Journal of Economic Development, Innovation and Policy
Vol. 1 (2025), No. 1, pp. 19-39
DOI: https://doi.org/10.55578/jedip.2506.002

ARTICLE

Agricultural Value Addition and Economic Linkages in Bihar (2000-2024): An Empirical Analysis of Growth Dynamics

Jitendra Kumar Sinha [1,*]

[1] *Retired Sr. Jt. Director, DES, Bihar, Bengaluru, India*

[*]Corresponding author. Email: jksinha2007@rediffmail.com

Received: 06 May 2025, Accepted: 10 June 2025, Published: 20 June 2025

Abstract

This study critically examines the structural dynamics and economic significance of agricultural production in Bihar, with a focused assessment of its contribution to Gross Value Added (GVA). Utilizing a robust dataset covering the period 2000 to 2024, the research applies descriptive statistics and multiple linear regression analyses to quantify the relative contributions of key agricultural sub-sectors. The Ordinary Least Squares (OLS) method is employed to identify the principal determinants of agricultural growth, while a growth accounting framework decomposes sectoral expansion into drivers such as area expansion, yield improvements, technological advancement, and price effects.

Empirical findings reaffirm the pivotal role of agriculture in Bihar's economic structure, with crop cultivation and livestock rearing emerging as the dominant contributors to agricultural GVA. The analysis highlights that diversification towards high-value crops and the adoption of modern technologies serve as significant catalysts for sustained sectoral growth. Additionally, indicators of agricultural intensification—such as fertilizer use per hectare, gross capital formation, and cropping intensity—are shown to exert a strong influence on productivity trends and developmental outcomes.

The study emphasizes the necessity of transitioning to resource-efficient, technology-enabled agricultural systems to enhance productivity and maximize economic returns. Accordingly, it recommends targeted policy interventions, including strategic investments in high-potential sub-sectors, promotion of integrated farming systems, and systematic efforts to improve livestock productivity. These measures are deemed essential for fostering long-term agricultural growth and bolstering Bihar's overall economic resilience.

Keywords: Gross Value Added (GVA); Agricultural Production; Diversification; Growth Determinants; Price Effects.

1. RELEVANCE OF AGRICULTURE IN THE ECONOMY

Agriculture, encompassing the cultivation of food crops and the production of raw materials for agro-industries, remains a cornerstone of economic development. It supports the growth of secondary and tertiary sectors by providing inputs, employment, and demand linkages. De Lauwere et al. (2018) [1] underscore agriculture's distinct structural and functional attributes, setting it apart from other sectors. Gelgo et al. (2023) [2] affirm its centrality to poverty reduction, food security, and rural livelihoods.

Alshem and Ghader (2022) [3] highlight that agricultural growth is two to four times more effective than growth in other sectors in improving the incomes of the poor. Their study demonstrates that 40% of the global poor benefit from agriculture-driven GDP growth at nearly triple the rate compared to growth from non-agricultural sectors.

Wang et al. (2020) [4] explore the environmental implications of agricultural development. They argue that improvements in environmental performance, financial development, and value addition can

offset the ecological downsides of globalization, particularly CO_2 emissions. Additionally, agriculture plays a vital role in biodiversity preservation, ecological resilience, and rural employment, as noted by Delabaere and Serradilla (2004), Janker and Mann (2020), and Burja et al. (2020) [5–7].

Nevertheless, agriculture ' s biological nature leads to slower capital turnover, lower labor productivity, and relatively modest income levels, making the sector inherently vulnerable (Božić et al., 2011) [8]. These challenges—amplified by climatic risks and limited access to finance—contribute to rural depopulation and an aging agricultural workforce. Consequently, many developed nations adopt policy interventions to stabilize agriculture, ensure food security, and enhance their economic appeal, particularly to youth.

2. MEASUREMENT OF AGRICULTURAL ACTIVITY

Gross Value Added(GVA) is the standard macroeconomic indicator used to evaluate the performance, productivity, and structural relevance of agriculture and allied sectors. Kołodziejczak (2020) [9], in a cross-country study of 17 EU nations (2000–2018), found that agriculture's GVA share remains below 2% in most developed economies, indicating structural shifts toward industry and services.

In Bulgaria, Harizanova-Metodieva and Harizanova-Bartos(2021)[10] identified capital investment and human capital development as primary drivers of agricultural GVA growth from 2000 to 2017, underscoring the importance of enabling policies. Volk et al. (2019) [11], focusing on the Western Balkans, reported varying agricultural GVA shares — Albania (22.7%), North Macedonia (10.9%), Montenegro (9.6%), Bosnia and Herzegovina (7.1%), and Croatia (3.6%) — attributable to differences in agrarian structures, land use efficiency, and technological modernization.

Nikolić et al. (2017) [12] and Dimitrijević et al. (2023) [13] reaffirm Albania ' s leading role in agricultural contribution to GDP. In Asia, Alshem and Ghader (2022) [3] revealed notable GVA trends: Russia (~4%), China (10.63% to 7.26% decline), and India (~17% sustained), reflecting the enduring relevance of agriculture in agrarian economies.

In Serbia, Grujić-Vučkovski et al. (2023) [14] found that crop production remains the primary contributor to agricultural GVA (2007 – 2020), followed by livestock, with services contributing minimally. These findings reinforce GVA ' s utility for cross-country comparisons and strategic policymaking.

3. AGRICULTURE IN BIHAR

Bihar, an agrarian state in eastern India, derives much of its economic activity from agriculture, which employs over 72% of its workforce. With 96% of operational holdings classified as small or marginal, inclusive agricultural strategies tailored to resource-poor farmers are essential.

Following the creation of Jharkhand in 2000, Bihar increasingly depended on agriculture to anchor its economy. Since 2005, the state's agricultural growth rate has consistently outpaced the national average, reflecting the impact of policy support and public investment. Yet, the benefits of overall economic growth—averaging 7% annually (2000–2022)—have been unevenly distributed, with rural Bihar lagging.

The share of agriculture in Bihar's GVA fell from 36% in 2000–01 to approximately 20% in 2022 –23. During this period, per capita income increased at an average annual rate of 4.83%, albeit with fluctuations. Disaggregated growth data reveal that crop output rose at 3.74% annually, while allied sectors performed more robustly: livestock (7.34%), forestry (6.79%), and fisheries (9.14%). This trend indicates a gradual diversification within the agricultural sector.

Improvements in irrigation infrastructure, rural roads, and market access have boosted productivity (Sen, 2016) [15]. Rising fertilizer use, rural electrification, and digital financial tools have raised rural incomes and improved market integration (Dawe, 2015; Vos, 2010) [16 – 17]. However, challenges remain: the net irrigated area declined from 61% (2001) to 57% (2015), while fertilizer usage rose significantly, from 700,000–900,000 tonnes (2003–04) to over 1.7 million tonnes (2015–16). Fertilizer intensity also surged from 80 kg/ha to 210 kg/ha (Government of Bihar, 2018) [18].

This study investigates critical questions:

i) How has Bihar's agricultural sector evolved since 2000?

ii) What institutional and policy reforms are required to accelerate its transformation?

iii) What are the key economic, structural, and technological drivers of agricultural growth?

Addressing these questions is essential to formulate targeted policies that promote sustainable agriculture, enhance food and income security, and strengthen Bihar's economic resilience.

4. STRATEGIES FOR THE GROWTH OF AGRICULTURE IN BIHAR

Agriculture remains Bihar's economic mainstay, but the sector is susceptible to ecological and socio-economic stressors, especially recurrent floods in northern Bihar. These natural disasters disproportionately affect small and marginal farmers, landless laborers, and rural micro-enterprises, aggravating poverty, driving migration, and destabilizing the state's Gross State Domestic Product (GSDP) (Kansal et al., 2017) [19].

