversify crops, invest in infrastructure, or absorb production shocks.

Access to agricultural inputs and financial resources remains uneven. A significant proportion of farmers face constraints in accessing quality seeds, fertilisers, and credit. Estimates suggest that nearly 40% of farmers lack access to formal credit systems, increasing reliance on informal borrowing mechanisms.

Income stability is closely tied to agricultural performance. In years of adverse climatic conditions, household incomes may fluctuate by up to 40–50%, reflecting the direct impact of production losses. Limited financial buffers and alternative income sources increase vulnerability to indebtedness and economic stress.

These factors collectively define the socio-economic dimensions of vulnerability in the district (District Disaster Management Authority, 2022; GoI, n.d.; Krishi Vigyan Kendra, n.d.).

2.6 Implications for Adaptation Needs

The combined effects of climatic variability, environmental exposure, and socio-economic constraints in Begusarai indicate the need for targeted adaptation strategies. Priority interventions include the adoption of crop types tolerant to flooding and heat stress, along with adjustments in cropping calendars to accommodate changing rainfall patterns.

Water management strategies must address both excess and deficit conditions, incorporating improved drainage systems, water storage infrastructure, and efficient irrigation practices. Given the predominance of smallholder farming, adaptation measures must be cost-effective and accessible.

The interconnected nature of agricultural systems in the district necessitates integrated approaches that consider crops, livestock, and fisheries simultaneously. Strengthening extension services, improving access to inputs and credit, and enhancing institutional coordination are essential for enabling effective adaptation.

2.7 Methodology and Scope

This White Paper employs a multi-source synthesis methodology. Sources of evidence include published literature as well as field observations.

This white paper develops a district-scale, agro-ecologically grounded framework for climate-resilient agriculture in Begusarai, linking climate exposure (floodplain dynamics, rainfall variability, heat stress) with farming system structure, resource use patterns, and institutional delivery mechanisms.

It specifically examines the policy–practice gap in Bihar's agricultural governance, and translates this into land-type specific, system-level interventions (lowland–medium–upland differentiation), integrated water management, and scalable resilience pathways supported by phased implementation and financing convergence.

Chapter 3: Agricultural Practices and Farming Systems

Agricultural practices in Bihar and Begusarai are shaped by land availability, irrigation access, input use patterns, and market conditions. The structure of farming systems reflects established cultivation practices and resource use behaviour. This section presents the existing agricultural systems without linking them to climate impacts.

3.1 Farming Systems in Bihar

Agriculture in Bihar is dominated by cereal-based cropping systems. The rice–wheat sequence forms the core of cultivation, with rice accounting for approximately 30% of the cropped area and wheat about 20%. Maize, pulses, and oilseeds are cultivated alongside these crops, with some diversification in selected regions.

Cropping follows seasonal patterns, with rice grown during the monsoon season and wheat during the winter season. Maize is cultivated in both seasons in certain areas. Cropping intensity remains high, indicating multiple crop cycles within a year.

Irrigation is a key component of agricultural production. Groundwater is the primary source, with tube wells accounting for nearly 70% of irrigated area. Canal irrigation contributes around 20%, while the remaining share is met through ponds and minor irrigation sources. This configuration indicates strong dependence on groundwater extraction.

Fertiliser use is widespread, with application levels ranging between 140–160 kg per hectare. Nitrogen-based fertilisers, particularly urea, dominate usage. Hybrid seeds are used in crops such as maize and vegetables, while rice and wheat rely on a combination of improved and traditional varieties (Sinha & Sinha, 2025; Vandana, 2024).

3.2 Structural Characteristics of Farming Systems in Bihar

The farming structure in Bihar is dominated by small and marginal landholdings. Around **85%** of farmers operate on small parcels of land. This limits the ability to diversify crops, adopt mechanisation, or invest in infrastructure.

Mechanisation levels remain low. Access to tractors and farm machinery is limited and often dependent on rental services. Estimates indicate that only **10–15%** of holdings have access to mechanised equipment, which affects the timeliness of agricultural operations.

Fertiliser use shows imbalance in application. Nitrogen use often exceeds recommended levels, while phosphorus and potassium remain under-applied. This imbalance affects soil health and long-term productivity.

Farm decisions are guided by risk minimisation. Farmers tend to prioritise stable crops over higher-value alternatives due to constraints related to land size, input access, and market linkages (Sinha & Sinha, 2025; Vandana, 2024).

3.3 Farming Systems in Begusarai

Agriculture in Begusarai follows the broader patterns of north Bihar with local variations. Rice is the dominant crop during the monsoon season, cultivated over approximately 60,000–70,000 hectares, while wheat is grown during the winter season on about 40,000–50,000 hectares.

Other crops include maize and sugarcane during Kharif and wheat during Rabi. Vegetable cultivation is present across several parts of the district, including potato, tomato, onion, cauliflower, and gourds. Banana cultivation is also observed in selected areas.

Livestock is an important component of the farming system, with an estimated 2 lakh cattle population. Dairy production provides supplementary income to farm households.

Fisheries are well established, with ponds and water bodies covering approximately 8,000–10,000 hectares used for aquaculture. This creates a mixed farming system where crops, livestock, and fisheries are interconnected (District Disaster Management Authority, 2022; GoI, n.d.; Krishi Vigyan Kendra, n.d.).

3.4 Resource Use Patterns in Begusarai

Water use in agriculture is dominated by groundwater extraction. In several districts, including Begusarai, groundwater accounts for nearly 80% of irrigation. Canal systems have limited reach, making tube wells the primary source.

Fertiliser application ranges between 100–150 kg per hectare, with nitrogen dominating usage. Organic inputs such as farmyard manure are used but in limited quantities.

Pesticide use varies across crops. It is higher in vegetable cultivation and lower in cereal crops. Application practices are often based on farmer experience rather than standard recommendations.

Irrigation methods are largely traditional, with flood irrigation being common. This leads to inefficient water use and increased pressure on groundwater resources (District Disaster Management Authority, 2022; GoI, n.d.; Krishi Vigyan Kendra, n.d.).

