

Impact Assessment of the DBT Biotech-KISAN Hub Programme on Livelihood Development of Small and Marginal Farmers in the Aspirational Districts of West Bengal, India

Keshab Chandra Dhara

adfwbuaafs@gmail.com

West Bengal University of Animal and Fishery Sciences

S S Kesh

West Bengal University of Animal & Fishery Sciences

U Roy

West Bengal University of Animal & Fishery Sciences

Suprava Roy

West Bengal University of Animal and Fishery Sciences

Biman Sarkar

West Bengal University of Animal and Fishery Sciences

Shrestha Roy

West Bengal University of Animal and Fishery Sciences

Aditi Datta

West Bengal University of Animal and Fishery Sciences

Prof S Batabyal

West Bengal University of Animal and Fishery Sciences

Prof A Goswami

Baba Saheb Ambedkar Education University

Research Article

Keywords: Biotech-KISAN Hub, Livelihood Development, Knowledge Enhancement, Technology Adoption, Animal Husbandry, Aquaculture, Aspirational Districts, West Bengal, Rural Livelihoods, Sustainable Development Goals

Posted Date: October 9th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10991583/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.
[Read Full License](#)

Additional Declarations: No competing interests reported.

Impact Assessment of the DBT Biotech-KISAN Hub Programme on Livelihood Development of Small and Marginal Farmers in the Aspirational Districts of West Bengal, India.

Dr. Keshab Chandra Dhara^{1*}, Dr. S S Kesh⁴, Dr U Roy⁷, Dr. Suprava Roy², Biman Sarkar², Shrestha Roy², Aditi Datta³, Prof S Batabyal⁵ and Prof A Goswami⁶

¹Deputy Director of Farms & Principal Investigator, DBT Biotech-KISAN Hub Programme,

²Young Professional, DBT Biotech-KISAN Hub Programme, WBUAFS

³Project Assistant DBT Biotech-KISAN Hub Programme, Directorate of Research, Extension and Farms, WBUAFS

⁴ Assistant Professor Veterinary Clinics (Bio Chemistry), WBUAFS

⁵ Director of Research, Extension and farms, WBUAFS

⁶ Vice-Chancellor, Baba Saheb Ambedkar Education University Kolkata, West Bengal

⁷ Sr. Scientist and Head, Murshidabad KVK, WBUAFS

West Bengal University of Animal & Fishery Sciences,

37 & 68 Kshudiram Bose Sarani, Kolkata 700037, West Bengal, India

*Corresponding author

Keshab Chandra Dhara

Email: adfwbuaafs@gmail.com

Abstract

The Department of Biotechnology (DBT), Government of India, launched the Biotechnology–Krishi Innovation Science Application Network (Biotech-KISAN) Hub Programme to bridge the gap between scientific research and field-level application by promoting location-specific technologies for sustainable agricultural development. The present study assessed the impact of the DBT Biotech-KISAN Hub Programme implemented by the West Bengal University of Animal & Fishery Sciences (WBUAFS) in the five Aspirational Districts of West Bengal—Birbhum, Nadia, Maldah, Murshidabad and Dakshin Dinajpur—on the knowledge, technology adoption, household income and livelihood development of small and marginal farmers. A baseline–endline research design was adopted, covering 21,460 beneficiary households during the baseline survey and the same households during the endline survey. Primary data were collected using a structured and pre-tested interview schedule, while secondary information was obtained from project records and government publications. Composite indices, including the Knowledge Index, Technology Adoption Index and Livelihood Development Index (LDI), were developed to quantify programme outcomes. The data were analysed using descriptive statistics, chi-square test, paired t-test, one-way ANOVA, Pearson's correlation, multiple linear regression and Principal Component Analysis (PCA) using IBM SPSS Statistics. The baseline assessment revealed that the overall scientific knowledge of farmers was relatively low, with a Knowledge Score of 25.89 ± 2.22 , while the Technology Adoption Index averaged 5.87 ± 1.14 , indicating limited adoption of recommended livestock and aquaculture technologies before programme implementation. Following scientific training, frontline demonstrations, quality input support, ICT-enabled advisory services, Farm Schools and continuous technical guidance, significant improvements were observed in knowledge, technology adoption and enterprise

management practices across all five districts. Household income increased substantially through improved livestock, poultry and aquaculture production systems, with animal husbandry contributing the highest proportional increase in income (approximately 78%). The Livelihood Development Index increased from 42.80 at baseline to 68.90 at endline, representing an overall improvement of 60.98%, reflecting significant enhancement in human, financial, physical, natural and social capital. Statistical analyses confirmed that participation in scientific training, landholding, education and occupation significantly influenced technology adoption and livelihood improvement ($P < 0.05$). The programme also strengthened women's participation in livestock and fisheries enterprises, promoted entrepreneurship, enhanced institutional participation through Farmer Producer Organizations (FPOs), and improved access to scientific advisory services. The integrated intervention model contributed directly to several Sustainable Development Goals (SDGs), particularly SDG 1 (No Poverty), SDG 2 (Zero Hunger), SDG 5 (Gender Equality), SDG 8 (Decent Work and Economic Growth), SDG 13 (Climate Action) and SDG 17 (Partnerships for the Goals). Overall, the findings demonstrate that the DBT Biotech-KISAN Hub Programme effectively translated biotechnology-based scientific innovations into measurable improvements in productivity, technology adoption, household income and livelihood security. The study highlights the potential of integrated, science-led extension approaches as a scalable model for sustainable rural transformation in Aspirational Districts and other resource-constrained regions of India.