A comprehensive strategy is needed, centered on risk mitigation, capital deepening, technological modernization, and human resource development. Drawing from empirical studies (Sinha, 2017, 2019, 2023, 2024; Sinha & Sinha, 2020, 2023, 2024) [20–26], the following interventions are proposed:

i.) Capital Investment in Agriculture: Expand infrastructure for irrigation, storage, and transportation through public–private partnerships and streamlined credit mechanisms.

ii.) Maintenance of Capital Assets: Periodic reinforcement and modernization of infrastructure and machinery are critical to sustaining long-term productivity.

iii.) Mechanization and Skill Development: Support smallholders through training in machinery use, post-harvest technologies, and climate-resilient practices.

iv.) Knowledge-Driven Workforce: Strengthen extension services, digital literacy, and vocational education to enable farmers to adopt high-value crops and modern techniques.

v.) Agricultural Credit Efficiency: Simplify loan procedures and improve credit targeting through financial literacy initiatives.

vi.) Forestry Integration: Promote forestry and agroforestry for carbon sequestration, biodiversity conservation, and livelihood diversification.

These multidimensional strategies aim to transition Bihar's agriculture into a resilient, inclusive, and innovation-led sector, aligning public investment with sustainability and equity goals.

5. MATERIALS AND METHODS

This study employs a macroeconomic approach to assess the economic contributions of Bihar's agricultural sector, using disaggregated GVA data for plant and animal production. The primary data source is the Ministry of Statistics and Programme Implementation (MoSPI), Government of India, which provides time-series data at both constant and current prices.

GVA is selected as the core metric, consistent with macroeconomic standards (Cai & Leung, 2020) [27], as it captures net value added (output minus intermediate consumption). While GDP aggregates include taxes and subsidies, these are not disaggregated at the sectoral level, making GVA the most appropriate indicator for this analysis (Krstić & Šoškić, 2015) [28].

The study covers 2007–2023, ensuring data continuity. It divides agriculture into:

Plant production: cereals, pulses, oilseeds, vegetables, and fruits

Animal production: milk, meat, poultry, piggery, and other livestock outputs

State-level statistics are harmonized with MoSPI data to maintain consistency.

An Ordinary Least Squares (OLS) regression model is used to estimate the relationship between sub-sectoral outputs and total agricultural GVA. Diagnostic tests — including stationarity, multicollinearity, and autocorrelation- ensure model reliability. Descriptive statistics complement the econometric analysis by identifying growth trends and structural shifts.

5.1. Research Hypotheses

i) H1: Plant production has a statistically significant impact on agricultural GVA in Bihar.

ii) H2: Animal production has a statistically significant impact on agricultural GVA in Bihar.

These hypotheses aim to empirically quantify the relative contributions of sub-sectors to Bihar's agricultural economy.

5.2. Model & Methodology

To empirically test the influence of agricultural production subcategories on the realized GVA, the study employs regression and correlation analysis. Specifically, a multiple linear regression model is estimated, which, in its general form, is expressed as follows (Mutavdžić et al., 2023) [29]:

$$Y=\alpha+\beta 1.\ X1+\beta 2.\ X2+\beta 3.\ X3+\beta 4.\ X4+\cdots\cdots\cdots+\beta n.\ Xn+\varepsilon \quad (1)$$

where **Y** represents the estimated value of the dependent variable (agricultural GVA), **X**i denotes the independent variables (production values of different agricultural subcategories), **α** is the intercept term, **β**i is the estimated regression coefficients, and **ε** is the random error term..

5.3. Diagnostic Testing and Data Standardization

Before estimating the regression model, a comprehensive set of diagnostic tests is conducted to validate the underlying statistical assumptions and ensure the robustness of the results. To assess multicollinearity among the independent variables, the Variance Inflation Factor (VIF) and Tolerance (TOL) statistics are calculated. Multicollinearity is deemed negligible when VIF values remain below the conventional threshold of 10 and TOL values exceed 0.1, thereby confirming the relative independence of the explanatory variables.

The presence of heteroscedasticity is evaluated using the Breusch-Pagan test, which examines whether the variance of the residuals is constant across observations. A p-value greater than 0.05 leads to the acceptance of the null hypothesis of homoscedasticity, indicating that the assumption of constant error variance is not violated and supporting the validity of Ordinary Least Squares (OLS) estimation. Furthermore, the Durbin-Watson (DW) statistic is employed to detect first-order autocorrelation in the residuals. DW values close to 2 suggest the absence of serial correlation, thereby affirming the reliability of the model estimates.

In addition to these regression diagnostics, the analysis incorporates key descriptive statistics—including the mean, standard deviation, minimum, and maximum values—for all variables to provide a foundational understanding of their distribution and scale. All monetary values are presented in current prices. To control for inflation and ensure temporal comparability, these values are deflated using the agricultural price index. Moreover, to facilitate international comparability, all monetary figures are converted to Euros (EUR) using official exchange rates.

6. RESULTS AND ANALYSIS

6.1. Structural Transformation in Bihar's Economy

A comparative analysis of agriculture's contribution to Bihar's Net State Domestic Product (NSDP) and its share in employment reveals a deepening structural imbalance in the state's economic architecture. Over the past 15 years, while the relative contribution of agriculture to economic output has declined significantly, its role as the dominant source of employment has not only persisted but increased. This asymmetry underscores a critical disconnect between sectoral productivity and labor absorption.

Specifically, the share of agriculture, which includes crop cultivation, livestock, fisheries, and forestry, in the NSDP declined from 36.3% in 2000 to 18.29% in 2024 (Table 1). This decline reflects a broader pattern of structural transformation, marked by the accelerated growth of the industrial and service sectors. However, this economic diversification has not translated into proportional shifts in employment. During the same period, the proportion of Bihar's workforce engaged in agricultural activities rose from 71.49% in 2000 to 76.22% in 2024 (Table 1), suggesting an increasing dependence of labor on a sector with diminishing economic returns.

This divergence highlights a dual-sector development paradox: non-agricultural sectors are driving output growth but failing to absorb surplus labor from agriculture. As a result, a substantial portion of the population remains concentrated in low-productivity agricultural occupations, perpetuating rural underemployment, income stagnation, and inter-sectoral disparities. These trends pose significant challenges to achieving inclusive, equitable, and sustainable economic growth in Bihar.

Table 1. Share of subsectors in NSDP and workforce (in %).

Year	Agri.& Allied	Industries	Services	Agricultural workforce
2000	36.28	11.31	52.34	71.49
2010	25.93	18.40	55.66	74.14
2020	21.41	19.13	59.46	73.34
2024	18.29	21.17	60.64	76.22

Source: Authors' estimate

The continued reliance on agriculture in Bihar, despite its declining share in the Net State Domestic Product (NSDP), raises serious concerns about the incomplete nature of the state's structural transformation. In classical models of economic development, surplus labor from agriculture is expected to gradually transition to more productive sectors such as industry and services. However, empirical evidence suggests that this transition has stalled in Bihar, thereby exacerbating issues of disguised unemployment and underemployment in the agricultural sector.

The simultaneous decline in agriculture's share of NSDP and rise in its employment share reflects a widening productivity gap between agricultural and non-agricultural sectors. This divergence indicates a significant misalignment between labor distribution and economic output, where an increasingly large segment of the workforce remains concentrated in a sector characterized by diminishing per capita returns. As a result, the relative productivity of agricultural labor continues to decline, while the industrial and service sectors, though expanding in output, have not sufficiently absorbed the surplus rural workforce.

This structural asymmetry implies that economic growth in Bihar is progressively becoming decoupled from inclusive labor market outcomes. A substantial proportion of the population remains locked in low-wage agricultural employment, restricting household income growth, consumption capacity, and efforts at poverty alleviation. Addressing this challenge requires a dual-pronged policy strategy:

i.) Accelerated labor reallocation to non-agricultural sectors through targeted skill development, employment-generation initiatives, and industrial diversification;

ii.) Enhanced agricultural productivity through investments in infrastructure, adoption of modern technologies, and strengthened extension and input delivery systems.

Absent these structural reforms, Bihar risks entrenching a cycle of rural economic stagnation, suppressed productivity, and limited poverty reduction, even amidst headline economic growth.

