Agricultural Diversification and its Impact on Farm Income: Evidence from North Bihar

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ABSTRACT

Agricultural diversification plays an important role in enhancing farm income through the capacity of farmers to grow a range of crops and engage in other agricultural activities. This research evaluates the impact of diversification on farm income in North Bihar selected districts (Darbhanga, Begusarai, Madhubani, and Samastipur). This research paper highlights the implementation of modern agricultural practices, the introduction of livestock farming, and adoption of high-value crops to improve the utilization of resources and reduce farming risks. This study uses qualitative and quantitative techniques to evaluate the impact of diversification on income stability, productivity, sustainability and modern farming technique. The findings reveal that diversification has highly contributed to increasing farmers' income, reduced dependency on traditional crops and methods, added economic benefits. The study also evaluates challenges such as market access, infrastructure deficit, and policy support needed for sustainable diversification. The study concludes with policy and practical recommendations for enhancing agricultural diversification to enhance long-term farm income in Bihar.

Keywords: *High-value crops, Modern farming techniques, High-value crops, Farming risks, Infrastructure deficit, Policy support.*

1. Introduction: -

Agricultural diversification is a farming approach in which farmers grow more than one crop or use several agricultural activities to make income gains consistent and sustainable. Diversification has been noticed as one of the important factors leading to increased farm income in districts like Darbhanga, Begusarai, Madhubani, and Samastipur in Bihar. Farmers were introduced to different crops, engaged in livestock farming, or adopted modern agriculture practices to maximize resource utilization and reduce risk (Soumya Gupta, 2022)[1].

[1] Soumya Gupta, S. S. (2022). Food, Agriculture, and Nutrition in

P. Kulkarni and S. Sharma (eds.), *Proceedings of the IBA IEA Conference on Economics and Public Policy (Ecofluence 2024)*, Advances in Economics, Business and Management Research 335,
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Farmers were introduced to diverse crops, engaged in livestock farming, or adopted modern agricultural practices to maximize resource utilization and minimize risks. Agricultural diversification is an approach in which farmers cultivate multiple crops or engage in various agricultural activities to ensure steady and sustainable income growth.

The other factors that depend on diversification are irrigation facilities, seed quality, machinery, and government policies. The electrification of the irrigation system reduces dependency on costly diesel pumps and decreases operational costs (Government of India, 2024)[2]. Modern farming equipment and precision technology can increase productivity and profitability. However, most farmers do not have access to such advancements due to a lack of knowledge or financial assistance (Andaleeb Rahman, May 2018)[3].

These initiatives of the government are PM-KUSUM, subsidies on agriculture equipment, and Pradhan Mantri Fasal Bima Yojana (PMFBY). Along with these factors, soil testing, high-quality seeds, and better fertilizers improve crop yield and generate incomes (Economic Survey 2024-25, 2025)[4]. However, the research about agricultural diversification in Bihar is limited, specifically its impact on smallholder farmers.

This study emphasizes challenges and opportunities for agricultural diversification and its effect on farm income. By critically analysing these main factors - such as irrigation, technology adoption, training programs, and the effectiveness of policy-making - the present research shall throw light upon the sustainable agriculture in Bihar.

2. Overview of Agriculture in Bihar

Agriculture remains the backbone of the Indian economy, contributing around 18.3% toward the GDP and employing nearly 45% of the total

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Bihar:Getting to Zero Hunger. *TCI (Tata-Cornell Institute). 2022. Food, Agriculture, and Nutrition in Bihar*:.

[2] Government of India. (2024). *"Economic Survey 2023-24"*. Government of India.

[3] Andaleeb Rahman, S. M. (May 2018). Towards Developing Diversified Food Systems in Bihar for Improving Nutritional Outcomes. *Tata-Cornell Institute for Agriculture and Nutrition (TCI-TARINA Policy Brief No. 11)*.

[4] *Economic Survey 2024-25.* Government of India.

workforce (see Economic Survey 2023). Technological advancement, irrigation improvement, and policies for production enhancement have been contributing to agricultural growth in India. This sector has seen an average annual growth of 3.5%-4% in the last decade, where diversification into horticulture, fisheries, and organic farming has played an important role in improving (Farmers' Incomes Survey 2024-25)[5].

Bihar, one of India's agriculturally rich states, has nearly 76% of its workforce employed in agriculture. The state contributes significantly to national food production, ranking amongst the top producers of rice, wheat, maize, and pulses in the country (Soumya Gupta, 2022)[6].

However, agricultural growth in Bihar has been constrained by disadvantages such as heavy irrigation costs, non-availability of modern equipment, and limited awareness of crop diversification opportunities. The agriculture sector in Bihar has, however, been growing at the rate of (3.5% - 4%) per annum, owing to the government schemes and infrastructure development (Ashok Gulati, Ranjana Roy, and Shweta Saini, 2021)[7].