Keywords: Biotech-KISAN Hub, Livelihood Development, Knowledge Enhancement, Technology Adoption, Animal Husbandry, Aquaculture, Aspirational Districts, West Bengal, Rural Livelihoods, Sustainable Development Goals.

1. Introduction

Agriculture and allied sectors continue to play a pivotal role in India's economy by contributing to food security, employment generation and rural livelihoods. Nearly half of the country's workforce depends directly or indirectly on agriculture and allied activities, including livestock, poultry and fisheries, for their livelihood. However, despite substantial progress in agricultural production, rural households—particularly small and marginal farmers—continue to face challenges such as fragmented landholdings, low productivity, inadequate access to quality inputs, poor technology adoption, climate variability, disease outbreaks, limited institutional support and weak market linkages. These constraints collectively reduce farm profitability and increase livelihood vulnerability, especially among resource-poor farming communities. Livestock and fisheries have emerged as major drivers of agricultural growth in India because they provide regular income, nutritional security, employment opportunities and resilience against crop failures. Scientific interventions involving improved germplasm, balanced feeding, preventive animal healthcare, biosecurity, scientific aquaculture, value addition and market-oriented production systems have demonstrated considerable potential to improve productivity and farm income. Nevertheless, adoption of these technologies remains uneven due to knowledge gaps, inadequate extension services and limited interaction between research institutions and farming communities.

Recognizing the need to accelerate inclusive rural development, the Government of India launched the **Aspirational Districts Programme (ADP)** in January 2018 under the leadership of **NITI Aayog**. The programme seeks to transform 112 socio-economically underdeveloped districts through the principles of **Convergence, Collaboration and Competition**, focusing on

measurable improvements in health and nutrition, education, agriculture and water resources, financial inclusion and skill development, and basic infrastructure. The programme adopts a data-driven monitoring system based on incremental progress (delta ranking) and encourages convergence of Central and State schemes with active participation of research institutions, local governments and development partners.

To strengthen science-based agricultural development in these priority districts, the **Department of Biotechnology (DBT), Ministry of Science and Technology, Government of India**, initiated the **Biotechnology–Krishi Innovation Science Application Network (Biotech-KISAN)** as a farmer-centric mission programme. Biotech-KISAN aims to bridge the gap between laboratory research and farmers' fields by promoting location-specific technologies through a Hub-and-Spoke model involving research institutions, Krishi Vigyan Kendras (KVKs), line departments and farming communities. The programme emphasizes participatory technology development, scientific capacity building, biotechnology-enabled livestock and crop improvement, women farmer empowerment, entrepreneurship development and climate-resilient agriculture. Since its inception, the programme has expanded across multiple agro-climatic zones of India and has benefited hundreds of thousands of farmers through improved productivity, income generation and technology adoption.

The West Bengal University of Animal & Fishery Sciences (WBUAFS) has been implementing the DBT Biotech-KISAN Hub Programme in the five Aspirational Districts of Birbhum, Nadia, Murshidabad, Maldah and Dakshin Dinajpur. The programme integrates scientific interventions in Black Bengal goat improvement, backyard poultry development, freshwater aquaculture, balanced feeding, mineral supplementation, vaccination, deworming, fodder development, ICT-enabled advisory services, Farm Schools, entrepreneurship promotion and Farmer Producer Organization (FPO) strengthening. Unlike conventional subsidy-oriented programmes, the Biotech-KISAN Hub combines scientific knowledge dissemination, quality production inputs, continuous technical backstopping and institutional convergence to promote sustainable livelihood development among small and marginal farmers.

Previous studies have consistently shown that farmer training, participatory extension, access to improved technologies and institutional support positively influence agricultural productivity, technology adoption and rural household income (Chambers & Conway, 1992; Rogers, 2003; Anderson & Feder, 2007; Davis et al., 2012). The Sustainable Livelihood Framework further emphasizes that improvements in human, financial, physical, natural and social capital collectively determine long-term livelihood resilience rather than income enhancement alone. However, empirical evidence on the integrated impact of biotechnology-based extension programmes combining livestock, poultry and fisheries interventions in the Aspirational Districts of eastern India remains limited.