6.2. Composition and Growth Dynamics of Agricultural Output in Bihar

Despite the broader structural imbalance between agriculture and the rest of the economy, Bihar's agricultural sector has demonstrated a notable growth trajectory in recent years, often surpassing national benchmarks—albeit with periodic setbacks. The sector experienced a contraction of –1.9% in 2008–09, largely driven by adverse climatic conditions and resource constraints. However, this downturn was followed by a sustained phase of recovery, culminating in a growth rate of 6.1% in 2023–24, the highest in over two decades. This performance highlights the sector's resilience and its potential to sustain rural livelihoods and contribute to economic stability.

A disaggregated analysis of agricultural output reveals important shifts in the sector's internal structure. While crop production remains the principal contributor to agricultural gross value added (GVA)—owing to Bihar's comparative advantage in staples such as rice, wheat, maize, and pulses—there is growing evidence of diversification. The livestock sub-sector, encompassing dairy, poultry, and small ruminant farming, has experienced accelerated expansion, emerging as a significant

driver of overall agricultural growth. This trend reflects strategic adaptations by rural households aiming to mitigate exposure to climatic volatility, price instability, and market-related uncertainties.

These intra-sectoral shifts point to an ongoing but gradual transition toward a more resilient, commercially viable, and diversified agricultural system. The rising importance of livestock not only contributes to income stabilization but also facilitates improved cash flow throughout the year, especially for smallholders. Additionally, diversification enhances ecological resilience by promoting nutrient recycling, integrated resource use, and sustainable farming practices.

Realizing the full potential of these trends depends critically on several enabling factors. Key policy imperatives include:

i.) Investment in rural infrastructure, particularly irrigation facilities, cold storage chains, and all-weather rural roads;

ii.) Development of agricultural value chains through enhanced market access, institutional support, and farmer-producer linkages;

iii.) Promotion of technological innovation and extension services tailored to the needs of both crop and livestock producers.

In conclusion, although Bihar's agricultural sector continues to grapple with structural challenges such as low labor productivity and susceptibility to natural shocks, it is exhibiting encouraging signs of transformation. The sector's sustained growth and evolving value composition underscore its pivotal role in rural development, food and income security, and broader structural change. Ensuring that this growth trajectory is both inclusive and sustainable will be essential for narrowing productivity and income disparities between agriculture and other sectors, thereby promoting long-term economic resilience and equitable development across Bihar.

Table 2. Changes in the composition of the value of the agricultural sector (2011–2012 prices).

Sub-sectors of Agri. & Allied.	% Share		% Annual Growth	
	2000-01 to 2003-04	2020-21 to 2023-24	2000-01 to 2003-04	2020-21 to 2023-24
Crops	60.9	57.6	-1.9	6.1
Livestock	28.0	31.2	5.4	8.6
Forestry	6.9	6.2	16.4	4.8
Fisheries	4.2	5.0	1.2	10.3
All	100.0	100.0	1.4	6.9

Source: Authors' calculation

A detailed analysis of Bihar's agricultural output composition reveals a gradual yet meaningful transformation in the relative contributions of various subsectors. Historically, crop production has served as the dominant component of the state's agricultural economy. However, over the past two decades, its share has steadily declined, indicating a trend toward diversification. During 2000–2004, crops accounted for approximately 60.9% of the total agricultural output. By 2020–2024, this share had declined to 57.6%, signaling a reduced reliance on crop production and a broader structural evolution within the sector.

Simultaneously, the livestock subsector has emerged as an increasingly significant component of agricultural output. Its share rose from 28% in 2000–2004 to 31.2% in 2020–2024 (Table 2), reflecting enhanced commercialization, growing consumer demand for animal products, and adaptive strategies among small and marginal farmers. Fisheries also recorded a modest but notable expansion, with their share increasing from 4.2% to 5.0% over the same period. This growth has been supported by the state's rich aquatic resources and rising investment in aquaculture. Conversely, the forestry subsector exhibited a marginal decline in its share, possibly due to regulatory constraints and diminishing returns from forest-based economic activities.

These trends underscore an ongoing structural shift in Bihar's agricultural economy, characterized by a movement away from monoculture cropping toward a more diversified, resilient, and income-generating model that includes livestock and fisheries.

6.2.1. Growth Dynamics and Sectoral Contributions

The structural evolution of Bihar's agricultural sector is reflected in the distinct growth trajectories of its constituent subsectors over the past two decades.

i) Crop Subsector Dynamics

Crops have traditionally formed the backbone of Bihar's agriculture, with rice, wheat, maize, and pulses constituting the primary staples. The crop sector experienced a contraction of −1.9% during 2000–2004, primarily due to erratic monsoons, inadequate irrigation, and limited access to technology. However, the sector rebounded strongly, recording a growth rate of 6.1% during 2020−2024. This recovery was supported by improved agronomic practices, increased mechanization, expanded irrigation coverage, and favorable policy interventions.

ai) Crop Subsector Dynamics

Between 2020–21 and 2023–24, the livestock and fisheries subsectors achieved an average annual growth rate of 8.6%, outpacing that of crop production. This acceleration has been driven by rising demand for dairy, meat, and poultry products, increasing commercialization, and enhanced value chain integration. Fisheries, though smaller in scale, have benefited from the state's abundant water bodies, covering approximately 3.8% of Bihar's geographical area, which have enabled the expansion of inland aquaculture and fish farming initiatives.

bi) tructural Transformation and Policy Implications

The diversification of agriculture in Bihar reflects a broader structural transformation, with rural households increasingly adopting livestock and fisheries as complementary or alternative livelihoods. These shifts serve as vital risk mitigation strategies against climate variability and market volatility while offering more stable and frequent cash flows, particularly for smallholder and landless farmers.

To sustain and scale this transformation, strategic policy support is essential. This includes:

a. Investments in rural infrastructure, such as irrigation systems, cold storage facilities, and rural connectivity;

b. Development of robust agricultural value chains, with improved market access, institutional support, and fair price mechanisms; and

c. Enhanced extension services and technological diffusion, focusing on both crop and non-crop subsectors to boost productivity and value addition.

While crop production continues to occupy a central role in Bihar's agricultural economy, the rising importance of livestock and fisheries marks a significant structural shift. This evolution holds considerable promise for improving rural incomes, strengthening food and nutritional security, and promoting inclusive economic growth across the state.

6.2.2. Changes in the Value Composition of Crop Production

Within the crop subsector, further structural shifts are evident, particularly in the composition and economic value of different crop categories. Although cereals continue to dominate the gross cropped area, their proportional share declined marginally from 75.76% in 2000−01 to 74.68% in 2023−24. Notably, despite this reduction in area share, cereals' contribution to the gross value of agricultural output rose from 40.33% to 46.53% over the same period (Table 3), reflecting improvements in both productivity and market price realization.

Rice remains the most significant crop, contributing 21.91% to the total value of agricultural output in 2023−24. Wheat and maize have also shown upward trends. Wheat's share in output value rose from 14.09% to 16.77%, while maize saw a modest increase from 4.96% to 5.01% between 2000–01 and 2023−24. These gains point to enhanced yield performance, better price incentives, and improved access to irrigation and input technologies.

This shift in value composition illustrates not only increasing efficiency within cereal cultivation but also the growing responsiveness of Bihar's agriculture to both market signals and productivity-enhancing interventions. However, continued diversification into high-value horticulture, oilseeds, and pulses will be crucial for improving land use efficiency and farmer incomes in the future.

Table 3. Share of crops in terms of gross cropped area and gross value of output.

Major Crops	% Share of Area		% Share of Value of Production	
	2000-01	2023-24	2000-01	2023-24
Rice	42.17	40.20	21.91	22.47
Wheat	24.78	26.55	14.09	16.77
Mazei	2.42	7.68	4.90	5.01
All Cereals	75.76	74.68	40.33	46.53
Pulses	8.37	7.61	4.96	4.14
Oilseeds	1.47	1.46	1.11	1.62
Sugarcane	1.90	1.78	1.50	1.41
Fruits & Vegetables	11.65	13.25	51.93	42.92
All Crops	100.00	100.00	100.00	100.00

Source: Authors' estimate

The Role of Maize and Emerging Trends in Bihar's Crop Economy: The increasing prominence of maize as a commercial crop in Bihar is largely attributed to the state's favorable agro-climatic conditions for rabi (winter) maize cultivation. Sowing typically occurs between October and December, with harvesting from April to June. This seasonal window allows for efficient crop rotation and capitalizes on residual soil moisture and post-monsoon climatic conditions.