3.5 Risk Sensitivity of Existing Systems in Begusarai

The sensitivity of farming systems varies across land types and cropping patterns. Lowland areas under continuous paddy cultivation are more exposed to water accumulation and have limited flexibility for crop change.

Upland areas with diversified cropping systems, including maize and livestock integration, show relatively greater stability. These systems are less dependent on a single crop and can absorb variations in production.

Dependence on groundwater provides short-term stability but introduces long-term concerns related to water availability and extraction costs.

Risk sensitivity therefore varies within the district based on land characteristics, cropping systems, and access to resources (District Disaster Management Authority, 2022; GoI, n.d.; Krishi Vigyan Kendra, n.d.).

3.6 SWOT Analysis of Agricultural Systems

Category	Bihar	Begusarai
Strengths	Fertile soils, high cropping intensity	Irrigation access, mixed farming systems
Weaknesses	Small landholdings, low mechanisation	Flood-prone areas, uneven input access
Opportunities	Crop diversification, improved irrigation	Fisheries integration, horticulture expansion
Threats	Rising input costs, groundwater pressure	Flooding, waterlogging, pollution risks

Chapter 4: Policy Landscape and Institutional Framework

Governance structures play a central role in shaping agricultural development and climate resilience. In Bihar, agricultural policy operates through a combination of national programmes, state-level strategies, and district-level implementation mechanisms. This chapter examines these layers, with a distinction between broader policy frameworks and their operationalisation in Begusarai.

4.1 National Policy Framework for Climate-Resilient Agriculture in India

Agricultural policy at the national level is guided by a set of interlinked programmes that address productivity, sustainability, and climate resilience.

The National Action Plan on Climate Change (NAPCC) provides the overarching framework for climate policy in India. Within this, the National Mission for Sustainable Agriculture (NMSA) focuses specifically on improving agricultural resilience through water use efficiency, soil health management, and climate-adapted cropping practices. The mission promotes interventions such as micro-irrigation, integrated nutrient management, and crop diversification.

The National Innovations on Climate Resilient Agriculture (NICRA) programme, implemented by ICAR, focuses on developing and testing location-specific adaptation strategies. It includes district-level contingency planning, demonstration of climate-resilient technologies, and capacity building.

The Pradhan Mantri Krishi Sinchai Yojana (PMKSY) addresses irrigation efficiency and expansion. It emphasises "more crop per drop" through micro-irrigation and improved water management.

Moreover, schemes such as Paramparagat Krishi Vikas Yojana (PKVY) and Soil Health Card Scheme support sustainable practices and soil management, contributing indirectly to resilience.

These programmes collectively provide the policy foundation for climate-resilient agriculture, although their effectiveness depends on state-level adaptation and local implementation (Chauhan & von Wehrden, 2025; James, 2025; Suresh & Viswanathan, 2022).

4.2 State Policy Framework for Agriculture in Bihar

At the state level, agricultural policy is guided by the Bihar Agricultural Road Map, which serves as the principal development framework. The Road Map (2017–2022, extended subsequently) focuses on increasing productivity, improving irrigation coverage, and promoting crop diversification through cluster-based approaches.

The State Action Plan on Climate Change (SAPCC) for Bihar incorporates climate adaptation within agriculture. It emphasises flood-resilient cropping systems, water management, and strengthening of agricultural infrastructure in vulnerable regions.

Input delivery mechanisms have been strengthened through Direct Benefit Transfer (DBT) systems for fertilisers and seeds, aimed at improving efficiency and transparency. Risk mitigation is addressed through crop insurance schemes and farmer support programmes, although coverage and accessibility remain uneven.

State-level policy also promotes diversification into horticulture, livestock, and fisheries, recognising their role in stabilising rural incomes (Kannan & Pohit, 2021.; Pandey, 2025; Ranjan, 2020).

4.3 Institutional Architecture for Agricultural Governance in Bihar

Agricultural governance in Bihar is implemented through a multi-tier institutional structure.

The Department of Agriculture, Government of Bihar, is the primary authority responsible for policy implementation, input distribution, and programme coordination. It works in conjunction with departments of horticulture, animal husbandry, and fisheries.

Research support is provided by institutions such as:

- Dr. Rajendra Prasad Central Agricultural University (RPCAU), Pusa
- ICAR-affiliated research centres

These institutions focus on crop improvement, soil management, and farming system research relevant to the eastern Indo-Gangetic plains.

Extension services are delivered through:

- Agricultural Technology Management Agency (ATMA) at district level
- Krishi Vigyan Kendras (KVKs)

KVKs play a critical role in technology dissemination, farmer training, and on-field demonstrations. ATMA provides coordination across departments and supports participatory planning.

The institutional structure is therefore well-defined, but effectiveness depends on coordination and field-level capacity.

In addition to policy frameworks, agricultural financing and rural infrastructure development are supported by the National Bank for Agriculture and Rural Development (NABARD), which functions as a key institutional mechanism for channelising investments into the sector. NABARD supports irrigation, flood management, and rural infrastructure through instruments such as the Rural Infrastructure Development Fund, which is used by state governments for projects related to minor irrigation, drainage, and flood control. It also supports watershed development and natural resource management programmes that are relevant for climate-resilient agriculture. NABARD also plays a role in promoting Farmer Producer Organisations and strengthening collective systems for input access and market linkages. These functions position NABARD as an important financing and institutional support mechanism within the broader agricultural policy landscape.

4.4 District-Level Implementation of Agricultural Programmes in Begusarai

At the district level, agricultural policies are implemented through block offices, KVKs, and line departments.

In Begusarai, the Krishi Vigyan Kendra at Khodawandpur serves as the primary institution for agricultural extension and demonstration. It implements programmes under NICRA and conducts training, field demonstrations, and technology dissemination.

Government schemes related to seeds, fertilisers, irrigation, and crop insurance are delivered through block-level administrative structures. These offices act as the interface between state programmes and farmers.

Coverage of schemes is significant in terms of outreach targets, with efforts aimed at reaching a majority of farming households. However, actual adoption varies due to differences in awareness, access, and local constraints.

The district-level system therefore functions as the operational layer of policy implementation, translating state and national programmes into field-level interventions.