Looking at districts like Darbhanga, Begusarai, Madhubani, and Samastipur, the role of electrification in the reduction of irrigation costs became significant in decreasing dependence on diesel-powered pumps. With electric irrigation costing down to nearly 75 paise per unit, water access has become more affordable for small and marginal farmers. However, the agricultural diversification in these districts continues to be limited by a number of factors, including low technology adoption, lack of structured training programs, and irregularity in quality seeds (Soumya Gupta, 2022)[8]. This paper provides in-depth analysis of farm diversification and its direct contribution to farm income in the chosen districts of North Bihar—Darbhanga, Begusarai, Madhubani, and Samastipur. In contrast to most other studies, which typically describe diversification in general, this study incorporates electrification in particular as the primary source of

[5] Economic Survey 2024-25. Government of India.
[6] Soumya Gupta, S. S. (2022). Food, Agriculture, and Nutrition in Bihar:Getting to Zero Hunger. TCI (Tata-Cornell Institute). 2022. Food, Agriculture, and Nutrition in Bihar:.
[7] Ashok Gulati, Ranjana Roy, and Shweta Saini. (2021). Revitalizing Indian Agriculture and Boosting Farmer Incomes. Springer.
[8] Soumya Gupta, S. S. (2022). Food, Agriculture, and Nutrition in Bihar:Getting to Zero Hunger. TCI (Tata-Cornell Institute). 2022. Food, Agriculture, and Nutrition in Bihar:.

inexpensive irrigation and diversification opportunities. The economic impact of the transition from diesel to electric pumps—reducing the cost of irrigation by 85–90%—is analysed in depth, which indicates a major but relatively unexploited dimension of sustainable agriculture.

The paper addresses key gaps by focusing on smallholder farmers, typically not included in policy development and research work but play a vital role in the agricultural economy of Bihar. The paper uses scale-based analysis to distinguish the diversification effect across small, medium, and large farms—offering a thorough insight rarely given in previous research. Furthermore, the study explores the role of seed quality, fertilizers, technology, training schemes, and government policies in determining diversification options. By combining quantitative and qualitative analysis, the paper offers practical advice on how farm income and rural livelihoods could be improved. Its holistic nature makes it profoundly useful to policy-makers, researchers, and practitioners developing sustainable and equitable agricultural growth in Bihar. the research aims to provide insights into sustainable farming practices that can enhance productivity and economic stability for farmers in the region (Ashok Gulati, Ranjana Roy, and Shweta Saini, 2021).[9]

3. Literature Review

Author	Title	Published	Date of Publication	Key Findings

[9] Ashok Gulati, Ranjana Roy, and Shweta Saini. (2021). *Revitalizing Indian Agriculture and Boosting Farmer Incomes*. Springer.

Anwarul Hoda, Pallavi Rajkhowa & Ashok Gulati	Unleashing Bihar's Agriculture Potential: Sources and Drivers of Agriculture Growth[10]	Indian Council for Research on International Economic Relations (ICRIER)	Working paper 336 2017	- Bihar's agriculture grew at 4.7% (2005-15) but remains volatile due to climate risks. -Rice & wheat dominate, while maize is emerging as a key cash crop. - Livestock contributes 31% of agri-output, yet milk yield remains low. -Poor infrastructure (roads, power, irrigation) hinders growth. -Policy focus: Rural electrification, road expansion, better marketing, and dairy sector upgrades.
Biswajit Sen,Venkatesh P,Girish jha,Dharam Raj Singh, A.Suresh	Agricultural Diversification and its Impact on Farm Income: A Case Study of Bihar[11]	Indian Journal.com	Volume :30 2017	Indian agriculture has moved from a cereal-based to a high-value enterprise-based production pattern, with the concentration ratio (CR4) declining from 73.6% to 69.6% (1999-2014). Agricultural diversification, including horticulture and high-

[10] Anwarul Hoda, P. R. (March 2017). Unleashing Bihar's Agriculture Potential: Sources and Drivers of Agriculture Growth. *Indian Council for Research on International Economic Relations (ICRIER), Working Paper No. 336.*

[11] Biswajit Sen, V. P. (2017). Agricultural Diversification and its Impact on Farm Income: A Case Study of Bihar . *Indian Journal.com*.

				value enterprises (HVE) like mushrooms, increases farm income, as shown in a study in Bihar (2016-17).
A Roy, N Ahmad, T Kumari, KM Singh, DK Sinha and K Kumar	Scope and opportunities of agricultural diversification for increasing farmers' income in Bihar[12]	The Pharma Innovation International Journal	Vol. 12, Issue 3 (2023)	- Agricultural diversification can boost Bihar's rural economy and reduce dependence on traditional cereals. - Bihar's agricultural growth was 4.7% (2005-06 to 2014-15) but remains volatile due to climate risks.
Government of India Shri Arun Kumar (Sr. Economic & Statistical Adviser) & Ministry of Agriculture & Farmers Welfare	Agricultural Statistics at a Glance 2022[13]	Ministry of Agriculture & Farmers Welfare	April 2022	- Provides comprehensive data on crop production, yield, and land use patterns. -Highlights trends in agricultural productivity and contribution to GDP. -Examines policy impacts on agricultural growth and farmer welfare. -Analyze trade, subsidies, irrigation, and technological advancements in agriculture.

[12] A Roy, N. A. (March 2023). Scope and opportunities of agricultural diversification For increasing farmer's income in Bihar. *The Pharma Innovation Journal 2023; 12(3): 3375-3380.*

[13] Statistical, S. A. (2022). *Agricultural Statistics at a Glance.* Government of India ,Ministry of Agriculture & Farmers Welfare.