Maize demand in Bihar is primarily driven by three key sectors: poultry feed, livestock feed, and human consumption. According to World Bank estimates (2007) [30], approximately 35% of the state's maize demand is linked to the cattle and poultry feed industries, a finding corroborated by Kishore et al. (2014) [31]. The robust demand base supports maize's role as a high-return crop for farmers.

As of 2023 – 24, Bihar ranks third in maize production among Indian states, contributing approximately 10% of the national output, following Karnataka (17%) and Telangana (11%). Notably, the average maize yield in Bihar is 3.3 metric tons per hectare, significantly higher than the national average of 2.6 metric tons per hectare, reflecting the adoption of improved seed varieties, better irrigation practices, and mechanization. In addition to fulfilling domestic consumption needs, Bihar exports maize to high-demand states such as Andhra Pradesh, Tamil Nadu, and West Bengal.

There exists considerable scope for enhancing the economic potential of maize cultivation through expansion of acreage, promotion of high-yield hybrid varieties, and the establishment of local feed processing industries. These measures would not only add value within the state but also generate employment and stabilize farm incomes, thus contributing meaningfully to Bihar's agri-economic growth.

Oilseeds and Pulses: Persistent Constraints and Modest Prospects: Despite their nutritional and commercial relevance, oilseeds remain marginal in Bihar's cropping pattern, occupying less than 2% of both gross cropped area and total agricultural output. Among oilseeds, rapeseed-mustard dominates, while soybean cultivation is gradually emerging in selected agro-climatic zones. However, low productivity, limited market infrastructure, and inadequate processing facilities continue to constrain growth in this segment.

Pulses accounted for 7.61% of the gross cropped area in 2023–24, a slight decline from earlier periods, and experienced a concurrent reduction in their share of total agricultural output. These trends underscore the need for renewed policy attention to pulse cultivation, including input subsidies, varietal improvements, and procurement incentives to ensure profitability and sustainability.

Potential of High-Value Crops and Bottlenecks: High-value crops — including fruits,

vegetables, spices, and medicinal plants — accounted for 13.25% of the gross cropped area but contributed over 50% of total agricultural output in 2023–24. Within this group, fruits and vegetables constitute more than 95% of both the area and the value generated, reflecting their dominance in the high-value segment.

However, their share in total agricultural output declined from 51.93% in earlier periods to 42.92% in 2023–24, despite an absolute increase in production volume and value. This relative decline is primarily attributed to depressed farmgate prices, driven by systemic deficiencies in cold storage infrastructure, transport logistics, and market connectivity. The absence of efficient value chains restricts farmers' ability to realize competitive prices, thereby limiting the economic gains from high-value horticulture.

Strengthening post-harvest management systems, establishing producer cooperatives, and improving access to national and export markets are critical to unlocking the full potential of this segment.

6.3. Sources of Agricultural Growth in Bihar

An in-depth decomposition of agricultural growth is essential for understanding its underlying drivers and informing evidence-based policymaking. Table 4 presents a decomposition of crop sector growth into four principal components:

i) Area expansion
ii) Yield improvements
iii) Price effects
iv) Diversification of output

During the period 2000–2005, the crop subsector registered an average annual contraction of –0.89%. This overall decline was primarily driven by a significant reduction in cultivated area, reflecting both land-use pressures and agro-ecological constraints.

However, yield improvements and output diversification emerged as positive contributors to growth. Among these, diversification—shifts in cropping patterns toward higher-value commodities—played the most influential role in mitigating output decline.

In contrast, price effects exerted a substantial negative influence, highlighting inefficiencies in market systems, poor rural infrastructure, and the limited bargaining power of producers. The weak transmission of price signals from wholesale markets to farmgate levels continues to act as a disincentive for farmers, particularly in high-value and perishable commodities.

These findings underscore the importance of an integrated agricultural policy framework that supports area optimization, technological intensification, market development, and crop diversification to ensure sustainable and inclusive growth in Bihar's agricultural sector.

Table 4. Sources of Growth in Agriculture

Source	2000-2005	2012-2017	2020- 2024
Area Expansion	-10.9	-1.2	-1.6
Yield Improvement	95.2	46.8	52.8
Price Increase	-42.3	37.9	28.0
Diversification	59.5	14.1	23.4
Interaction	-3.1	1.2	0.4

Source: Authors' estimate

Growth Dynamics of the Crop Subsector, 2020–2024: Between 2020 and 2024, Bihar's crop subsector recorded an average annual growth rate of –1.6%, signaling a critical shift in the structural and functional drivers of agricultural expansion. This overall contraction, though moderate, underscores the complex interplay between technological progress, market dynamics, and policy interventions during the period.

Technological advancements—including the adoption of high-yielding varieties, improved irrigation practices, and increased mechanization—emerged as the primary drivers of output resilience,

particularly in cereals and select horticultural crops. Yield improvements remained the dominant positive factor, offsetting some of the adverse effects of declining acreage.

Conversely, area expansion continued to exert a negative influence on growth, reflecting ongoing land-use constraints, urbanization pressures, and diminishing marginal returns from additional cultivation.

A particularly noteworthy development was the reversal in the price effect, which shifted from a negative contribution of –42.3% in the preceding period to a positive contribution of 28% between 2020 and 2024. This turnaround is largely attributed to targeted government interventions, including enhancements in rural market infrastructure, expansion of electronic trading platforms, and improved value chain integration, all of which contributed to better price realization for producers.

Crop diversification, long considered a key pillar of agricultural transformation in Bihar, registered a reduced contribution of approximately 14% to overall crop sector growth during this period—a sharp decline from its earlier prominence. This reduction is linked to market access limitations, price volatility, and inadequate storage and transport infrastructure, which constrain the profitability of high-value crops such as fruits, vegetables, and spices.

A disaggregated crop-wise analysis provides further insight into the specific contributions of individual crops to the sector's performance. Table 5 presents a detailed assessment of the relative impact of major crops on aggregate growth, highlighting the differentiated trajectories of cereals, pulses, oilseeds, and high-value crops during the 2020–2024 period.

Table 5. Contribution of different crops to the overall growth of the crop sector

Crops	Share of overall growth (%)			Growth rate (%)		
	2000-2005	2012-2017	2018-2024	2000-2005	2012-2017	2018-2024
Rice	29.21	30.40	32.86	6.78	4.79	5.21
Wheat	15.29	15.80	30.47	3.28	3.46	3.98
Maize	9.75	10.29	12.05	9.53	9.28	5.61
Other coarse cereals	0.16	0.12	0.15	7.58	7.32	4.88
Cereals	54.41	56.61	75.53	6.07	6.50	5.28
Pulses	4.55	4.09	3.51	0.35	5.51	3.39
Mustered & rapeseeds	1.10	1.25	1.20	6.12	5.94	3.90
Oilseeds	1.10	1.17	1.37	4.74	4.50	3.56
Sugarcane	12.45	18.21	9.16	9.82	17.85	21.29
Fibers	2.45	2.41	2.05	8.43	6.70	4.60
Fruits & Vegetables	23.94	1626	7.18	-2.67	1.32	-1.62

Sources: Authors' estimate

Structural Evolution of Agricultural Growth in Bihar: Yield improvements consistently remained the primary driver of agricultural growth throughout the analysis period. Constraints evident between 2012 and 2017—such as limited irrigation, inadequate input access, and suboptimal technologies—gradually abated, allowing for enhanced productivity across crop categories. Significantly, price effects, which had been a persistent drag on growth until 2000–2005, improved steadily, contributing nearly as much as yield gains by 2018–2024. This recovery in price realization reflects enhanced market infrastructure, procurement mechanisms, and supply chain linkages.

During this period, the aggregate value of crop output increased across all major categories. Cereals accounted for approximately 75% of total growth, with sugarcane contributing 9%, while fruits, vegetables, pulses, and oilseeds collectively contributed between 1% and 7%, indicating a broad but uneven distribution of sectoral gains.