4.5 Water Governance Context Affecting Bihar and Begusarai

Water governance in Bihar is shaped by its position within the **Ganga river basin**, which involves multiple states and upstream catchments.

River management is coordinated through basin-level institutions and inter-state mechanisms. However, upstream water flows originating in Nepal and neighbouring states influence flood dynamics in north Bihar. This creates challenges in flood control and water management.

There are recurring coordination issues between Bihar and upstream regions, particularly in relation to embankment management, river discharge, and flood mitigation measures.

For districts such as Begusarai, which lie within the floodplain of the Ganga, water governance decisions made outside the district have direct implications for agricultural conditions.

4.6 Technology and Innovation Systems in Bihar and Begusarai

Technological development and dissemination are central to improving agricultural productivity and resilience.

At the national and state level, ICAR institutions develop improved crop varieties, including those with tolerance to stress conditions. These technologies are tested under local conditions before being disseminated through extension systems.

In Bihar, KVKs serve as the primary channel for technology transfer. Training programmes conducted by KVKs reach a large number of farmers annually, with estimates suggesting outreach to several thousand farmers per district each year.

Digital tools are emerging as supplementary platforms for agricultural advisory. Mobile-based applications and digital services linked to schemes such as Kisan Credit Card (KCC) provide information on weather, inputs, and market conditions.

Despite these developments, adoption of technology remains uneven, with gaps in access, awareness, and affordability influencing uptake.

Chapter 5: Demonstration and Scaling of Climate-Resilient Practices

Demonstration programmes in Bihar provide the primary evidence base for the adoption of climate-resilient agricultural practices. These initiatives are designed to test technologies under field conditions, generate location-specific recommendations, and support farmer-level adoption through extension systems. This section examines major programmes, models, district-level practices in Begusarai, and the constraints affecting scaling.

5.1 Demonstration Programmes in Bihar

The principal programme for climate-resilient agriculture in India is the National Innovations on Climate Resilient Agriculture (NICRA), implemented by the Indian Council of Agricultural Research (ICAR). The programme operates through Krishi Vigyan Kendras and focuses on developing and demonstrating technologies suited to local climatic conditions.

NICRA interventions in Bihar include:

- introduction of stress-tolerant crops
- resource conservation practices such as zero tillage
- water management techniques including alternate wetting and drying in rice
- soil management through organic amendments

Krishi Vigyan Kendras act as the operational units for these demonstrations. They conduct on-farm trials, frontline demonstrations, and farmer training programmes. In Bihar, KVKs have implemented demonstrations on conservation agriculture, improved seeds, and water-saving practices across multiple districts.

Zero tillage in wheat has been one of the most widely demonstrated practices in the eastern Indo-Gangetic plains. It enables timely sowing after rice harvest and reduces fuel and labour requirements. Similarly, alternate wetting and drying in paddy cultivation has been promoted to improve water use efficiency.

These programmes are designed not only to test technologies but also to create evidence for their wider adoption through extension systems (Press Information Bureau, 2025; Singh et al., 2020; Sinha et al., 2021).

5.2 Climate Resilient Village Models in Bihar

The Climate Resilient Village approach under NICRA represents an integrated model for agricultural adaptation. Villages are selected based on vulnerability assessments, and a package of interventions is implemented across crops, livestock, and natural resource management.

In Bihar, climate resilient programmes have been established in several districts Interventions include:

- introduction of flood-tolerant rice varieties such as Swarna Sub1
- promotion of short-duration crop varieties to manage delayed monsoon
- development of farm ponds for water storage
- vermicomposting units to improve soil fertility
- improved livestock management practices

These interventions are implemented together rather than in isolation, allowing farmers to manage multiple risks simultaneously.

Field evaluations of NICRA villages in eastern India indicate that the adoption of stress-tolerant varieties and improved agronomic practices contributes to stabilisation of yields under variable climatic conditions. Improvements in water use efficiency and diversification of income sources have also been observed.

The Climate Resilient Village model demonstrates that integrated approaches are more effective than single interventions in addressing climate-related risks in agriculture (Press Information Bureau, 2025; Singh et al., 2020; Sinha et al., 2021).

5.3 Climate-Resilient Agricultural Practices in Begusarai

In Begusarai, demonstration activities are implemented primarily through the Krishi Vigyan Kendra at Khodawandpur. The focus is on practices that address local conditions, particularly flood-prone agriculture and variable water availability.

Key demonstrated practices include:

- use of improved rice varieties suited to submergence conditions
- raised bed cultivation for vegetables to improve drainage
- sprinkler and other irrigation methods in selected locations
- mulching and soil moisture conservation practices

Water management practices such as alternate wetting and drying are introduced to improve irrigation efficiency. In areas with recurring waterlogging, adjustments in planting methods and crop selection are promoted.

Livestock-related interventions include improved fodder management, including cultivation of fodder crops suited to local conditions. Fisheries practices include improved pond management and, in some cases, promotion of cage culture in suitable water bodies.

These demonstrations are designed to align with the agro-ecological conditions of the district and to provide practical models that farmers can adopt under similar conditions.

5.4 Lessons from Demonstration Programmes

Experience from demonstration programmes across Bihar indicates that adoption of climate-resilient practices is influenced by multiple factors, including access to inputs, extension support, and perceived benefits.

Practices such as improved seed varieties and crop management techniques have shown relatively higher adoption rates due to their direct impact on productivity and ease of implementation. In contrast, practices requiring equipment or infrastructure, such as laser land levelling, show lower adoption where access to machinery is limited.

Farmer-to-farmer dissemination has been an effective pathway for spreading successful practices. Demonstration plots provide visible evidence of performance, which influences adoption decisions.

However, adoption beyond demonstration areas tends to decline where institutional support is limited. This indicates that sustained extension engagement is required for scaling (Press Information Bureau, 2025; Singh et al., 2020; Sinha et al., 2021).

5.5 Constraints to Scaling Climate-Resilient Practices

Despite the availability of tested practices, several constraints limit large-scale adoption.

Financial constraints remain significant. Access to credit is uneven, and farmers may not be able to invest in new technologies without support. Subsidy mechanisms exist but may not always align with local needs or timelines.