The present study was therefore undertaken to evaluate the effectiveness of the DBT Biotech-KISAN Hub Programme in improving scientific knowledge, technology adoption, household income and livelihood development among beneficiary farmers in the five Aspirational Districts of West Bengal. A comprehensive baseline–endline evaluation involving 21,460 beneficiary households was conducted using standardized survey instruments and composite livelihood indicators. The study also examined the influence of socio-economic characteristics on programme outcomes and assessed the contribution of the interventions towards achieving the Sustainable Development Goals (SDGs). The findings are expected to provide scientific evidence for policymakers, researchers and

development practitioners regarding the effectiveness of biotechnology-driven agricultural extension models in promoting sustainable and inclusive rural development.

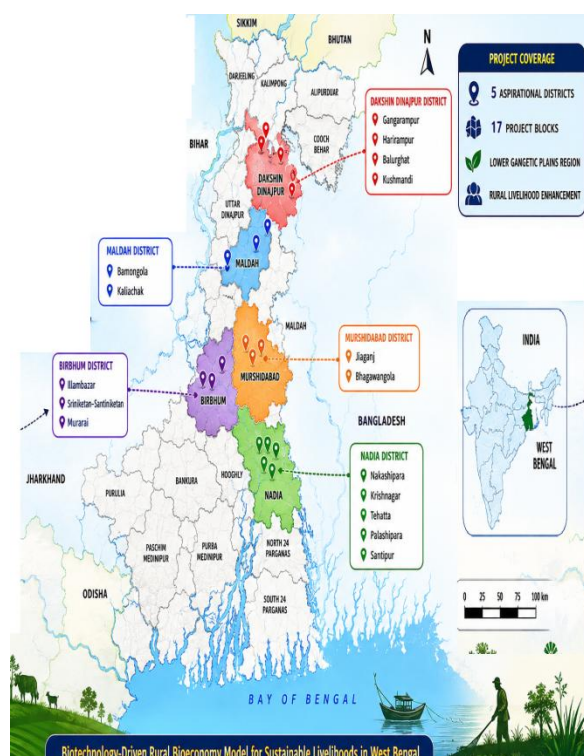
Objectives of the Study

1. To assess the socio-economic profile of beneficiary farmers in the five Aspirational Districts of West Bengal.
2. To evaluate the impact of the DBT Biotech-KISAN Hub Programme on farmers' scientific knowledge and technology adoption.
3. To quantify changes in household income and livelihood development following programme interventions.
4. To identify the socio-economic factors influencing livelihood improvement and technology adoption.
5. To examine the contribution of the programme towards achieving the Sustainable Development Goals (SDGs) through science-led agricultural development.

2. Materials and Methods

2.1 Study Area

The present study was conducted under the Department of Biotechnology (DBT), Government of India-sponsored Biotech-KISAN (Biotechnology–Krishi Innovation Science Application Network) Hub Programme, implemented by the West Bengal University of Animal & Fishery Sciences (WBUAFS) through the Directorate of Research, Extension and Farms. The programme was implemented in the five Aspirational Districts of West Bengal, namely Birbhum, Nadia, Murshidabad, Maldah and Dakshin Dinajpur, during the period from November 2022 to July 2026. The selected districts fall within the Lower Gangetic Plains agro-climatic zone, characterized by fertile alluvial soils, tropical monsoon climate, annual rainfall ranging from approximately 1,100 to 1,600 mm and an agriculture-based rural economy. Crop cultivation, livestock rearing, backyard poultry and freshwater aquaculture constitute the principal livelihood activities.



Despite favourable natural resources, these districts continue to experience low agricultural productivity, fragmented landholdings, inadequate access to scientific technologies and limited institutional support, making them suitable for science-led livelihood interventions.

2.2 Research Design and Sampling Methodology

A baseline–endline impact evaluation design was adopted to assess the effectiveness of the DBT Biotech-KISAN Hub Programme on farmers' knowledge, technology adoption, household income and livelihood development. The study employed a multistage sampling technique. In the first stage, the five Aspirational Districts covered under the programme were purposively selected. In the second stage, intervention blocks and villages were identified based on programme implementation. Finally, beneficiary households were selected using systematic random sampling from the official project database.

A total of 21,460 beneficiary households were surveyed during the baseline assessment before implementation of the major interventions. The same households were revisited during the endline survey after completion of programme activities, generating 42,920 observations for comparative analysis. The study population consisted primarily of small and marginal farmers engaged in agriculture, livestock, backyard poultry and freshwater aquaculture. Women farmers, Scheduled Castes (SC), Scheduled Tribes (ST) and economically disadvantaged households were given special emphasis in accordance with the programme objectives.

2.3 Data Collection and Questionnaire Development

Primary data were collected using a structured, pre-tested interview schedule developed specifically for the study. The questionnaire was prepared following an extensive review of literature, DBT Biotech-KISAN operational guidelines and the Sustainable Livelihood Framework. The draft schedule was reviewed by experts in Veterinary and Animal Husbandry Extension, Fisheries Extension, Animal Genetics, Agricultural Economics and Statistics to establish content validity.