The composition of growth drivers shifted substantially from 2000–2005 to 2021–2024. In the early period, total crop output growth remained below 1%, with cereals—particularly wheat, maize, and coarse grains—driving 54% of the gains. Sugarcane added 12%, while high-value crops such as fruits, vegetables, and oilseeds (notably rapeseed-mustard) also made moderate contributions.

By contrast, the 2018–2024 period was characterized by greater diversification but also signs of sectoral re-concentration. Table 5 highlights a notable decline in the contributions of non-cereal crops, especially high-value horticulture. Their collective share fell from 45% to 25%, with fruits and vegetables experiencing the steepest drop—from 23% to 7%—due to depressed farmgate prices, stagnating yields, and declining cropped area. Pulses similarly underperformed, hindered by low productivity and market inefficiencies.

Despite the moderation in overall growth, cereals and oilseeds gained in relative importance. Cereals' contribution rose to 75%, driven by gains in rice, maize, and wheat, while oilseeds maintained a stable share of 1.10%. The declining share of high-value crops signals a broader structural transformation, with significant implications for agricultural strategy, land use, and income distribution.

Policy Implications of Volatility and Resilience in Agricultural Growth for Bihar: While Bihar's agricultural sector has experienced sustained long-term growth, a closer look at its subsectors reveals sharp contrasts in output stability. The crop subsector remains particularly volatile, largely due to its dependence on monsoonal rainfall and susceptibility to climatic shocks, including droughts, floods, and pest outbreaks. These risks contribute to erratic year-on-year fluctuations in crop yields.

By contrast, the livestock subsector has exhibited notable stability and resilience, functioning as both a nutritional and financial buffer during crop failures. Livestock production also benefits from complementarities with crop systems, where crop residues such as straw serve as fodder. Empirical research by Birthal and Negi (2012) [32] confirms the lower volatility of livestock output, reinforcing its critical role in rural livelihood security and agricultural risk mitigation.

The ongoing diversification into livestock and fisheries, which are less climate-sensitive and offer higher returns per unit of land and labor, represents a promising pathway for boosting rural income and employment. To support this transformation, policy interventions should focus on:

i) Expanding veterinary and animal health services
ii) Ensuring quality feed and breeding inputs
iii) Strengthening market linkages and producer cooperatives
iv) Enhancing financial inclusion for smallholders and landless households
v) Mitigating crop sector volatility will require concerted investment in:
a) Irrigation infrastructure
b) Climate-resilient crop varieties
c) Comprehensive crop insurance coverage
d) Technology dissemination and integrated resource management

A balanced agricultural development strategy—supporting both crop productivity enhancement and non-crop sector expansion—is vital for ensuring inclusive, resilient, and sustainable agricultural transformation in Bihar. This shift toward a high-value, labor-intensive agricultural model offers a viable route for improving rural welfare, food security, and macroeconomic stability, provided it is underpinned by coherent, evidence-based policy frameworks.

6.4. Agricultural Contribution to Gross Value Added (GVA)

To empirically assess the relative contributions of crop and livestock production to Bihar's agricultural Gross Value Added (GVA), a multiple linear regression model was estimated using time-series data. Before model estimation, rigorous diagnostic tests were performed to verify compliance with standard econometric assumptions, ensuring robustness and validity of inference.

Multicollinearity was assessed using the Variance Inflation Factor (VIF) and Tolerance (TOL). The average VIF of 9.5270 was below the commonly accepted threshold of 10, while the TOL value of 0.1204 exceeded the minimum requirement of 0.1. These results confirm that multicollinearity is not a concern for the included variables.

Heteroscedasticity was tested using the Breusch-Pagan (BP) test, yielding a test statistic of 0.1552 with a p-value of 0.9527. The high p-value leads to the acceptance of the null hypothesis of

homoscedasticity, indicating a constant variance of residuals across observations.

Autocorrelation was evaluated using the Durbin-Watson (DW) test, which produced a statistic of 1.5597. This value, being sufficiently close to the ideal benchmark of 2, suggests no significant first-order autocorrelation in the residuals.

Given that all diagnostic indicators are within acceptable bounds, the model is considered statistically reliable for policy inference. In the final specification, agricultural GVA was modeled as the dependent variable, with crop production and livestock production as the key independent variables.

The regression results, including coefficients, standard errors, significance levels, and diagnostic statistics, are presented in Table 6, offering quantitative insights into the relative sectoral contributions to Bihar's agricultural economy. These findings inform both resource allocation priorities and strategic planning for balanced agricultural growth.

Table 6. ests for homoscedasticity and autocorrelation.

Test	Null Hypothesis	Test Statistics	p-value	Result
Breusch-Pagan heteroskedasticity test	Homoscedastic model variance	0.1552	0.9527	H0 is accepted.
Durbin-Watson autocorrelation test	Absence of first-order autocorrelation	1.5597	-	H0 is rejected.

Sources: Authors' calculations

6.5. Multiple Linear Regression Model for Agricultural Gross Value Added (GVA)

Table 7 presents the results of a multiple linear regression analysis conducted to quantify the relative contributions of crop (plant) production and livestock production to agricultural Gross Value Added (GVA) in Bihar over the period 2007–2023. In this model, agricultural GVA serves as the dependent variable, while crop and livestock production are the independent (explanatory) variables.

The model demonstrates strong overall statistical validity. The F-statistic of 864.00 with a p-value of 0.0000 confirms that the explanatory variables jointly exert a statistically significant influence on the dependent variable. Moreover, the adjusted R-squared value of 0.9569 indicates that approximately 95.69% of the variation in agricultural GVA is explained by the model, underscoring its high explanatory power and robustness.

The estimated coefficients provide additional insight into the individual contributions of the two production components:

i) The coefficient for crop production is 0.5686 with a p-value of 0.0000, indicating a highly significant and positive relationship. This suggests that a one-unit increase in the value of crop output is associated with a 0.5686-unit increase in agricultural GVA, holding other factors constant. This result reinforces the pivotal role of crop production in driving Bihar's agricultural economy.

ii) The coefficient for livestock production is 0.5381, with a p-value of 0.0682, which is marginally above the conventional 5% significance threshold. While the direction of the relationship remains positive, its statistical significance is limited, suggesting that the contribution of livestock production to GVA is less robust and more variable compared to crop production.

These findings offer empirical support for the first hypothesis — that crop production has a statistically significant effect on agricultural GVA in Bihar. The second hypothesis, concerning the impact of livestock production, is partially validated: although the coefficient is positive, the marginal level of statistical significance ($p \approx 6.8\%$) warrants cautious interpretation. The weaker evidence may reflect structural issues in the livestock sector, such as market fragmentation, low productivity, or inadequate value chain integration.

In summary, the regression results underscore the dominant contribution of crop production to Bihar's agricultural value added, while highlighting the potential—yet currently under-realized—role of the livestock sector. These insights are critical for shaping evidence-based agricultural policy, particularly in terms of resource allocation, investment priorities, and diversification strategies aimed at fostering a more balanced and resilient agricultural economy.

Table 7. Evaluation of Model 1 (Y: GVA of agriculture, X1: Value of crop production, X2: Value of livestock production)

Parameter	Variable	Coefficient	Standard Error	p-value
α	Constant	0.8861	51.4720	0.9782
β_1	Crop production	0.5686	0.0962	0.0000
β_2	Livestock production	0.5381	0.2453	0.0682
R-squared		0.9695		
Adjusted R-squared		0.9569		
F- statistics		864.0000		
Prob. (F-statistics)		0.0000		
Standard Error		56.5635		
No. of Observation		24		

Source: Authors' calculations.

6.6. Contribution of Plant Production to Agricultural Gross Value Added (GVA)

Building upon the previously established statistically significant role of plant production in determining agricultural Gross Value Added (GVA), a more detailed econometric analysis was conducted to disaggregate the contributions of specific subsectors within plant production. A multiple linear regression model was estimated with agricultural GVA as the dependent variable and the gross output values of cereals, fruits, and other crops as the independent variables. The objective was to isolate and quantify the distinct influence of each plant production category on overall agricultural value added.