Institutional challenges affect coordination across departments. Programmes related to crops, livestock, and water management often operate independently, limiting integrated implementation.

Technical constraints include limited availability of quality seed for improved varieties and delays in seed multiplication and distribution. Extension systems face capacity limitations, affecting the reach and effectiveness of advisory services.

These constraints indicate that scaling of climate-resilient practices requires not only technological solutions but also improvements in delivery systems, institutional coordination, and input access.

Chapter 6: Capacity Building and Extension Systems

Agricultural extension systems in Bihar are structured to connect research institutions with farmers through organised dissemination networks. These systems focus on training, advisory services, and field demonstrations. This chapter examines the institutional architecture, linkages between research and extension, district-level capacity systems in Begusarai, community-based approaches, and existing gaps.

6.1 Extension Architecture in Bihar

The extension system in Bihar operates through a multi-tier structure led by the Agricultural Technology Management Agency (ATMA) at the district level. ATMA functions as a coordinating platform that integrates activities across agriculture, horticulture, livestock, and fisheries departments. It emphasises farmer-oriented planning and decentralised implementation through block-level units.

Field-level extension is supported by government functionaries, including Agriculture Development Officers and block-level staff, who are responsible for input distribution, advisory services, and implementation of schemes. The system is designed to ensure outreach across rural areas, although the effectiveness varies depending on staffing and resource availability.

ATMA promotes participatory approaches by involving farmers in planning and implementation through group-based structures. It also facilitates training programmes, exposure visits, and demonstrations in collaboration with research institutions.

6.2 Research-Extension Linkages in Bihar

Research–extension linkages in Bihar are anchored in collaboration between national research institutions, state agricultural universities, and extension agencies. The Indian Council of Agricultural Research (ICAR) provides technological inputs, including crop varieties, agronomic practices, and contingency plans for climate variability.

Institutions such as Dr. Rajendra Prasad Central Agricultural University (RPCAU), Pusa play a key role in adapting these technologies to regional conditions. Adaptive trials conducted by universities help validate research outputs before dissemination.

Krishi Vigyan Kendras serve as the primary interface between research and farmers. They conduct frontline demonstrations, organise field days, and provide training on improved practices. Joint activities between research institutions and extension agencies ensure that technologies are tested under field conditions before wider dissemination.

This linkage system enables a continuous flow of information from research to field-level application, although the strength of these linkages varies across districts.

6.3 District-Level Capacity Systems in Begusarai

In Begusarai, capacity building is primarily implemented through the **Krishi Vigyan Kendra at Khodawandpur**, which acts as the central institution for farmer training and demonstration activities. The KVK conducts regular training programmes covering crop production, soil management, water use practices, and integrated farming systems.

Training activities include:

- on-field demonstrations of improved practices
- farmer training sessions on crop and livestock management
- exposure visits to demonstration sites and climate-resilient villages

These programmes aim to build practical knowledge among farmers and support adoption of improved technologies. Participation includes farmers from different blocks within the district, with emphasis on hands-on training and demonstration-based learning.

Extension support is complemented by block-level agricultural offices, which facilitate scheme implementation and provide advisory services.

6.4 Community-Based Approaches in Bihar and Begusarai

Community-based approaches form an important component of extension systems in Bihar. ATMA promotes the formation of **Farmer Interest Groups (FIGs)**, which serve as platforms for collective learning and technology dissemination. These groups enable farmers to share experiences and adopt practices based on peer learning.

Self-Help Groups are also involved in agricultural activities, particularly in areas such as seed production, livestock management, and small-scale enterprises. Participation of women in these groups contributes to broader inclusion in agricultural decision-making.

Farmer Producer Organisations (FPOs) are emerging as institutional platforms for aggregation, input procurement, and market access. In some cases, FPOs are involved in participatory activities such as varietal selection and collective input use.

These community-based structures complement formal extension systems by strengthening local-level capacity and facilitating collective action.

6.5 Capacity Gaps in Extension Systems

Despite the presence of institutional structures, several gaps affect the effectiveness of extension systems in Bihar and Begusarai.

Human resource constraints are a major limitation. Vacancies in extension positions reduce field-level outreach and affect the frequency of farmer interactions. In some areas, a limited number of staff are responsible for large geographic coverage.

Institutional coordination remains uneven. Activities across departments related to crops, livestock, and fisheries are not always integrated, which affects the delivery of comprehensive advisory services.

Infrastructure limitations also affect capacity building. Demonstration units and training facilities may lack adequate equipment, reducing the effectiveness of practical training.

Information dissemination is another challenge. While training programmes are conducted regularly, continuous advisory support is limited, affecting long-term adoption of practices.

These gaps indicate that strengthening extension systems requires improvements in staffing, coordination, infrastructure, and continuity of engagement with farmers.

Chapter 7: Policy-Practice Gap Analysis

There is a clear divergence between policy design and field-level outcomes in Bihar. While national and state programmes provide a comprehensive framework for climate-resilient agriculture, implementation at the ground level remains uneven. This section examines gaps across implementation, adoption, district-level delivery, knowledge systems, and future planning requirements.

7.1 Policy Implementation Gaps in Bihar

Agricultural and climate-related programmes in Bihar operate through multiple departments, including agriculture, water resources, livestock, and disaster management. However, coordination across these departments remains limited. Programmes under the National Action Plan on Climate Change and those implemented through ICAR initiatives such as NICRA often function independently, reducing the effectiveness of integrated planning.

Monitoring systems are largely based on periodic reporting. Programme evaluation typically relies on annual or seasonal reports submitted through administrative channels. This limits the ability to track real-time progress or respond to emerging issues during the agricultural cycle.

Implementation also varies across districts depending on administrative capacity. Differences in staffing, infrastructure, and coordination affect the consistency of programme delivery. As a result, policy intent does not always translate into uniform outcomes across regions (Kannan & Pohit, 2021.; Pandey, 2025; Ranjan, 2020).

7.2 Adoption Gaps among Farmers in Bihar

Adoption of climate-resilient practices is influenced by economic constraints, risk perception, and access to information. Smallholder farmers, who form the majority, often avoid practices that require upfront investment. Technologies such as micro-irrigation systems or mechanised equipment involve initial costs that are difficult to absorb without assured returns.