The questionnaire consisted of six major sections covering:

- Socio-economic characteristics of respondents;
- Scientific knowledge of livestock and fisheries technologies;
- Technology adoption behaviour;
- Household income from different livelihood sources;
- Livelihood assets and institutional participation;
- Constraints and farmers' perceptions.

A pilot survey was conducted among farmers outside the study sample to evaluate clarity, reliability and field applicability of the questionnaire. Necessary modifications were incorporated before the final survey. Face-to-face interviews were conducted in the local language by trained investigators under the supervision of scientists and extension personnel. Secondary information relating to programme implementation was obtained from project reports, training records, beneficiary databases, district statistical publications and official reports of the Department of Biotechnology.

2.4 Variables and Operational Definitions

The study included both independent and dependent variables. Independent variables comprised district, age, gender, religion, caste, educational qualification, marital status, occupation, family type, family size, landholding, housing condition and participation in training programmes. Dependent variables included Knowledge Score, Technology Adoption Index, household income and Livelihood Development Index.

Knowledge was defined as the scientific understanding of recommended livestock, poultry and fisheries technologies promoted under the programme. Technology adoption represented the extent to which recommended scientific practices were implemented by beneficiary farmers. Household income referred to the total monthly income earned from agriculture, animal husbandry, fisheries and other economic activities. The Livelihood Development Index (LDI) represented the overall livelihood status of beneficiary households based on multiple livelihood dimensions.

2.5 Construction of Knowledge, Adoption and Livelihood Indices

Knowledge was measured through objective questions covering breeding, feeding, housing, health care, vaccination, deworming, biosecurity, aquaculture management and value addition. Each correct response was assigned one mark, while incorrect responses received zero. The Knowledge Index was calculated as:

$$\text{Knowledge Index (KI)} = \left(\frac{\text{Knowledge Score Obtained}}{\text{Maximum Obtainable Knowledge Score}} \right) \times 100$$

Where:

KI = Knowledge Index

Knowledge Score Obtained = Total score secured by an individual respondent
Maximum Obtainable Knowledge Score if all knowledge questions are answered correctly

Example:

If a farmer scored 28 out of 40,

$$\text{KI} = \left(\frac{28}{40} \right) \times 100 = 70\%$$

This formula is appropriate for inclusion in the Materials and Methods section of your research paper under Construction of Knowledge Index.

Technology adoption was assessed for major interventions including superior Black Bengal goat breeding, mineral supplementation, balanced feeding, vaccination, deworming, scientific housing, backyard poultry management and scientific aquaculture. The Adoption Index was calculated as:

Technology Adoption Index Formula

$$\text{Adoption Index (AI)} = \left(\frac{\text{Adoption Score Obtained}}{\text{Maximum Obtainable Adoption Score}} \right) \times 100$$

Where:

AI = Technology Adoption Index

Adoption Score Obtained = Total adoption score secured by an individual farmer

Maximum Obtainable Adoption Score = Maximum possible adoption score for all recommended technologies

Livelihood Development Index (LDI)

The Livelihood Development Index (LDI) was developed using the Sustainable Livelihood Framework by integrating indicators of human, financial, physical, natural and social capital, together with food security, institutional participation, technology adoption and income security.

The composite LDI was estimated as:

The standard formulation for a composite Livelihood or Security Index (LSI or LDI)

$$\text{LDI} = \left(\frac{\sum_{i=1}^n W_i Z_i}{\sum_{i=1}^n W_i} \right) \times 100$$

where:

- LDI = Livelihood Development Index
- W_i = Weight assigned to the i^{th} livelihood indicator
- Z_i = Standardized score of the i^{th} indicator
- n = Total number of livelihood indicators

Standardization Formula

Before calculating the LDI, each indicator is standardized using the Min–Max normalization method:

$$Z_i = \frac{X_i - X_{\min}}{X_{\max} - X_{\min}}$$

where:

- X_i = Observed value
- $X_{\min}$ = Minimum value

- X_{max} = Maximum value

Equal Weight Method (Recommended for Your Study)

Since your study assigns equal weights to all livelihood dimensions, the LDI simplifies to:

$$LDI = \left(\frac{\sum_{i=1}^n Z_i}{n} \right) \times 100$$

where:

- n = Number of livelihood indicators

If Using Five Livelihood Capitals Only

If the index is based only on the five livelihood capitals (Human, Financial, Physical, Natural and Social), then:

$$LDI = \frac{HC+FC+PC+NC+SC}{5}$$

where:

- HC = Human Capital Index
- FC = Financial Capital Index
- PC = Physical Capital Index
- NC = Natural Capital Index
- SC = Social Capital Index

This last formula is particularly suitable for your Biotech-KISAN impact assessment if you computed separate indices for the five livelihood capitals and then averaged them to obtain the overall LDI.