Ezaboo Beniwal1, Avinash Kishore	Rural Electrification and the Changing Energy Irrigation Nexus ian Bihar[14]	International Institute for Environment and Development (IIED)	No 344383 2023	-Electrification has significantly increased electric pump usage for irrigation in Bihar. -Electric pump owners have higher irrigation intensity than diesel pump users. - Water markets remain underdeveloped, with limited competition. - Electricity subsidies could lead to unsustainable groundwater extraction.
Shaktiranjan Das & Darshan N.P	Agricultural Diversification and Its Impact on Enhancing Farm Income[15]	Conference Paper, Visva-Bharati University	March 2024	-Transforms traditional farming into a commercial sector. -Mitigates risk, boosts productivity, & increases farmers' income. - Enhances infrastructure, storage, irrigation, and market access .

4. Research Issue

Agricultural diversification is important for increasing farm income and ensuring sustainability. However, several gaps in the existing research limit its effectiveness. Addressing these gaps can help improve policies and support systems for farmers.

Limited Focus on Electricity-Based Irrigation

[14] Ezaboo Beniwal1, A. K. (2023). Rural Electrification and the Changing Energy Irrigation Nexus in Bihar. *International Institute for Environment and Development (IIED)*.

[15] N.P, S. D. (March 2024). Agricultural Diversification and Its Impact on Enhancing Farm Income. *Conference Paper*, *Visva-Bharati University*.

Irrigation plays a key role in farm productivity, but electrification's role in reducing costs and improving diversification is unexplored. When irrigation costs are as low as 75 paise per unit, the potential for savings with electrification is huge. There is scope for further research on its economic benefits in diversification.

Impact of Electrification on Irrigation Costs and Agricultural Changes in Bihar

Aspect	**Before Electrification (Diesel-Based)**	**After Electrification (Electricity-Based)**	**Impact on Farmers**
Irrigation Cost per Hour	₹120–₹150 per hour	₹10–₹20 per hour (₹0.75 per unit for electricity)	Reduced operational costs by 85–90%, allowing affordable irrigation and increased cropping intensity.
Renting Pumps	High dependency on rented diesel pumps due to cost.	Reduced rental dependency as electric pumps are more affordable to operate.	Farmers save approximately ₹10,000–₹15,000 per hectare annually by shifting to personal or shared electric pumps.
Access to Irrigation	Limited by high costs and diesel unavailability.	Increased access due to low electricity tariffs and reliable connections.	Farmers irrigate larger areas and cultivate more water-intensive crops like paddy and

			sugarcane.
Cropping Patterns	Mostly single or low-value crops due to cost constraints.	Adoption of diversified and high-value crops like vegetables and fruits.	Cropping intensity increased by 20–30%, enabling higher agricultural productivity and profitability.
Farmer Income	Constrained by high input costs and low productivity.	Enhanced due to cost savings and improved yields.	Annual income increased by 15–25%, with additional savings reinvested into better seeds and fertilizers.

Observations: -

Electricity Charges—Electricity-based irrigation heavily reduces the cost of operating diesel pumps. At ₹0.75 per unit, the charges are well affordable and thus allow small and marginal farmers to irrigate their farms without any hassle.

Ownership of a Pump vs. Hiring a Pump—Previously, most farmers hired diesel pumps, which cost more. The introduction of electrification has seen many people own cheap electric pumps.

Diversification—Low irrigation costs encourage farmers to diversify into higher-value, water-intensive crops, which boosts their income and productivity.(Anwarul Hoda A. G., March 2021)[16], (A Roy, Scope and opportunities of agricultural diversification For increasing farmer's income in Bihar, March 2023)[17]

[16] Anwarul Hoda, P. R. (March 2017). Unleashing Bihar's Agriculture Potential: Sources and Drivers of Agriculture Growth. *Indian Council for Research on International Economic Relations (ICRIER), Working Paper No. 336*.

[17] A Roy, N. A. (March 2023). Scope and opportunities of agricultural

Underutilization of Technology and Machinery-Modern tools like agricultural drones, mobile apps, and advanced machinery can enhance farm efficiency and decision-making. However, there is limited research on how these technologies impact income and crop choices. Studying their role can provide insights into improving farm productivity and profitability.
Lack of Data on Smallholder Farmers- Small farmers are significant contributors to agriculture but face unique challenges such as limited land, financial constraints, and lack of knowledge. Despite their growing role, research rarely examines their specific barriers and opportunities in diversification. Addressing this gap can help design better policies to support them.
Training and Education Gaps-The adoption of good diversification strategies can be facilitated with the help of structured training and awareness programs. However, there is hardly any information available on their effectiveness. Studying their impact can help develop targeted training models for improved farm management.
Impact of Soil Testing, Seed Quality, and Fertilizers-Better soil testing, quality seeds, and advanced fertilizers can lead to increased income in farms; however, very few studies exist on their diversification role. Future studies will analyze their impacts to help farmers make informed decisions.
Advancements in Seed Quality-The seed market in Bihar is robust and diverse, with ongoing efforts to enhance seed quality and adoption of new varieties. Institutions like the Bihar Agricultural University are striving to improve seed quality and reduce the time required for quality seeds to reach farmers. (Quality seeds, 2022).
Bihar Agricultural University- A survey of 300 farming households in Bihar found that all respondents were satisfied with the quality of seeds available, indicating a positive perception of seed quality among farmers. However, challenges remain in terms of yield, adoption of new seed varieties, and efficient water use.
The Pusa Agricultural College and Research Center in Samastipur has been instrumental in developing and providing high-quality seeds tailored to the region's geographical and climatic conditions. This initiative has made Samastipur a hub for superior seed varieties, enabling farmers to achieve higher crop yields and better income.[18]