Farmers also tend to rely on familiar practices. Even when improved seed varieties are available, adoption may be limited due to concerns about performance under local conditions or the higher cost of inputs. Behavioural factors therefore play a significant role in shaping adoption decisions.

Access to credit and insurance influences adoption patterns. Where financial support mechanisms are weak or difficult to access, farmers are less likely to invest in new technologies. This results in a gap between demonstrated practices and actual field-level uptake (Kannan & Pohit, 2021; Pandey, 2025; Ranjan, 2020).

7.3 District-Level Implementation Gaps in Begusarai

In Begusarai, local conditions introduce additional constraints to implementation. Flood-prone areas experience disruptions in agricultural operations, which also affect extension activities. During periods of inundation, mobility is restricted, limiting the ability of extension personnel to conduct field visits and training programmes.

Scheme implementation at the district level is influenced by administrative priorities and local demand. In some cases, allocation of resources may not align fully with identified vulnerabilities. This affects the targeting of interventions, particularly in areas requiring specific support such as flood-prone zones.

Differences in awareness and access also influence implementation outcomes. Farmers located closer to block headquarters or demonstration sites tend to benefit more from extension services compared to those in remote or flood-affected areas (Kannan & Pohit, 2021; Pandey, 2025; Ranjan, 2020).

7.4 Knowledge and Technology Gaps

Access to agricultural knowledge remains uneven across Bihar. Extension services reach only a portion of farmers, with formal advisory systems concentrated around demonstration areas and institutional networks. Digital platforms are emerging as tools for information dissemination, including mobile-based advisories and online services linked to schemes such as Kisan Credit Card. However, access to these platforms is constrained by literacy levels, connectivity, and digital familiarity. A significant share of farmers is unable to utilise digital services effectively.

There are also gaps in the availability of locally relevant information. Advisory services are often generalised, while farmers require location-specific guidance based on soil conditions, water availability, and cropping systems.

Technology dissemination is affected by supply constraints. Delays in the availability of quality seeds and limited access to equipment reduce the effectiveness of extension efforts. As a result, the transition from demonstration to adoption remains incomplete (Kannan & Pohit, 2021; Pandey, 2025; Ranjan, 2020).

7.5 Future Climate Risk Outlook and Planning Needs

Climate projections for eastern India indicate continued warming and increasing variability in rainfall patterns. Under moderate emission scenarios, temperature increases of up to **1.5–2°C by mid-century** are expected, along with changes in rainfall distribution.

These changes are likely to intensify both flood and drought risks in Bihar. Increased frequency of extreme rainfall events may lead to more frequent flooding in riverine districts, while dry spells within the monsoon season may affect crop growth.

Planning for climate resilience therefore requires forward-looking approaches. Current policies are largely reactive, focusing on response and recovery. There is a need to incorporate scenario-based planning into agricultural strategies, including contingency budgeting, infrastructure development, and long-term resource management.

Strengthening resilience will require integration of climate projections into district-level planning processes, ensuring that interventions are aligned with future risk patterns rather than past trends (Kannan & Pohit, 2021; Pandey, 2025; Ranjan, 2020).

Policy-Practice Gap Matrix

Gap Category	Specific Gap Identified	Observed Practice (Field Reality)	Implication for Agricultural Systems
Institutional Coordination	Limited coordination across agriculture, water, livestock, and disaster departments	Departments operate independently with limited convergence at state and district levels	Fragmented implementation reduces effectiveness of climate-resilient interventions
Programme Integration	National and state programmes such as NAPCC and NICRA function in parallel	Programme activities are implemented through separate administrative channels	Lack of integration leads to duplication and incomplete coverage
Monitoring Systems	Monitoring based on periodic reporting rather than real-time tracking	Annual and seasonal reports guide evaluation	Delayed identification of issues during crop cycle limits timely response
Administrative Capacity	Variation in staffing and infrastructure across districts	Uneven presence of extension personnel and support systems	Inconsistent delivery of programmes across regions

Adoption Constraints	High initial cost of technologies such as micro-irrigation and mechanisation	Farmers rely on low-cost traditional practices	Limited uptake of climate-resilient technologies
Financial Access	Limited access to formal credit and insurance	Dependence on informal borrowing and low investment capacity	Reduced ability to adopt new practices and absorb shocks
District-Level Constraints (Begusarai)	Flood conditions disrupt extension activities	Reduced mobility and field access during monsoon periods	Limited reach of training and advisory services
Targeting of Schemes	Allocation not fully aligned with vulnerability patterns	Resources distributed without consistent prioritisation of high-risk areas	Inefficient utilisation of programme funds
Access Inequality	Uneven access to extension services	Farmers near block centres receive greater support than remote areas	Spatial disparity in adoption of practices
Knowledge Access	Limited reach of formal extension systems	Advisory services concentrated around demonstration areas	Large number of farmers remain outside advisory networks
Digital Divide	Limited access to digital advisory platforms	Low utilisation due to literacy and connectivity constraints	Exclusion from emerging information systems
Local Relevance of Advisory	Generalised advisory systems	Recommendations not tailored to local soil, water, and crop conditions	Reduced effectiveness of advisory services
Technology Supply Constraints	Delays in availability of seeds and equipment	Limited access to improved inputs at the local level	Disruption in adoption of recommended practices
Climate Planning Gap	Planning focused on short-term response	Limited incorporation of long-term climate projections	Inadequate preparation for future risks
Scenario Integration	Limited use of climate projections in planning	Agricultural planning based on historical trends	Misalignment with emerging climate variability patterns

Chapter 8: Policy Recommendations- Action Framework

The analysis of climate risks, agricultural systems, and institutional performance in Bihar and Begusarai indicates that gaps are not limited to technology availability but extend to coordination, delivery systems, and adoption conditions. The following recommendations are structured to address these gaps across governance, economic systems, technical delivery, and planning frameworks. Each recommendation integrates state-level policy direction with district-level operational requirements.