2.6 Statistical Analysis

Data were coded, validated and analysed using IBM SPSS Statistics Version 29.0. Descriptive statistics including frequency, percentage, mean, standard deviation (SD) and standard error of the mean (SEM) were used to summarize the data. The arithmetic mean and SEM were calculated using standard statistical procedures.

Differences between baseline and endline observations were evaluated using the paired Student's t-test. Associations among categorical variables were examined using the Chi-square (χ^2) test. One-way Analysis of Variance (ANOVA) was performed to compare mean values among districts and socio-economic groups, followed by Tukey's Honest Significant Difference (HSD) test for post hoc comparisons where significant differences were detected. Pearson's product-moment correlation coefficient was used to examine relationships among knowledge, technology adoption, income and livelihood development. Multiple linear regression analysis was performed to identify the major determinants of livelihood improvement. Principal Component Analysis (PCA) was employed to identify the principal dimensions contributing to livelihood development and to validate the composite index structure. Internal consistency of the questionnaire was assessed using Cronbach's alpha coefficient. All statistical tests were performed at 5% and 1% levels of significance, and results were considered statistically significant at $P < 0.05$.

2.7 Ethical Considerations and Data Quality Assurance

The study was conducted in accordance with accepted ethical principles for social science and agricultural research. Prior informed consent was obtained from all respondents before data collection. Participation was voluntary, and respondents were assured that their personal information would remain confidential and would be used exclusively for research purposes.

To ensure data quality, investigators received intensive training on interview techniques, questionnaire administration and data recording procedures. Completed questionnaires were scrutinized daily for completeness and internal consistency. Random field verification

and cross-checking with project records were undertaken to minimize reporting errors. Double data entry, logical consistency checks and validation procedures were employed before statistical analysis to ensure the accuracy and reliability of the dataset.

3. Results

3.1 Socio-demographic Profile of the Beneficiary Farmers

The socio-demographic characteristics of the beneficiary farmers are presented in Table 1. A total of **21,460 beneficiary households** participated in both the baseline and endline surveys conducted under the DBT Biotech-KISAN Hub Programme in the five Aspirational Districts of West Bengal. The study population represented diverse socio-economic groups, including small and marginal farmers, women farmers, Scheduled Castes (SC), Scheduled Tribes (ST) and other economically disadvantaged households. The majority of respondents belonged to the economically active age group (30–60 years), indicating the availability of a productive workforce for adoption of scientific farming practices. Most households depended primarily on agriculture and allied enterprises, particularly livestock, backyard poultry and freshwater aquaculture, for their livelihood. Nuclear families predominated, although joint family systems remained common in several districts. The socio-demographic profile indicated that the programme successfully reached vulnerable farming communities, providing an appropriate basis for evaluating the effectiveness of scientific interventions across different socio-economic categories.

Table 1. Socio-demographic Profile of Beneficiary Farmers (Baseline and Endline Survey, N = 21,460 each)

Characteristics	Baseline (%)	Endline (%)	χ^2 value
Male	36.73	36.86	0.18NS
Female	63.27	63.14	
Young (≤ 30 years)	26.08	25.26	5.62NS
Middle (30–60 years)	67.00	68.13	
Elder (>60 years)	6.92	6.61	
Hindu	63.07	63.42	0.32NS
Muslim	36.93	36.58	
Married	88.15	88.72	1.54NS
Nuclear Family	38.15	41.66	21.80**
Joint Family	61.85	58.34	
Training Received	84.02	97.76	520.30**

3.2 Knowledge Enhancement among Beneficiary Farmers

The baseline assessment revealed that beneficiary farmers possessed relatively limited scientific knowledge regarding improved livestock husbandry, poultry production and aquaculture technologies. The overall **Knowledge Score** at baseline was **25.89 $\pm$ 2.22**, with approximately **65.66%** of respondents falling within the low knowledge category, **28.26%** in the medium category and only **6.09%** demonstrating a high level of scientific knowledge. These findings indicate considerable knowledge gaps before implementation of the programme.

Following implementation of scientific training programmes, frontline demonstrations, Farm Schools, ICT-enabled advisory services and continuous technical guidance, substantial improvements in knowledge were observed during the endline survey. Farmers demonstrated better understanding of improved breeding, balanced feeding, housing

management, fodder cultivation, vaccination, deworming, biosecurity, disease prevention, scientific aquaculture, water quality management and value addition. The proportion of respondents in the high knowledge category increased markedly, while the percentage of farmers with low knowledge declined substantially. Statistical analysis confirmed that the observed improvement in knowledge was highly significant ($P < 0.001$), demonstrating the effectiveness of the capacity-building interventions implemented under the Biotech-KISAN Hub Programme.