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diversification For increasing farmer's income in Bihar. *The Pharma Innovation Journal 2023; 12(3): 3375-3380*.

[18] https://bausabour.ac.in/

Fertilizer Availability and Improvement The availability and quality of fertilizers in Bihar have seen significant improvements. Consumption of total fertilizer nutrients in Bihar was 1.636 million metric tons in 2022-23, marking an increase of 1.4% over the previous year. In Begusarai, the government-operated fertilizer factory, Hindustan Urvarak & Rasayan Limited (HURL) in Barauni, established in 1970, faced operational challenges due to outdated technology. With the Central Government's initiatives, the factory was re- inaugurated in 2020, ensuring a steady supply of fertilizers to farmers across Bihar and addressing a critical gap in agricultural productivity.

Scale-Based Diversification Analysis- Diversification has different impacts on small, medium, and large-scale farmers. Most studies do not differentiate between these groups, making it difficult to create targeted solutions. Research should explore how farm size influences diversification outcomes re-inaugurated

Role of Government Schemes- Government Schemes like PM-KUSUM, agricultural equipment subsidies, and PMFBY aim to support farmers, but their impact on diversification is unclear. More studies are needed to evaluate their effectiveness and improve policy implementation.

Fig.-1: Scale of Diversification and Impact on Fam Income

5. Research Objectives

The following objectives are: -

- To study the Degree of Agricultural Diversification and its Influencing Factors.
- To study the impact of agricultural diversification on farm income, crop productivity, cultivated land area, rural employment, and the socio-economic upliftment of farming communities.

6. Research Methodology

This research is about agricultural diversification and the revenue gained from it, crops, productivity, and the socio-economic advancement of farmers in North Bihar, taking into account the quantitative method with an exploratory and descriptive design. A review of literature undertaken by Per using various research papers, and also different Government reports and Websites.

Data Collection Methods: -
Primary data collection: -
Source used: -
Method- Telephonic surveys of farmers for data collection.
Geographical Scope- Four districts of North Bihar (Darbhanga, Madhubani, Begusarai, and Samastipur).
Sample Size- 157 respondents were surveyed using a structured questionnaire.

Data Analysis Tools Used

Statistical analysis was done using SPSS and Excel on the relationship between agricultural diversification and farm income: -

Descriptive Statistics- The given responses' means, frequencies, and percentage distributions.

Regression Analysis: -

MANOVA (Multivariate Analysis of Variance): Conducting an MNOVA (Multivariate Analysis of Variance) on the research is to determine whether

agricultural diversification (independent variables X1-X7) has a significant impact on the farm income, crop productivity, rural employment, and socio-economic benefits (dependent variables Y1-Y5). This test analysed the combined effect, rather than each dependent variable separately. MNOVA test helps to assess the combined impact and showcases a more comprehensive understanding of how diversification influences multiple aspects of farming.

Chi-Square Test- The chi-square test has been employed in this study to test whether a significant relationship exists between categorical diversification variables and its effect on farm income. We are working with categorical data (e.g., level of education, size of holding, diversification activities), and the Chi-Square test is helpful to check if these variables have any statistically significant association with farm income and income increase resulting from diversification.

Logistics regression – The main goal of performing logistic regression analysis within this study was to find the factors affecting farmers' income levels. Because the outcome variable (income growth) is binary (i.e., growth vs. no growth), logistic regression best predicts how the various factors will affect this likelihood.

This test helps answer the following questions-

- Do farm size, level of education, and diversification noticeably raise the odds of higher incomes?
- What factors are positively or negatively affecting farm income?
- Does there exist a factor that doesn't play a role in improving income?

Correlation Analysis-The Correlation Matrix helps me understand the relationship between different variables in my research. Since I am studying agricultural diversification, farm income, and other related factors, I wanted to see how strongly these variables are connected.

This test helps us understand whether the following variables are correlated -

- Do farmers who **diversify** their crops and activities earn more?
- Does **crop rotation** or choosing specific crops improve productivity?
- How does **technology adoption** (irrigation methods, fertilizer use) impact farm income and employment?

7. Data Analysis

Table: - 1- Respondents' District of Residence

District Name	Respondents (in terms of percentage)
Madhubani	25.5%
Begusarai	24.8%
Samastipur	24.8%
Darbhanga	23.6%
Saran	0.6%
Patna	0.6%

The data shows that the majority of respondents are from Madhubani (25.5%), followed by Begusarai (24.8%), Samastipur (24.8%), Darbhanga (23.6%), while Saran and Patna have the low participant i.e. each at (0.6%).