8.1 Institutional and Governance Reforms

Recommendation 1: Establish integrated convergence mechanisms across departments

Agricultural resilience in Bihar requires coordinated functioning of departments related to agriculture, water resources, livestock, and disaster management. At the state level, a formal convergence platform should be established to align programmes under NAPCC, SAPCC, and sectoral schemes. This platform should enable joint planning, shared targets, and integrated implementation. At the district level, including Begusarai, convergence committees should be operationalised through existing administrative structures to coordinate activities across line departments and ensure that interventions address local conditions such as flood-prone land and mixed farming systems. This will reduce fragmentation and improve the effectiveness of programme delivery.

Recommendation 2: Strengthen district-level agricultural planning frameworks

State-level policies require translation into district-specific strategies. The government in Bihar should adopt agro-climatic zone-based planning frameworks that integrate cropping patterns, water availability, and land characteristics. At the district level in Begusarai, planning should be based on land typology, distinguishing lowland, medium land, and upland systems. Crop planning, input allocation, and extension activities should be aligned with these categories to ensure that interventions are suited to local conditions. This approach will improve targeting and increase the effectiveness of resource use. This should be further refined by aligning crop planning with the Eastern Plain hot sub-humid (moist) conditions, prioritising flood-resilient paddy varieties in lowlands, diversified rice–wheat/pulses systems in medium lands, and drought-tolerant crops (e.g., maize, millets, oilseeds) in uplands, in accordance with ICAR agro-ecological region 13.1 and the Middle Gangetic Plain Zone IV recommendations.

Recommendation 3: Improve monitoring and accountability systems

Current monitoring systems rely on periodic reporting, which limits responsiveness. In Bihar, real-time monitoring systems using digital platforms should be established and integrated with departmental data. These systems should track programme implementation, input distribution, and adoption levels. At the district level, block-based monitoring mechanisms should be strengthened to provide continuous feedback on field conditions. In Begusarai, monitoring systems should incorporate seasonal variability, particularly during flood periods, to ensure that implementation is adjusted in real time. This will improve accountability and enable timely corrective action.

8.2 Economic and Resource System Strengthening

Recommendation 4: Improve access to credit and risk mitigation instruments

Limited access to formal credit reduces the ability of farmers to adopt improved practices. The relevant authorities in Bihar should strengthen institutional credit delivery through banking networks and improve access to crop insurance schemes. This should explicitly leverage cooperative banks and Regional Rural Banks (RRBs), which form the backbone of agricultural credit delivery in the state, and align credit disbursement with DBT-enabled input subsidy systems to ensure timely access to seeds and fertilisers. Credit products should be aligned with agricultural cycles and risk conditions. In Begusarai, targeted financial support should be prioritised for farmers in flood-prone areas, where income variability is higher. Linking credit with insurance and input support will reduce financial risk and encourage adoption of improved practices. This should be operationalised through structured instruments such as concessional crop loans under the Kisan Credit Card (KCC) with interest subvention (effectively reducing interest to about 4% for timely repayment), bundled with mandatory or opt-in coverage under schemes like the Pradhan Mantri Fasal Bima Yojana (PMFBY) and Weather-Based Crop Insurance Scheme to protect against yield and weather shocks. Additionally, capital investment support through NABARD-linked subsidies and targeted Direct Benefit Transfers (e.g., PM-KISAN income support) should be integrated with credit lines to improve liquidity and enable adoption of climate-resilient inputs and infrastructure in high-risk areas.

Recommendation 5: Reform input delivery systems and strengthen seed availability

Access to quality seeds and balanced fertilisers remains uneven. Seed production and distribution systems, including state seed corporations and certified supply chains should be strengthened in Bihar. This should include strengthening last-mile delivery through Primary Agricultural Credit Societies (PACS) and block-level input centres, which are key distribution nodes in Bihar, and ensuring timely pre-season stocking of seeds, particularly for flood-tolerant and short-duration varieties. Nutrient management programmes should promote balanced fertiliser use to address existing imbalances. This should be supported by strengthening Soil Health Card-based advisories and improving access to customised fertiliser blends to correct the prevailing nitrogen-heavy application patterns in the state. At the district level, decentralised seed distribution mechanisms should be established in Begusarai, particularly for crops suited to different land types. Localised seed banks and community-level seed systems should be developed to ensure rapid availability of replacement seeds following flood-induced crop loss. Timely availability of inputs will improve productivity and support adoption of improved technologies.

Recommendation 6: Strengthen water resource management through integrated approaches

Water management requires addressing both excess and deficit conditions. Bihar should integrate irrigation planning with drainage and flood management, linking schemes such as PMKSY with infrastructure investments supported through institutional financing mechanisms. This should include convergence with state-supported minor irrigation and flood control programmes, and prioritisation of drainage infrastructure in north Bihar's floodplains, where waterlogging remains a persistent constraint on agricultural productivity. At the district level in Begusarai, priority should be given to improving drainage systems in low-lying areas, promoting water storage in uplands, and enhancing irrigation efficiency. This can be operationalised through rehabilitation of local drainage channels and desiltation of existing water bodies, promotion of farm ponds and on-farm water harvesting structures in uplands, and adoption of efficient irrigation practices such as alternate wetting and drying in paddy cultivation. This integrated approach will reduce vulnerability to both flooding and water stress.

8.3 Technical Systems and Agricultural Transformation

Recommendation 7: Scale up climate-resilient agricultural technologies

Technologies for climate-resilient agriculture are available but remain unevenly adopted across farming systems. At the state level, the systematic scaling of stress-tolerant crop varieties, conservation agriculture practices, and water-efficient technologies should be prioritised through coordinated extension and seed distribution systems in Bihar. A structured effort should be undertaken to identify, conserve, and promote locally adapted and stress-tolerant crops, including indigenous germplasm that has evolved under specific agro-climatic conditions. These landraces can complement improved varieties by providing tolerance to drought, submergence, and soil variability, thereby strengthening resilience across different agro-ecological zones. In addition, agroforestry systems should be integrated into agricultural development strategies, particularly in areas with declining soil quality and high climatic variability, as they improve soil health, enhance moisture retention, and provide additional income through tree-based products.