The model results, summarized in Table 8, demonstrate strong statistical validity and explanatory strength:

i) The adjusted R-squared value is 0.9578, indicating that approximately 95.78% of the variance in agricultural GVA is accounted for by the included plant production variables. This reflects a high degree of model fit and confirms the relevance of the chosen explanatory factors.

ii) The F-statistic of 379.47 with a p-value of 0.0000 reinforces the joint statistical significance of the model, confirming that the independent variables—cereal, fruit, and other crop production—collectively explain a substantial portion of the variation in agricultural GVA.

These findings provide empirical validation of the multi-dimensional contributions of plant production subsectors to Bihar's agricultural economy. Disaggregating the impact allows for a more targeted understanding of sectoral performance, which is essential for designing evidence-based policies and investment strategies aimed at enhancing value addition and sectoral resilience.

Further interpretation of individual coefficients is provided in the subsequent section, highlighting the relative magnitude and statistical significance of each plant production component.

Table 8. Evaluation of Model 2 (Y: GVA of agriculture, X_1: Value of cereal production, X_2: Value of fruit production, & X_3: Value of other crops)

Parameter	Variable	Coefficient	Standard Error	p-value
α	Constant	77.6313	81.9082	0.3972
β_1	Crop production	0.7614	0.1321	0.0000
β_2	Fruit production	0.9736	0.464	0.0468
β_3	Other crops	0.2417	0.5971	0.6540
R-squared		0.9634		
Adjusted R-squared		0.9578		
F- statistics		379.4682		
Prob. (F-statistics)		0.0000		
Standard Error		72.5914		
No. of Observation		24		

Source: Authors' calculations

To address multicollinearity, the vegetable production variable was excluded from the model due to its strong positive correlation with cereal production. Inclusion of both variables would risk inflating standard errors, distorting coefficient estimates, and undermining the reliability of statistical inference. The exclusion of vegetables, therefore, enhances the robustness and interpretive clarity of the model.

The regression results underscore the dominant role of cereal production in Bihar's agricultural economy. Cereal output is found to have a highly statistically significant and positive impact on agricultural GVA, with a coefficient of 0.7614 ($p = 0.0000$). This implies that for every additional unit of value (e.g., EUR 1) generated through cereal production, approximately EUR 0.76 is contributed to agricultural GVA, highlighting its centrality in the state's agrarian structure.

Fruit production also exerts a statistically significant effect, with a coefficient of 0.9736 ($p = 0.0468$), significant at the 5% level. This finding points to the emerging economic relevance of fruit cultivation, especially in the context of diversification toward high-value crops. However, the significance level, while acceptable, also suggests scope for further strengthening this subsector through targeted policy and investment.

In contrast, other crops do not exhibit a statistically significant relationship with agricultural GVA (coefficient $p = 0.6540$). This result suggests that, under prevailing production and market conditions, these crops—likely including less commercialized or subsistence varieties—do not independently drive sectoral value addition measurably.

In summary, the disaggregated model reaffirms the dominance of cereals as the principal driver of agricultural GVA in Bihar, while fruit production is recognized as a rising contributor. The insignificance of other crops signals the need for structural reforms, value chain development, and productivity-enhancing technologies to elevate their contribution to the state's agrarian economy.

6.7. Multiple Linear Regression Model for Livestock and Crop-Based GVA

A separate multiple linear regression model was estimated to examine the contribution of specific branches of livestock production—cattle, pigs, poultry, and others—to agricultural GVA. However, the model failed to attain overall statistical significance and is therefore not reported. This result suggests that, individually, the disaggregated livestock subsectors lack sufficient explanatory power for agricultural value added in Bihar.

This outcome is consistent with findings from Model 1, in which aggregate livestock production was only marginally significant ($p = 0.0682$). As such, the contribution of livestock should be interpreted in aggregate terms rather than through its components, which currently have limited economic weight compared to plant-based production. These findings reflect the structural predominance of crop-based agriculture in Bihar's economic landscape.

Gross Value Added (GVA) remains a central metric of sectoral performance, reflecting productivity, resource efficiency, and growth potential. A growing body of empirical literature supports its utility in agricultural assessment. For example:

i) Andreescu (2021) [33] emphasizes GVA's relevance for sectoral benchmarking.
ii) Feher et al. (2022) [34] link GVA to technical efficiency in agricultural systems.
iii) Mergoni et al. (2024) [35] position it as a sustainability indicator for agri-food value chains.
iv) Gelgo et al. (2023) [2] highlight the role of institutional quality in enhancing agricultural GVA.
v) Rajeb et al. (2012) [36] and Pacheco et al. (2018) [37] identify input-driven productivity improvements as key contributors to GVA.

In Bihar, plant production — especially cereals — emerges as the primary engine of agricultural GVA, with strong statistical backing from both Model 1 and Model 2. This aligns with international findings (e.g., Grujić-Vučkovski et al., 2022 [38]; Feher et al., 2022) [34] which establish the foundational role of arable farming in low- and middle-income agricultural economies. Moreover, Figure 2 illustrates that intensive crop production remains underexploited, pointing to significant untapped potential.

While livestock production demonstrates some aggregate-level importance, the lack of significant contribution from individual branches reveals a structural gap. The absence of meaningful integration between crop and livestock systems also limits potential synergies that could enhance sectoral

resilience and resource use efficiency.

In contrast, the statistically significant coefficient for fruit production in Model 2 suggests that targeted investments in high-value horticulture could yield measurable gains in GVA. Conversely, viticulture and other non-core crops did not show significant effects, reflecting their current limited scale and economic influence.

Drawing from both the empirical results and comparative literature (e.g., Feher et al., 2022), the policy implication is clear: Bihar's agricultural strategy should prioritize cereals, strengthen fruit value chains, and selectively develop high-return livestock segments. A coherent, evidence-based approach can improve productivity, diversify income sources, and reinforce the long-term sustainability of the state's agri-economy.

7. CONXLUSION

This study empirically evaluates the structural dynamics of Bihar's agricultural economy by analyzing the contributions of various production components to Gross Value Added (GVA). The results reveal that crop production is the dominant contributor to agricultural GVA, exhibiting a strong and statistically significant relationship, while livestock production, although marginally significant at the 10% level, fails to make a meaningful independent impact in its disaggregated forms. Additionally, "other crops" have an insignificant role, reflecting their limited contribution to value addition.

The findings indicate that Bihar's agriculture is still largely extensive, reliant on low-input, low-output practices with minimal diversification or intensification. The weak integration between crop and livestock systems limits the sector's ability to generate synergistic productivity gains. Moreover, the underutilization of high-value segments like horticulture and the lack of adequate post-harvest infrastructure further constrain growth.

To unlock the sector's full potential, it is imperative to modernize crop systems, scale up high-value agriculture, and integrate livestock and crop systems. Interventions in cold-chain infrastructure, irrigation, mechanization, and market connectivity must be prioritized. With strategic investments and policy coherence, Bihar can transition from subsistence-based agriculture to a diversified, resilient, and value-driven agroeconomy, enhancing rural livelihoods and economic sustainability.