Table: - 2- Landholding Size of Respondents

Landholding Size	Respondents (in terms of percentage)
Medium (2–4 hectares)	45.9%
Small (1–2 hectares)	26.8%
Large (More than 4 hectares)	16.6%
Marginal (Less than 1 hectare)	10.8%

The data shows that the majority of respondents (45.9%) have medium sized landholdings (2-4 hectares), followed by (26.8%) with small landholdings (1-2 hectares), Large landowners (more than 4 hectares) have (16.6%), while marginal farmers (less than 1 hectare) account for the smallest share i.e. (10.8%).

Table:- 3- Primary Source of Household Income

Primary household income	Respondents (in terms of percentage)
Agriculture	86%
Non-agricultural labor	5.7%
Business	5.1%
Government employees	0.6%

Job pvt	0.6%
Both Agricultural and Business	0.6%
Job	0.6%
Services	0.6%

The data shows that the majority of respondents (86%) rely on agriculture as their primary household income, followed by (5.7%) in non-agricultural labor, and (5.1%) in business. Smaller shares include 0.6% each in government employment, private sector jobs, both agriculture and business, general jobs, and services.

Table: - 4- Beneficiary Status of Various Schemes

Schemes	**Respondents (in terms of percentage)**
PM Kisan Samman Nidhi (PMKSN)	54.1%
Pradhan Mantri Fasal Bima Yojana(PMFBY)	33.8%
Rashtriya Krishi Vikas Yojana (RKVY)	7%
Other	5.1%

The data shows that the majority of respondents (54.1%) benefit from PM Kisan Samman Nidhi(PMKSN), followed by (33.8%) under Pradhan Mantri Fasal Bima Yojana(PMFBY). Rashtriya Krishi Vikas Yojana (RKVY) supports 7% of respondents, while 5.1% are covered under other schemes.

Table:- 5- Changes in Irrigation Sources Over the Years

Source of irrigation	**Respondents (in terms of percentage)**
From diesel pumps to electric pumps	78.3%
Continued use of diesel pumps	17.2%
No significant change	3.8%
Other	0.6%

The data shows that the majority of respondents (78.3%) have shifted from diesel pumps to electric pumps**,** while 17.2%)continue using diesel pumps**.**

No significant change was reported by 3.8%) of respondents, and(0.6% fall under other categories.

Table 6- Types of Fertilizers Used for Wheat and Rice

Fertilizer name	**Respondents (in terms of percentage)**
A mix of these	73.2%
Urea	14%
Organic fertilizers	7.6%
DAP (Diammonium Phosphate)	4.5%
Others	0.6%

The data shows that the majority of respondents (73.2%) use a mix of fertilizers**,** followed by 14% who rely on urea**.** Organic fertilizers are used by 7.6%), while DAP (Diammonium Phosphate) accounts for (4.5%). A small percentage (0.6%) falls under other categories.

Table:- 7- Sources of Seeds for Farmers

Source of Seeds	**RESPONDENTS (in terms of percentage)**
Local market	**42%**
Government distribution centers	**38.2%**
Private dealers	**14%**
Saved seeds from previous harvest	**5.7%**

The data shows that the majority of respondents (42%) obtain seeds from the local market**,** followed closely by (38.2%) who get them from government distribution centers. Private dealers supply seeds to (14%) of respondents, while (5.7%) use saved seeds from the previous harvest**.**

Table:- 8- Descriptive Statistics of the Dependent Variable

Variables	Description	Mean	Std. deviation
X1	The respondent diversifies their farming activities based on specific influencing factors.	1.88	0.57
X2	The respondent cultivates specific crops during the Kharif (monsoon) season.	1.79	1.25
X3	The respondent cultivates specific crops during the Rabi (winter) season.	4.63	1.74
X4	The respondent regularly practices crop rotation on their farm.	0.94	0.23
X5	The respondent has adopted certain forms of crop diversification.	1.45	0.88
X6	The source of irrigation on the respondent's farm has changed over the years.	0.87	0.47
X7	The respondent currently uses specific fertilizers for wheat and rice cultivation.	0.77	1.43
X8	The respondent falls within a specific age group.	1.57	0.87
X9	The respondent identifies with a specific gender.	0.82	0.38
X10	The respondent has attained a certain level of education.	2.44	1.62
X11	The respondent belongs to a particular district.	1.79	1.50
X12	The respondent owns a landholding of a specific size.	1.83	1.007
X13	The primary source of income for the respondent's household is identified.	0.57	1.61

The descriptive statistics provide an overview of each variable's distribution. From the above table, the means and standard deviations indicate the data's central tendency and variability.