Table 2. Knowledge Score and Knowledge Level Before and After Intervention

Parameter	Baseline	Endline	% Change	t value
Knowledge Score (Mean $\pm$ SEM)	25.89 $\pm$ 2.22	34.76 $\pm$ 2.08	34.27	186.74**
Low Knowledge (%)	65.66	18.54	-71.76	
Medium Knowledge (%)	28.26	35.47	+25.51	

District-wise analysis further revealed improvements across all five Aspirational Districts, although the magnitude of change varied according to programme intensity, training participation and local institutional support.

3.3 Technology Adoption among Beneficiary Farmers

The Adoption Index indicated considerable improvement in the implementation of recommended livestock and fisheries technologies following programme interventions. At baseline, the overall **Technology Adoption Index** was **5.87 $\pm$ 1.14**, with nearly two-thirds of respondents belonging to the low adoption category. Adoption of scientific breeding practices, balanced feeding, mineral mixture supplementation, vaccination, deworming, improved housing, fodder cultivation and scientific fish culture was relatively limited before programme implementation.

Table 3. Technology Adoption Index Before and After Intervention

Parameter	Baseline	Endline	% Change	t value
Adoption Index (Mean $\pm$ SEM)	5.87 $\pm$ 1.14	8.42 $\pm$ 1.09	43.44	198.61**
Low Adoption (%)	63.02	20.65	-67.23	
Medium Adoption (%)	27.69	39.74	+43.52	
High Adoption (%)	9.29	39.61	+326.37	

Following scientific training, field demonstrations and continuous technical support, adoption of recommended technologies increased substantially across all intervention districts. Improved Black Bengal goat breeding, backyard poultry management, freshwater aquaculture, balanced feeding and preventive animal healthcare recorded particularly high adoption rates. Farmers also demonstrated increased acceptance of ICT-based advisory services, Farm School activities and value addition practices. The shift from low to medium and high adoption categories clearly indicates successful behavioural change resulting from the programme. Statistical analysis confirmed that the increase in technology adoption was highly significant ($P < 0.001$).

3.4 Household Income from Different Livelihood Sources

Analysis of household income revealed significant improvements in income generated from agriculture, livestock, fisheries and other livelihood activities following implementation of

the programme. Baseline assessment indicated that agriculture contributed the largest proportion of household income, followed by other services and livestock enterprises. After scientific intervention, income increased across all livelihood sources, although the magnitude of improvement differed among enterprises.

The highest proportional increase was observed in **animal husbandry**, reflecting the positive impact of superior Black Bengal goat germplasm, balanced feeding, mineral supplementation, preventive healthcare and scientific management practices. Freshwater aquaculture also showed considerable improvement due to adoption of quality fish seed, pond preparation, water quality management and improved feeding practices. Overall monthly household income increased substantially, demonstrating that integrated livestock and fisheries interventions effectively diversified livelihood opportunities and enhanced economic resilience.

Table 4. Source-wise Monthly Household Income (₹)

Source	Baseline	Endline	Increase (₹)	% Increase
Agriculture	2,811.41	3,969.29	1,157.88	41.19
Animal Husbandry	1,339.54	2,384.38	1,044.84	78.00
Other Service/Business	5,470.92	9,041.33	3,570.41	65.26
Total Income	9,621.87	15,395.00	5,773.13	59.99

District-wise comparisons indicated that Birbhum recorded the highest average household income, followed by Nadia, Maldah, Dakshin Dinajpur and Murshidabad. However, positive income growth was observed consistently across all programme districts.

Table 5. District-wise Household Income Before and After Intervention (₹/Month)

District	Baseline	Endline	% Increase
Birbhum	10,049.51	16,079.22	59.99
Nadia	9,968.80	15,950.08	59.99
Maldah	9,470.55	15,152.88	59.99
Dakshin Dinajpur	9,375.69	15,000.35	60.00
Murshidabad	9,224.98	14,759.96	59.99

3.5 Livelihood Development

The Livelihood Development Index (LDI) demonstrated remarkable improvement following implementation of the Biotech-KISAN Hub Programme. The composite LDI increased from **42.80** during the baseline survey to **68.90** at the endline, representing an overall improvement of approximately **60.98%**. Significant improvements were observed across all dimensions of livelihood, including human capital, financial capital, physical capital, natural capital and social capital.

Human capital improved through enhanced scientific knowledge, technical skills and participation in farmer training programmes. Financial capital increased because of higher household income, diversified livelihood opportunities and improved enterprise profitability. Physical capital improved through better housing, livestock assets, aquaculture infrastructure and farm equipment. Natural capital benefited from improved management

of land, fodder resources and water bodies, while social capital strengthened through increased participation in Farmer Producer Organizations (FPOs), Self-Help Groups (SHGs), Farm Schools and institutional networks.

The substantial improvement in the Livelihood Development Index demonstrates that the programme contributed not only to higher income but also to broader socio-economic development and livelihood resilience among beneficiary households.