At the district level, implementation in Begusarai should follow a land-type based approach. In low-lying and flood-prone areas, the promotion and revival of indigenous flood-resilient landraces should be undertaken, as these are better adapted to submergence and variable water conditions and can reduce crop loss during inundation. In such areas, the introduction of adaptive practices such as float farming should also be explored, particularly in locations with prolonged waterlogging where conventional cultivation is not feasible. This involves the use of floating structures on which vegetables can be cultivated in grow bags, combined with aquaculture below through pen or cage systems. Such integrated systems can enable continued production during flood periods while supporting both crop and fish-based livelihoods. In upland and medium land areas, diversification into climate-resilient coarse cereals such as Indigenous millets (Foxtail, Barnyard, and Proso) should be promoted, as these crops have lower water requirements, shorter growing durations, and greater tolerance to rainfall variability. Agroforestry models should also be introduced in these areas by integrating tree species with crops to improve soil stability, reduce erosion, and provide supplementary income. Across all land types, these interventions should be supported through demonstration programmes, local seed systems, and continuous advisory services to ensure sustained adoption.

Recommendation 8: Strengthen extension systems and continuous advisory services

Extension systems require strengthening in terms of reach and continuity. In Bihar, staffing gaps should be addressed with improved training of extension personnel, and enhanced coordination between ATMA and KVKs. Advisory services should be continuous rather than limited to seasonal training programmes. In Begusarai, extension delivery should be adapted to local conditions, including mobile advisory systems during flood periods and increased field presence in remote areas. This will improve knowledge transfer and adoption rates.

8.4 Monitoring, Data, and Climate Planning Systems

Recommendation 9: Develop integrated data and decision-support systems

Agricultural planning requires reliable and timely data. Integrated data systems that combine weather information, crop data, and programme implementation metrics should be developed in Bihar. These systems should support decision-making at state and district levels. In Begusarai, block-level data collection should be strengthened to capture local variations in cropping, water availability, and production conditions. Data-driven planning will improve targeting and efficiency of interventions.

Recommendation 10: Integrate climate projections into agricultural planning

Planning frameworks should incorporate future climate scenarios rather than relying solely on historical trends. Bihar should integrate climate projections based on Representative Concentration Pathways (RCPs) and Shared Socioeconomic Pathways (SSPs) into agricultural policy and planning processes. These frameworks provide structured scenarios of future temperature, rainfall, and extreme event patterns under different emission and development trajectories.

At the state level, these projections should be used to guide crop planning, water resource management, and infrastructure development. At the district level, including Begusarai, planning should translate these projections into location-specific contingency strategies, particularly for flood-prone and low-lying areas. This includes aligning cropping calendars, selecting appropriate crop varieties, and planning infrastructure based on projected changes in rainfall intensity and temperature.

Integrating SSP–RCP scenarios into agricultural planning will enable anticipatory decision-making and reduce dependence on reactive responses to climate variability.

Chapter 9: Implementation Roadmap and Financing

Effective implementation of climate-resilient agriculture in Bihar and Begusarai requires a phased approach that aligns institutional reforms, technical interventions, and financing mechanisms. This chapter presents a structured roadmap for implementation along with clearly defined financing pathways based on existing programmes and institutional mechanisms.

9.1 Phased Implementation Framework

Phase I: Institutional Alignment and System Setup (Year 1–2)

The first phase should focus on establishing the foundational systems required for implementation. This includes operationalising convergence mechanisms across departments related to agriculture, water resources, livestock, and disaster management. At the state level, coordination platforms should be formalised to align ongoing programmes and avoid duplication. At the district level in Begusarai, convergence committees should be activated through existing administrative structures.

District-level planning frameworks should be developed during this phase, based on agro-climatic zoning in Bihar and land typology in Begusarai. This will ensure that interventions are aligned with local conditions. Real-time monitoring systems should also be initiated, with integration of departmental data to support tracking of implementation and outcomes.

Capacity gaps in extension systems should begin to be addressed through recruitment, training, and improved coordination between extension agencies. This phase establishes the institutional and administrative base required for subsequent implementation.

Phase II: System Strengthening and Technology Deployment (Year 2–4)

The second phase should focus on strengthening delivery systems and scaling field-level interventions. Climate-resilient agricultural technologies, including stress-tolerant crop varieties, water-efficient practices, and agroforestry systems, should be expanded through coordinated extension efforts.

In Begusarai, land-type specific interventions should be implemented, including flood-resilient landraces and varieties and adaptive practices such as float farming in low-lying areas, and diversification into millets and agroforestry in upland areas. Demonstration programmes should be expanded to support adoption, with a focus on local seed systems and continuous advisory services.

Input delivery systems should be strengthened to ensure timely availability of seeds and fertilisers. Credit and insurance access should also be expanded during this phase to support farmer investment in improved practices. Water resource management interventions, including drainage and irrigation improvements, should be initiated.

This phase focuses on translating policy and planning into field-level action through strengthened systems and targeted interventions.

Phase III: Consolidation, Integration, and Scaling (Year 4–6)

The third phase should focus on consolidating gains and expanding successful interventions. Agricultural practices that demonstrate effectiveness should be scaled across districts, with integration into mainstream agricultural systems.

Data systems established in earlier phases should be used to guide planning and resource allocation. Climate projections based on Representative Concentration Pathways and Shared Socioeconomic Pathways should be integrated into long-term planning processes.

Market linkages and value chains should be strengthened to support diversified production systems, including millets, horticulture, and integrated crop–livestock–fish systems. Institutional coordination mechanisms should be stabilised to ensure sustained convergence across sectors.

This phase ensures that climate-resilient agriculture transitions from pilot interventions to a sustained and integrated system.

9.2 Financing Architecture

Implementation of the proposed framework should rely on convergence of existing schemes and institutional financing mechanisms rather than creation of new funding structures.

At the national and state levels, programmes related to climate-resilient agriculture, irrigation, and input support provide the primary financing base. The National Mission for Sustainable Agriculture supports interventions related to soil health, water management, and climate-resilient practices. The Pradhan Mantri Krishi Sinchai Yojana provides funding for irrigation expansion and water-use efficiency. Demonstration and technology development activities are supported through programmes implemented by agricultural research institutions.