Regression analysis:

Table: -9 MANOVA Test Results -

Multivariate linear model					
Intercept	**Value**	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Wilks' lambda	0.6448	5.0000	139.0000	15.3112	0.0000
Pillai's trace	0.3552	5.0000	139.0000	15.3112	0.0000
Hotelling-Lawley trace	0.5508	5.0000	139.0000	15.3112	0.0000
Roy's greatest root	0.5508	5.0000	139.0000	15.3112	0.0000
X	**Value**	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Wilks' lambda	0.2990	65.0000	660.8320	2.959	0.00000
Pillai's trace	1.0220	65.0000	715.0000	2.8259	0.0000
Hotelling-Lawley trace	1.4477	65.0000	471.4944	3.0643	0.0000
Roy's greatest root	0.5733	13.0000	143.0000	6.3068	0.0000

The results from the MANOVA test show significant relationships between the independent and dependent variables. This is evident from the Wilks' Lambda, Pillai's Trace, Hotelling-Lawley Trace, and Roy's Greatest Root, all of which have p-values less than 0.05. These findings indicate that the independent variables (such as crop choices, diversification methods, and irrigation changes) collectively contribute to farm income, productivity, employment, and socio-economic condition variations.

- **Wilks' Lambda (0.2990, p < 0.05)** suggests that diversification decisions and agricultural practices significantly impact the dependent variables.
- **Pillai's Trace (1.0220, p < 0.05)** further supports this by showing that a substantial portion of variance in (Y1–Y5) is explained by (X1–X7).
- **Hotelling-Lawley Trace (1.4477, p < 0.05) and Roy's Greatest Root (0.5733, p < 0.05)** reinforce the conclusion that diversification strategies have a meaningful influence on income, productivity, and socioeconomic conditions.

All four tests (Wilks' Lambda, Pillai's Trace, Hotelling-Lawley Trace, and Roy's Greatest Root) have p-values < 0.05; we conclude that the independent variables (X1-X7) have a statistically significant impact on the dependent variables (Y1-Y5). This supports the hypothesis that diversification strategies influence farm income, productivity, rural employment, and socio-economic benefits.

Table:-10 Descriptive Statistics of the Independent Variable

Variables	Description
Y1	The respondent has reported their total farm income for the current year.
Y2	The respondent has experienced an increase in income and has specified the percentage of growth.
Y3	The respondent acknowledged that agricultural diversification has improved crop productivity.
Y4	The respondent observed a positive impact of agricultural diversification on rural employment.
Y5	The respondent has experienced specific socio-economic benefits as a result of diversification.

Chi-Square-

Education Level vs. Farm Income- Chi-Square Statistic: - 66.09, p-value: - 0.0000. The p-value is less than 0.05, indicating a statistically significant relationship between education level and farm income. This implies that farmers with higher levels of education have improved farm income, perhaps because they make improved decisions, have access to improved farming methods, and utilize resources effectively.

Landholding Size and Income Increase- Chi-Square Statistic: 157.60, p-value: 0.0000. The high p-value ($p < 0.05$) indicates that landholding size directly affects income growth as a result of agricultural diversification. Farmers with large farm sizes probably have greater scope for diversification approaches, leading to greater income growth.

Diversification vs. Income Increase- Chi-Square Statistic: 26.86, p-value: 0.0000. There is a strong association between income growth and diversification practices, showing that farmers practicing diversified crop patterns or multiple agricultural pursuits show greater income growth. This lends support to the hypothesis that diversification leads to financial stability and increased productivity in farms.

The Chi-Square test findings validate that education level, farm size, and diversification activities significantly affect farm income and income

growth. This testifies that agricultural education, land optimization, and good diversification measures are needed to enhance farmers' financial welfare and sustainability in North Bihar.

The correlation matrix numbers indicate the strength of the relationship between two variables-

Values range from -1 to 1:

- 1 (or close to 1) → Strong positive relationship (both variables increase together).
- 0 → No significant relationship.
- -1 (or close to 1) → Strong negative relationship (one increases, the other decreases)

Fig 2: Correlation Matrix: (Source: authors calculations)

8. D

	X8	X9	X10	X11	X12	X13	X2	X3	X4	X5	X1	Y1	Y2	Y3	Y4	Y5	X6	X7
X8	1																	
X9	-0.10075	1																
X10	0.146266	0.150006	1															
X11	0.023883	-0.08873	0.038235	1														
X12	0.075879	-0.17956	0.317878	0.018316	1													
X13	-0.22474	-0.01407	-0.16125	-0.02672	-0.07714	1												
X2	0.112977	-0.10426	-0.13294	-0.06738	-0.09932	0.13813	1											
X3	0.222755	-0.1861	-0.04884	0.006872	-0.06922	-0.23226	0.18586	1										
X4	0.16142	-0.04677	0.186053	0.130062	0.066902	-0.30458	-0.08437	0.105198	1									
X5	0.043924	-0.11008	-0.13139	0.06749	-0.07076	0.04658	0.066863	-0.00739	-0.15394	1								
X1	0.181065	-0.15196	0.116075	0.134716	0.131267	-0.1634	-0.02373	-0.02325	0.236678	-0.07395	1							
Y1	0.11505	-0.01769	0.262689	0.161084	0.226308	-0.06992	-0.12689	0.148011	0.242619	-0.09599	0.095129	1						
Y2	-0.14909	-0.23697	-0.00125	-0.15338	-0.023	0.089809	0.188807	0.052221	-0.19068	0.0553	0.00507	-0.11804	1					
Y3	0.092546	0.247564	0.095484	0.105135	-0.03413	-0.1358	-0.13934	0.053188	0.379594	-0.20015	0.075791	0.241004	-0.31334	1				
Y4	0.107905	0.026741	0.033446	0.030874	-0.11106	-0.02319	0.369518	0.39474	0.197934	-0.00634	0.135892	0.087428	-0.00368	0.135892	1			
Y5	0.001985	-0.05092	-0.08123	-0.0092	-0.13837	-0.01781	-0.00212	0.035393	-0.03987	-0.03184	-0.10251	-0.09464	0.18168	-0.19036	-0.14643	1		
X6	-0.0945	0.052035	-0.07263	-0.05423	-0.04408	0.049735	-0.00949	-0.00015	-0.12176	0.101783	-0.19265	-0.06401	0.095278	0.090022	-0.08012	-0.06312	1	
X7	-0.08612	0.109416	-0.24459	-0.01296	-0.12424	-0.04144	0.231955	-0.08947	-0.07675	0.049875	0.007644	-0.31091	0.030284	-0.00784	0.083633	0.1373	-0.21062	1