Table 6. Livelihood Development Index (LDI) Before and After Intervention

Component	Baseline	Endline	Improvement (%)
Human Capital	43.20	71.80	66.20
Financial Capital	39.60	68.40	72.73
Physical Capital	44.10	66.70	51.25
Natural Capital	46.30	62.80	35.64
Social Capital	37.80	67.50	78.57
Food & Nutritional Security	45.10	73.60	63.19
Institutional Participation	34.80	69.20	98.85
Technology Adoption	36.70	70.90	93.19
Income Security	40.20	69.90	73.88
Overall LDI	42.80	68.90	60.98

Table. 7: District-wise Livelihood Development Index (LDI) of Beneficiary Farmers Before and After the DBT Biotech-KISAN Hub Programme (n = 21,460)

District	Sample Size (n)	Baseline LDI (0–100) (Mean ± SEM)	Endline LDI (0–100) (Mean ± SEM)	Absolute Gain	Improvement (%)	Livelihood Status (Endline)
Birbhum	4,340	44.20 ± 1.18	70.85 ± 1.09	26.65	60.29	Good
Nadia	4,280	43.85 ± 1.12	70.96 ± 1.04	27.11	61.82	Good
Maldah	4,260	41.95 ± 1.21	68.15 ± 1.16	26.20	62.46	Good
South Dinajpur	4,240	41.10 ± 1.16	67.95 ± 1.11	26.85	65.33	Good
Murshidabad	4,340	42.90 ± 1.14	66.62 ± 1.07	23.72	55.29	Good
Overall	21,460	42.80 ± 1.16	68.90 ± 1.09	26.10	60.98	

3.6 Contribution towards Sustainable Development Goals

The DBT Biotech-KISAN Hub Programme made measurable contributions towards several Sustainable Development Goals (SDGs). Increased household income and livelihood diversification supported **SDG 1 (No Poverty)**, while improved livestock and fisheries productivity contributed to **SDG 2 (Zero Hunger)**. Scientific training and farmer capacity building strengthened **SDG 4 (Quality Education)**, whereas increased participation of women farmers promoted **SDG 5 (Gender Equality)**. Enterprise development and higher productivity supported **SDG 8 (Decent Work and Economic Growth)**, and adoption of climate-resilient livestock and fisheries technologies contributed to **SDG 13 (Climate Action)**. Institutional collaboration among DBT, WBUAFS, Krishi Vigyan Kendras, Farmer Producer Organizations and beneficiary communities strengthened **SDG 17 (Partnerships for the Goals)**.

3.7 Factors Influencing Livelihood Improvement

One-way Analysis of Variance (ANOVA) revealed significant differences among socio-economic groups with respect to knowledge, technology adoption, income and livelihood development. Landholding, educational level, occupation, family type and participation in scientific training significantly influenced programme outcomes. Farmers who actively participated in training programmes generally exhibited higher knowledge scores, greater adoption of recommended technologies and significantly better livelihood outcomes than untrained farmers.

Table 7. Sustainable Development Goal (SDG) Impact Assessment

SDG	Programme Outcome	Impact
SDG 1	Household income enhancement	High
SDG 2	Livestock and fish productivity	High
SDG 4	Scientific knowledge improvement	High
SDG 5	Women empowerment	High
SDG 8	Employment and entrepreneurship	High
SDG 13	Climate-resilient technologies	Moderate
SDG 17	Institutional partnership	High

Pearson's correlation analysis further demonstrated positive relationships among scientific knowledge, technology adoption, household income and Livelihood Development Index, indicating that improvements in knowledge promoted behavioural change, which subsequently enhanced productivity and livelihood security.

3.8 Overall Programme Impact

The integrated scientific interventions implemented under the DBT Biotech-KISAN Hub Programme produced substantial improvements in farmers' knowledge, technology adoption, productivity, income and livelihood development across the five Aspirational Districts of West Bengal. The combination of scientific capacity building, superior germplasm distribution, preventive animal healthcare, aquaculture development, ICT-enabled advisory services, entrepreneurship promotion and institutional strengthening effectively translated research-based innovations into measurable socio-economic benefits. The findings clearly demonstrate that the Biotech-KISAN Hub Programme represents a successful model for science-led rural transformation capable of enhancing livelihood resilience, improving food and nutritional security and promoting sustainable agricultural development among small and marginal farmers.

Table 10. Overall Impact Framework of the DBT Biotech-KISAN Hub Programme

Indicator	Baseline	Endline	Improvement (%)
Knowledge Score	25.89	34.76	34.27
Adoption Index	5.87	8.42	43.44
Household Income (₹/month)	9,621.87	15,395.00	59.99
Livelihood Development Index	42.80	68.90	60.98
Women Participation (%)	63.14	72.85	15.38
Scientific Training Coverage (%)	29.71	100.00	236.58

4. Discussion

The present study demonstrates that the DBT Biotech-KISAN Hub Programme significantly enhanced the knowledge, technology adoption, household income and livelihood status of beneficiary farmers in the five Aspirational Districts of West Bengal. The integrated intervention model, which combined scientific capacity building, quality production inputs, continuous technical support and institutional strengthening, successfully translated biotechnology-based innovations into measurable socio-economic benefits. The observed improvements across multiple livelihood dimensions indicate that science-led extension approaches can effectively address the constraints faced by small and marginal farmers and contribute to sustainable rural development.