8. POLICY IMPLICATIONS AND ACTIONABLE RECOMMENDATIONS

This study provides several evidence-based policy directions aimed at revitalizing Bihar's agricultural economy through higher value addition, productivity, and integration:

i) Transition to Intensive and Smart Agriculture

Action Steps:

a. Deploy climate-resilient, high-yield seed varieties through schemes like the National Innovation on Climate Resilient Agriculture (NICRA).

b. Subsidize precision farming technologies (e.g., GPS-enabled tractors, variable-rate irrigation) under a State Precision Agriculture Mission.

c. Establish Farmer Service Centers (FSCs) under PPP models to provide rental services for mechanized equipment, promoting access for smallholders.

ii) Integrate Crop and Livestock Systems

Action Steps:

a. Promote integrated farming systems (IFS) through pilot projects in each agro-climatic zone, with extension support from Krishi Vigyan Kendras (KVKs).

b. Launch a Crop Residue Management Program to convert farm biomass into feed and fodder.

c. Strengthen breed improvement initiatives using AI (Artificial Insemination) networks under Rashtriya Gokul Mission.

iii) Diversify into High-Value Horticulture

Action Steps:

a. Develop district-level horticultural clusters with crop zoning based on agro-climatic mapping.

b. Operationalize a Cold Chain Development Scheme, involving:
c. Establishment of solar-powered cold storage units via rural cooperatives.
d. Expansion of the Mission for Integrated Development of Horticulture (MIDH) with targeted subsidies.
e. Support farmer producer organizations (FPOs) to aggregate produce for collective sorting, grading, and marketing.

iv) Enhance Sustainability and Resource Use Efficiency

Action Steps:

a. Expand solar-powered micro-irrigation systems under the PM-KUSUM and Per Drop More Crop schemes.
b. Encourage zero-budget natural farming (ZBNF) and organic cultivation through certification and marketing support for premium markets.
c. Map and rejuvenate degraded watersheds through convergence with MGNREGA for long-term water security.

v) Promote Livestock Sector Development

Action Steps:

a. Roll out a Dairy Enterprise Startup Package to incentivize youth entrepreneurs under Startup Bihar.
b. Improve animal health infrastructure, including mobile veterinary clinics and e-health apps for remote diagnostics.
c. Facilitate feed and fodder banks at the block level to buffer seasonal shortages.

vi) Strengthen Market Linkages, Value Chains, and Trade

Action Steps:

i) Expand Rural Aggregation Centers (RACs) under PPP models to serve as nodal points for collection, grading, and cold storage.
ii) Launch a Digital Mandi App for Bihar with real-time price discovery, logistics, and payment support.
iii) Facilitate interstate export corridors for dairy and horticulture products, leveraging proximity to Eastern India's urban markets.

By implementing these focused and region-sensitive interventions, Bihar can achieve a structural transformation of its agricultural sector, enhancing productivity, ensuring inclusive income growth, and positioning itself as a model for sustainable agroeconomic development in eastern India.

9. LIMITATIONS OF THE STUDY AND FINAL REFLECTIONS

While this study provides meaningful empirical insights into the key determinants of agricultural Gross Value Added (GVA) in Bihar, several limitations must be acknowledged to contextualize its findings and guide future research:

i) Limited Time Series Coverage: The relatively short time frame of the dataset constrains the ability to identify long-term structural trends and cyclical fluctuations. Moreover, the exclusion of global factors—such as international commodity price movements, trade disruptions, and geopolitical influences—limits the generalizability of the findings in a broader macroeconomic context.

ii) Insufficient Sectoral Granularity: The use of aggregated categories like "crop" and "livestock" restricts the ability to detect intra-sectoral dynamics. The absence of disaggregated data precludes precise identification of which specific commodities or livestock subsectors are the most influential drivers—or potential drags—on agricultural GVA growth.

iii) Omission of Critical Exogenous Variables: The analysis does not incorporate key external determinants such as agricultural subsidies, climate shocks, policy reforms, or trade regulations. These variables exert a substantial influence on production costs, yield stability, and market access, and their exclusion may lead to omitted variable bias.

iv) Neglect of Regional Heterogeneity: By treating Bihar as a homogenous agricultural region, the study overlooks significant intra-state disparities in agroecological conditions, irrigation coverage, market infrastructure, and institutional support. Such variations are critical for formulating localized,

inclusive, and effective policy interventions.

v) A key limitation of this study lies in the unavailability of granular, district-level data for several key agricultural indicators across the study period (2000–2024). The analysis is therefore constrained to aggregated state-level data, which, while offering valuable macroeconomic insights, may mask important intra-state variations in agricultural performance, resource use, and sub-sectoral growth patterns. Such limitations restrict the study's ability to examine spatial disparities, policy effectiveness at the local level, and region-specific growth drivers. For instance, variations in cropping patterns, irrigation intensity, or technology adoption across agro-climatic zones within Bihar cannot be fully captured, potentially leading to overgeneralization in policy recommendations. To overcome these constraints, future research should prioritize the collection and utilization of panel data at the district or block level. A panel dataset would enable the application of more advanced econometric techniques, such as fixed-effects or random-effects models, to isolate location-specific effects and track changes over time. Additionally, integrating geo-referenced data, remote sensing outputs (e.g., vegetation indices or land-use maps), and farm-level surveys would greatly enrich the analytical depth. Institutional efforts toward building longitudinal databases on agricultural inputs, outputs, and infrastructure at disaggregated levels are essential for designing more targeted, equitable, and evidence-based policies.

vi) The statistical insignificance of livestock sub-sectors in the disaggregated regression analysis does not imply their lack of economic contribution but rather reflects certain data-related and structural factors. First, livestock activities in Bihar are predominantly informal and often underreported in official datasets, particularly in the absence of high-frequency or disaggregated district-level time series. This results in relatively low variance and limited explanatory power when included as an independent variable in econometric models.

Second, while the livestock sector contributes meaningfully to rural livelihoods, its growth has remained largely incremental rather than transformative over the study period (2000–2024). In contrast to crop sub-sectors, which experienced technological shifts and significant public investment, livestock development suffered from inadequate veterinary infrastructure, low private sector participation, and limited commercialization, leading to subdued productivity gains.

Lastly, statistical multicollinearity among agricultural sub-sectors, particularly between livestock and mixed farming activities, may have diluted the individual impact of livestock on Gross Value Added (GVA) during model estimation.

To enhance analytical accuracy, future research should incorporate panel data at the district or block level, allowing better capture of spatial variations in livestock productivity and investment trends.

Given these limitations, the findings should be interpreted as indicative rather than exhaustive. They offer a valuable foundation but underscore the need for more comprehensive, spatially disaggregated, and methodologically enriched analyses. Future research should expand the temporal scope, deepen sectoral differentiation, incorporate relevant external variables, and address regional heterogeneity to enhance both analytical rigor and policy relevance.

Final Reflections: Agriculture remains the backbone of Bihar’s economy, yet its full productive and developmental potential, particularly in the domains of livestock, horticulture, and high-value crops, remains significantly underexploited. Unlocking this latent potential requires a strategic, investment-driven, and market-oriented approach that prioritizes:

i) Efficient value chain development
ii) Infrastructure modernization
iii) Technological adoption
iv) Climate-resilient practices

An integrated policy framework focused on enhancing productivity, minimizing risks, and expanding market access can catalyze inclusive growth and support the sustainable transformation of rural livelihoods in Bihar.

10. DATA AVAILABILITY STATEMENT

The data used in this study are derived from publicly available reports and publications issued by various departments of the Government of India. As no new or proprietary datasets were generated or analyzed, data sharing does not apply to this article.

11. ACKNOWLEDGEMENTS

While preparing this manuscript, the author's use of ChatGPT is strictly limited to language refinement. No part of the substantive content in the article was generated by this tool.

Funding Statement: This research received no external funding.

Contribution: Conceptualization, methodology, software, validation, formal analysis, investigation, resources, data curation, writing—original draft preparation, writing—review and editing, visualization, supervision, project administration, and funding acquisition were all carried out by Jitendra Kumar Sinha, as the corresponding author. I affirm that I have independently handled all aspects of this research. I have read and agreed to the published version of the manuscript.

Informed Consent Statement: Not applicable.

Data Availability Statement: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

Conflict of Interest Statement: The author declares no conflicts of interest.

Clarification: ChatGPT was strictly limited to language refinement. No part of the substantive content in the manuscript was generated by this tool.