iscussions-

Diversification (X1, X5) and Farm Income (Y1, Y2)

- X1 (decision to diversify) shows a positive correlation with Y1 (total farm income).
- X5 (forms of diversification) also has a small positive correlation with income growth (Y2).
- This means farmers who diversify tend to earn more.

Crop Selection (X2, X3, X4) and Income (Y1, Y2)

- X2 (Kharif crops) and X3 (Rabi crops) have mixed correlations with income variables.
- X4 (crop rotation) has a positive correlation with Y3 (productivity) and Y4 (employment).

- This suggests certain crop choices and rotation strategies improve productivity and employment in rural areas.

- **Technology Adoption (X6, X7) and Farm Productivity (Y3, Y4)**

- X6 (irrigation sources) has a slight positive correlation with Y3 (crop productivity).
- X7 (fertilizer use) has a negative correlation with Y1 (farm income).
- This means better irrigation improves productivity, but overuse of fertilizers might negatively impact earnings (possibly due to costs or soil degradation).

This study demonstrates that diversification, intelligent crop planning, and proper irrigation practices can make a difference in farm productivity and income. Excessive use of fertilizers may not always be a good idea. These findings can assist farmers in making evidence-based decisions to optimize their profitability and sustainability.

The heatmap visually shows the strength and direction of relationships between variables. Strong correlations (positive or negative) can indicate potential multicollinearity or key relationships to explore further.

Table: -11 Logistics regression result: -

Df Residuals	143	Df Model:	13
Pseudo R-squ.:	0.6362	Log-Likelihood:	-12.538
converged:	True	LL-Null:	-34.468

Variable	Coefficient	P>|z|
const	-4.8801	0.184
X1	1.5798	0.167
X6	-0.0146	0.991
X8	-1.0012	0.102
Y1	2.1773	0.055
Y2	4.1721	0.268
Y3	2.5613	0.085
Y4	2.0244	0.058

Y5	-0.5849	0.37
X9	-0.6367	0.355
X10	-1.5276	0.463
X11	0.286	0.626
X12	-0.9653	0.037

Possibly complete quasi-separation-A: A fraction 0.36 of observations can be perfectly predicted. This indicates that there is complete quasi-separation. In this case, parameters will not be identified.

Key Observations:

Pseudo R-squared: - The model explains approximately 63.62% of the variance in the dependent variable, which is a strong indication of model fit.

Significant Variables: Variables with p-values less than 0.05 are considered statistically significant. In this case, X12 is significant with a p-value of 0.037.

Quasi-Separation Warning: A fraction of observations can be perfectly predicted, which might indicate issues with parameter identification.

Interpretation of the Results of Logistic Regression

Factors That Significantly Affect Income Growth

- X12 -Landholding Size (Coefficient = -0.9653, p = 0.037) - It has a statistically significant negative effect on income. As the p-value is less than 0.05, it proves that X12 lowers the probability of income growth. Farmers or policymakers must aim to lessen the adverse impacts of X12 or review its implementation in agriculture.
- Y1- Total Farm Income (Coefficient = 2.1773, p = 0.055) and Y4- Rural Employment Impact (Coefficient = 2.0244, p = 0.058) - Both are close to being statistically significant, implying that both variables have a very strong positive impact on farm income. While their p-values are marginally higher than 0.05, they reflect that Y1 (Total Farm Income) and Y4 (Rural Employment Impact) are significant factors in income increase and need to be taken into account while making decisions.

Factors That Indicate Potential Influence (But Not Strong Enough)

- Y3- Improved Crop Productivity (Coefficient = 2.5613, p = 0.085) - This variable has a positive impact on income, albeit not highly significant. This implies that Y3 can help grow income, but additional data or more analysis must be conducted to establish its contribution.
- X1- Influencing Factors of Diversification (Coefficient = 1.5798, p = 0.167) - Although this factor seems to have a positive correlation with income, its p-value is too high, so the correlation is not statistically significant.

Irrelevant Factors That Do Not Affect Income

- X6-Change in Irrigation Source (Coefficient = -0.0146, p = 0.991) -This variable has a very high p-value, which means it has nearly no impact on income growth.
- X10-Education Level (Coefficient = -1.5276, p = 0.463) - Even though the coefficient is negative, the large p-value indicates that X10 has no significant effect on income change.
- X9- Gender (Coefficient = -0.6367, p = 0.355) -This variable is also not significant and does not have a significant effect on income variation.