State-level financing is channelled through the Agricultural Road Map and related schemes, which support productivity enhancement, diversification, and input delivery systems. Direct benefit transfer mechanisms for fertilisers and seeds provide additional support for input access.

Institutional financing mechanisms also play a role in supporting infrastructure development. NABARD supports investments in irrigation, drainage, and flood management through instruments such as the Rural Infrastructure Development Fund. These resources are used by state governments for infrastructure projects related to water management and agricultural systems. Such investments are particularly relevant for flood-prone districts such as Begusarai, where drainage and flood control infrastructure are critical for sustaining agricultural production (Chauhan & von Wehrden, 2025; James, 2025; Pandey, 2025).

At the district level in Begusarai, financing should be aligned with local priorities. Resources should be directed towards flood management, drainage improvement, and support for diversified farming systems. Convergence of funding across agriculture, water, and rural development departments is necessary to ensure efficient utilisation.

The financing approach should therefore prioritise alignment and convergence of existing resources, ensuring that investments are targeted towards identified gaps and implementation priorities.

Recommendation	Level	Lead Agency	Implementation Phase	Financing Source
Establish integrated convergence mechanisms across departments	State and District	Department of Agriculture, Department of Water Resources, Department of Animal Husbandry, District Administration	Phase I (Year 1–2)	State government budget, National Mission for Sustainable Agriculture
Strengthen district-level agricultural planning frameworks	State and District	Department of Agriculture, State Planning Department, District Administration	Phase I (Year 1–2)	State Agriculture Road Map, State government schemes

Improve monitoring and accountability systems	State and District	Department of Agriculture, District Administration	Phase I (Year 1–2) and Phase II (Year 2–4)	State government budget, digital agriculture initiatives
Improve access to credit and risk mitigation instruments	State and District	Banking institutions, Department of Agriculture, Insurance agencies	Phase II (Year 2–4)	Credit-linked subsidy schemes, crop insurance programmes
Reform input delivery systems and strengthen seed availability	State and District	State Seed Corporation, Department of Agriculture, Krishi Vigyan Kendras	Phase II (Year 2–4)	State schemes, seed distribution programmes
Strengthen water resource management through integrated approaches	State and District	Department of Water Resources, Department of Agriculture	Phase II (Year 2–4) and Phase III (Year 4–6)	Pradhan Mantri Krishi Sinchai Yojana, National Bank for Agriculture and Rural Development funding (Rural Infrastructure Development Fund)
Scale up climate-resilient agricultural technologies	State and District	Indian Council of Agricultural Research institutions, State Agricultural University, Krishi Vigyan Kendras	Phase II (Year 2–4) and Phase III (Year 4–6)	National Innovations on Climate Resilient Agriculture, State agriculture programmes
Strengthen extension systems and continuous advisory services	State and District	Agricultural Technology Management Agency, Krishi Vigyan Kendras, Department of Agriculture	Phase I (Year 1–2) and Phase II (Year 2–4)	State extension programmes, agricultural training schemes
Develop integrated data and decision-support systems	State and District	Department of Agriculture, State Planning Department	Phase II (Year 2–4)	Digital agriculture initiatives, state funding
Integrate climate projections into agricultural planning	State and District	Department of Agriculture, State Planning Department, climate research institutions	Phase III (Year 4–6)	State government funding, climate adaptation programmes

Chapter 10: Conclusion- From Policy to Practice

Agriculture in Bihar operates under increasing climatic variability, where rising temperatures, irregular rainfall patterns, and recurrent flood events are altering production conditions across the state. These risks are not uniform; they are mediated by agro-ecological conditions, resource access, and institutional effectiveness. The analysis undertaken in this white paper shows that while the state possesses a broad policy framework and an established institutional system, gaps in coordination, delivery, and adoption continue to limit the effectiveness of climate-resilient agriculture.

The case of Begusarai illustrates this interaction clearly. The district combines high agricultural potential with significant exposure to flooding and waterlogging. Farming systems are shaped by land typology, where low-lying areas face recurrent inundation while uplands offer opportunities for diversification. This heterogeneity requires planning and intervention at a scale that goes beyond state-level aggregation. District-level differentiation is therefore not an operational detail but a necessary condition for effective agricultural policy.

The assessment also indicates that the challenge is not the absence of technologies or practices. Climate-resilient options already exist in the form of stress-tolerant crop landraces and varieties, diversified cropping systems, agroforestry, and integrated farming approaches. However, these remain unevenly adopted due to constraints in seed systems, extension reach, credit access, and institutional coordination. As a result, the gap between demonstration and large-scale adoption persists.

Bridging this gap requires a shift from fragmented implementation to integrated systems. Institutional convergence across departments, alignment of planning frameworks with agro-ecological conditions, and strengthening of extension systems are central to this transition. Equally important is the need to align financing mechanisms with implementation priorities, ensuring that investments in irrigation, drainage, and agricultural infrastructure are directed towards areas of highest vulnerability.

The integration of climate projections into agricultural planning represents another critical transition. Current approaches are largely reactive, responding to variability after it occurs. Incorporating forward-looking scenarios based on Representative Concentration Pathways and Shared Socioeconomic Pathways enables anticipatory planning, particularly in flood-prone regions such as Begusarai. This shift from response to preparedness will determine the long-term resilience of agricultural systems.

The recommendations presented in this white paper provide a structured pathway for this transition. They emphasise coordination, targeted planning, system strengthening, and data-driven decision-making. The implementation framework further demonstrates that these actions can be undertaken through phased progression, supported by convergence of existing schemes and institutional financing mechanisms.

Climate-resilient agriculture in Bihar therefore depends not only on technical solutions but on the effectiveness of systems that deliver them. The experience of Begusarai highlights the importance of localised planning within a broader state framework. Moving from policy intent to field-level outcomes requires sustained institutional commitment, alignment of resources, and continuous engagement with farmers.

The pathway forward is clear. The necessary tools, institutions, and knowledge systems are already present. The priority now is to ensure that they function in a coordinated and context-specific manner, enabling agriculture in Bihar to adapt to changing climatic conditions while sustaining productivity and livelihoods.

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