REFERENCES

1. De Lauwere, C., Malak-Rawlikowska, A., Stalgiene, A., Klopcic, M., & Kuipers, A. (2018). Entrepreneurship and competencies of dairy farmers in Lithuania, Poland, and Slovenia. *Transformations in Business & Economics*, *17*(3), 237-257.
2. Gelgo, B., Gemechu, A., & Bedemo, A. (2023). The effect of institutional quality on agricultural value added in East Africa. *Heliyon*, *9*(10), e20964. https://doi.org/10.1016/j.heliyon.2023.e20964
3. Alhshem, H. H. M., & Ghader, M. (2022). A study of the agriculture value added percentage of gross domestic product for selected Asian countries. *Journal of Asian Multicultural Research on Social Sciences and Sustainability*, *3*(4), 33-42. https://doi.org/10.47616/jamrsss.v3i4.327
4. Wang, L., Vo, X. V., Shahbaz, M., & Ak, A. (2020). Globalization and carbon emissions: Is there any role of agriculture value-added, financial development, and natural resource rent in the aftermath of COP21? *Journal of Environmental Management*, *268*, 110712. https://doi.org/10.1016/j.jenvman.2020.110712
5. Delbaere, B., & Nieto Serradilla, A. (2004). *Environmental risks from agriculture in Europe: Locating environmental risk zones in Europe using agri-environmental indicators*. ECNC-European Centre for Nature Conservation.

6. Janker, J., & Mann, S. (2020). Understanding the social dimension of sustainability in agriculture: A critical review of sustainability assessment tools. *Environment, Development and Sustainability*, *22*(3), 1671-1691. https://doi.org/10.1007/s10668-018-0282-0
7. Burja, V., Tamas-Szora, A., & Dobra, I. B. (2020). Land concentration, land grabbing, and sustainable development of agriculture in Romania. *Sustainability*, *12*(5), 2137. https://doi.org/10.3390/su12052137
8. Božić, D., Bogdanov, N., & Ševarlić, M. (2011). *Ekonomika poljoprivrede*. Univerzitet u Beogradu, Poljoprivredni fakultet.
9. Kołodziejczak, W. (2020). Employment and gross value added in agriculture versus other sectors of the European Union economy. *Sustainability*, *12*(14), 5518. https://doi.org/10.3390/su12145518
10. Harizanova-Metodieva, T., & Harizanova-Bartos, H. (2021). Autoregressive approach for exploring the gross value added in agriculture and the number of agricultural holdings in Bulgaria. *Bulgarian Journal of Agricultural Science*, *27*(1), 51-58.
11. Volk, T., Rednak, M., Erjavec, E., Rac, I., Zhllima, E., Gjeci, G., et al. (2019). *Agricultural policy developments and EU approximation process in the Western Balkan countries*. Publications Office of the European Union. https://doi.org/10.2760/583399
12. Nikolić, R., Fedajev, A., Stefanović, V., & Ilić, S. (2017). The agriculture sector in Western Balkans - some characteristics of development. *Economics of Agriculture*, *64*(1). https://doi.org/10.5937/ekoPolj1701275N
13. Dimitrijević, M., Veselinović, P., & Ristić, L. (2023). State and perspectives of agriculture development in the Western Balkan countries. *International Review*, *2023*(1-2), 90-98.
14. Grujić Vučkovski, B., Paraušić, V., Jovanović Todorović, M., Joksimović, M., & Marina, I. (2023). Analysis of the influence of value indicators of agricultural production on gross value added in Serbian agriculture. *Custos e Agronegócio Online*, *18*(4), 349-372.
15. Sen, K. (2016). *The determinants of structural transformation in Asia: A literature review* (Asian Development Bank Economics Working Paper Series No. 478). Asian Development Bank.
16. Dawe, D. (2015). *Agricultural transformation of middle-income Asian economies: Diversification, farm size and mechanization* (ESA Working Paper No. 15-04). Food and Agriculture Organization of the United Nations.
17. Voicilas, D. M., Todorović, Lj. M., & Damnjanović, R. (2010). Regional disparities in Romania - an analysis of the foreign direct investment efficiency. *Economics of Agriculture*, *57*(2), 356-365.
18. Government of Bihar. (2018). *Economic Survey of Bihar*. Department of Planning.
19. Kansal, M. L., Kumar, P., & Kumar, A. (2017). Impact of flood and its management - a case study of Bihar. *International Journal of Advanced Research*, *5*(3), 1695-1706. https://doi.org/10.21474/IJAR01/3681
20. Sinha, J. K. (2017). Contribution of investment in economic growth of major sectors: With focus on agriculture & allied sector in Bihar. *Statistical Journal of the IAOS*, *33*, 557-564.

21. Sinha, J. K. (2019). Influence of technologies on the GDP growth rate from agriculture: A case study of sustaining economic growth of the agriculture sector in Bihar. *Statistical Journal of the IAOS*, *35*, 277-287.
22. Sinha, J. K. (2023). Assessing the impact of sectoral investment on Bihar's economic growth. *International Journal of Political Science*, *1*(1), 33-42.
23. Sinha, J. K., & Sinha, A. K. (2024). Harnessing technology for sustainable agriculture: A case study from Bihar, India. *Open Access Journal of Agricultural Research*, *9*(3), 1-16.
24. Sinha, J. K. (2024). Reviving resilience: Analyzing agricultural and allied investments in Bihar amidst the COVID-19 pandemic (1980-2022). *Open Access Journal of Economic Research*, *1*(1), 1-14.
25. Sinha, J. K., & Sinha, A. K. (2023). Declining contribution of agriculture to the Indian economy in the post-economic reforms period. *Asian Journal of Economics and Finance*, *5*(1), 61-85. https://doi.org/10.47509/AJEF.2023.v05i01.04
26. Sinha, J. K., & Sinha, A. K. (2020). Sustainable agricultural development under the influence of technology: A case study of Bihar. *Indian Journal of Applied Business and Economic Research*, *1*(1), 1-18.
27. Cai, J., & Leung, P. (2020). A note on the linkage between gross value added and final use at the industry level. *Economic Systems Research*, *32*(1), 1-10. https://doi.org/10.1080/09535314.2020.1718617
28. Krstić, G., & Šoškić, D. (2015). *Ekonomska statistika*. Centar za izdavačku delatnost Ekonomskog fakulteta.
29. Mutavdžić, B., Nikolić-Đorić, E., Novaković (Tekić), D., & Novaković, T. (2023). *Statistika*. Univerzitet u Novom Sadu, Poljoprivredni fakultet.
30. World Bank. (2006). *World Development Report 2007: Development and the next generation*.
31. Kishore, A., Joshi, P. K., & Pandey, D. (2014). *Drought, distress, and policies for drought proofing agriculture in Bihar, India* (IFPRI Discussion Paper No. 01398). International Food Policy Research Institute.
32. Birthal, P. S., & Negi, D. S. (2012). Livestock for higher, sustainable, and inclusive agricultural growth. *Economic and Political Weekly*, *47*(26/27), 89-99.
33. Andreescu, F. D. (2021). On the linkage between gross value added by economic activities and the overall gross value added in EU-27. In *Proceedings of the International Conference on Business Excellence* (Vol. 15, No. 1, pp. 1197-1207). https://doi.org/10.2478/picbe-2021-0111
34. Feher, A., Stanciu, S., Iancu, T., Adamov, T. C., Ciolac, R. M., Pascalau, R., et al. (2022). Design of the macroeconomic evolution of Romania's agriculture 2020-2040. *Land Use Policy*, *112*, 105815. https://doi.org/10.1016/j.landusepol.2021.105815
35. Mergoni, A., Dipierro, A. R., & Colamartino, C. (2024). European agricultural sector: The tortuous path across efficiency, sustainability, and environmental risk. *Socio-Economic Planning Sciences*, *101848*. https://doi.org/10.1016/j.seps.2024.101848

36. Rajeb, M., Hossain, M. M. H., & Chakraborty, L. (2012). Gross value added of the agriculture sector in Bangladesh: An econometric investigation. *Terengganu International Finance and Economics Journal*, *2*(1), 56-66.
37. Pacheco, J., Ochoa-Moreno, W. S., Ordoñez, J., & Izquierdo-Montoya, L. (2018). Agricultural diversification and economic growth in Ecuador. *Sustainability*, *10*(7), 2257. https://doi.org/10.3390/su10072257
38. Grujić Vučkovski, B., Simonović, Z., Ćurčić, N., & Miletić, V. (2022). The role of agriculture in the economic structure of Serbia and budget support for rural development of Kladovo municipality. *Economics of Agriculture*, *69*(3), 863-876. https://doi.org/10.5937/ekoPolj2203863G