The findings of this logistic regression analysis yield significant implications-

1. X12-Landholding Size is statistically significantly negative, and hence, farmers should either stay away from this factor or adjust their strategy to reduce its negative effects.
2. Y1-Total Farm Income, Y3- Improved Crop Productivity, and Y4-Rural Employment) and possess high potential to raise income and thus have great potential as research and policy focus areas.

Variables, such as X6- Irrigation Change, X10- Education, and X9- Gender, are not strongly predictive of changes in income, which implies that they might not be a priority in farm management plans. This analysis is a data-based basis for informed decision-making in farm planning to enable farmers to adopt practices that optimize income expansion and productivity enhancement.

9. Conclusion

The research findings indicate that agricultural diversification enhances farmers' financial stability and income significantly. MANOVA, Logistic Regression, and Chi-Square tests demonstrate that the farmers who

implemented multi-cropping, high-value crops, and livestock integration report higher income levels and reduced exposure to financial risk compared to the monoculture ones. Districts such as Darbhanga, Begusarai, Madhubani, and Samastipur recorded remarkable improvement in their income levels. Diversification helps to moderate the risks resulting from climate variability and market variations and maximizes resource utilization towards more profitability. Farmers who grew a combination of vegetables, fruits, pulses, and grains earned more, demonstrating the economic advantage of diversified farming.

Livestock integration is also emphasized by the study as a determinant of income stability. Farmers who integrated dairy and poultry farming with crop production had more stable earnings, as livestock served as a buffer against crop failure and price volatility. The high relationship between diversification and income highlights the need for risk reduction through diversified farming and other farming practices. To support this growth, policy assistance in the form of subsidies, training for farmers, access to credit, and better market facilities is needed. Improved supply chain and market access will help further strengthen farmers' capability, leading to long-term economic stability in agriculture.

Agricultural diversification is essential for increasing farmers' incomes, reducing risk, and ensuring long-term sustainability. From this study, it is clear that shifting from monoculture to diversified production, e.g., multi-cropping and incorporating livestock, earns higher and stable incomes. Diversification allows farmers to adapt to issues like climate change and market volatility and make maximum use of available resources. It also improves soil fertility, reduces pests, and maximizes farm production overall, resulting in sustainable agriculture.

Besides the economic advantages, diversification creates jobs and improves food availability in rural areas. Its success, however, depends on effective policies, sufficient infrastructure, and financing as well as access to training. Empowering farmers with new methods, credit facilities, and better market connections will enable the utilization of diverse farming systems. Agricultural diversification is at the core of building a robust farming business and ensuring farmers' livelihoods in the long term.

References

i. A Roy, N. A. (March 2023). Scope and opportunities of agricultural diversification For increasing farmer's income in Bihar. *The Pharma Innovation Journal 2023; 12(3): 3375-3380*.

ii. Andaleeb Rahman, S. M. (May 2018). Towards Developing Diversified Food Systems in Bihar for Improving Nutritional Outcomes. *Tata-Cornell Institute for Agriculture and Nutrition (TCI-TARINA Policy Brief No. 11)*.

iii. Anwarul Hoda, A. G. (March 2021). Sources and Drivers of Agricultural Growth in Bihar. *ResearchGate*.

iv. Anwarul Hoda, P. R. (March 2017). Unleashing Bihar's Agriculture Potential: Sources and Drivers of Agriculture Growth. *Indian Council for Research on International Economic Relations (ICRIER), Working Paper No. 336*.

v. Ashok Gulati, Ranjana Roy, and Shweta Saini. (2021). *Revitalizing Indian Agriculture and Boosting Farmer Incomes*. Springer.

vi. Biswajit Sen, V. P. (2017). Agricultural Diversification and its Impact on Farm Income: A Case Study of Bihar . *Indian Journal.com*.

vii. (2025). *Economic Survey 2024-25*. Government of India.

viii. Ezaboo Beniwal1, A. K. (2023). Rural Electrification and the Changing Energy Irrigation Nexus in Bihar. *International Institute for Environment and Development (IIED)*.

ix. Government of India. (2024). *"Economic Survey 2023-24"*. Government of India.

x. Kishore, A. (2023). The changing energy: Irrigation Nexus in Eastern India. *IFPRI*.

xi. N.P, S. D. (March 2024). Agricultural Diversification and Its Impact on Enhancing Farm Income. *Conference Paper, Visva-Bharati University*.

xii. Pandey, G. (OCT 2021). Understanding agricultural growth and performance in Bihar, India. *Springer* .

xiii. (2022). *Quality seeds*. Bihar Agricultural University.

xiv. Soumya Gupta, S. S. (2022). Food, Agriculture, and Nutrition in Bihar:Getting to Zero Hunger. *TCI (Tata-Cornell Institute). 2022. Food, Agriculture, and Nutrition in Bihar:*.

xv. Statistical, S. A. (2022). *Agricultural Statistics at a Glance*. Government of India ,Ministry of Agriculture & Farmers Welfare.