One of the most significant outcomes of the programme was the substantial improvement in the scientific knowledge of beneficiary farmers. The baseline survey revealed limited awareness of improved livestock husbandry, backyard poultry and aquaculture technologies, reflecting inadequate access to scientific information and extension services. Following systematic training programmes, frontline demonstrations, Farm Schools and ICT-enabled advisory services, farmers exhibited marked improvements in scientific knowledge related to breeding, feeding, animal health care, vaccination, biosecurity and aquaculture management. These findings are consistent with the observations of Anderson and Feder (2007), who reported that agricultural extension plays a crucial role in improving farmers' knowledge and decision-making capacity. Similarly, Davis et al. (2012) concluded that participatory extension approaches and continuous technical guidance significantly improve farmers' technical competence and facilitate adoption of modern agricultural technologies.

The increase in technology adoption observed in the present study further demonstrates the effectiveness of the Biotech-KISAN intervention model. Beneficiary farmers showed substantial improvement in the adoption of superior Black Bengal goat germplasm, balanced feeding, mineral mixture supplementation, vaccination, deworming, scientific housing, backyard poultry management and freshwater aquaculture practices. According to Rogers (2003), knowledge is the first stage in the innovation-decision process, and increased awareness promotes the adoption of improved technologies. The positive association observed between Knowledge Score and Adoption Index in the present study supports this concept, indicating that scientific training and regular extension contact encouraged behavioural change among beneficiary farmers. Similar findings have been reported by Feder, Just and Zilberman (1985), who identified access to information, education and extension support as major determinants of technology adoption in agriculture.

The programme generated substantial improvements in household income through integrated livestock and fisheries interventions. Among the different livelihood enterprises, animal husbandry recorded the highest proportional increase in income, followed by fisheries and agriculture. These improvements can be attributed to the introduction of superior breeding stock, balanced feeding, preventive health care, scientific management practices and improved market-oriented production systems. Livestock and fisheries have long been recognized as important components of livelihood diversification because they provide regular cash flow, nutritional security and resilience against crop failures (FAO, 2023). Ellis (2000) emphasized that diversification of rural livelihood sources reduces household vulnerability and enhances income stability, which is consistent with the findings of the present investigation.

The Livelihood Development Index (LDI) increased considerably following programme implementation, indicating improvements in human, financial, physical, natural and social capital. Enhancement of human capital resulted from increased scientific knowledge and technical skills, while financial capital improved through higher household income and

diversified livelihood opportunities. Physical capital strengthened through improved livestock assets, housing and production infrastructure, whereas social capital improved because of greater participation in Farmer Producer Organizations (FPOs), Self-Help Groups (SHGs), Farm Schools and institutional networks. These findings support the Sustainable Livelihood Framework proposed by Chambers and Conway (1992) and further developed by DFID (1999), which emphasizes that sustainable livelihood improvement depends on strengthening multiple livelihood capitals rather than increasing income alone. Scoones (1998) similarly argued that integrated development programmes that simultaneously improve human, financial, natural, physical and social assets are more likely to produce sustainable livelihood outcomes.

The statistical analyses further demonstrated that education, landholding, occupation and participation in scientific training significantly influenced knowledge enhancement, technology adoption and livelihood development. Farmers who participated in training programmes consistently achieved higher knowledge scores, greater technology adoption and better livelihood outcomes than those with limited exposure to scientific interventions. Similar observations have been reported by Mittal and Mehar (2016), who found that access to agricultural information and extension services significantly influences technology adoption and farm productivity among smallholders in India.

An important achievement of the programme was its emphasis on women farmers and socially disadvantaged communities. Women actively participated in goat rearing, backyard poultry, fish farming, value addition and entrepreneurship development, resulting in improved technical capacity, greater decision-making ability and increased household income. These findings support the conclusions of FAO (2011), which reported that empowering women through improved access to agricultural technologies and extension services substantially enhances household food security and rural economic development.

The DBT Biotech-KISAN Hub Programme also contributed to several Sustainable Development Goals (SDGs). Improved household income and diversified livelihoods directly support **SDG 1 (No Poverty)**, while increased livestock and fisheries productivity contributes to **SDG 2 (Zero Hunger)**. Capacity building and scientific training promote **SDG 4 (Quality Education)**, and women's participation advances **SDG 5 (Gender Equality)**. Entrepreneurship development and enhanced productivity contribute to **SDG 8 (Decent Work and Economic Growth)**, whereas climate-resilient livestock and fisheries technologies support **SDG 13 (Climate Action)**. Collaboration among the Department of Biotechnology, WBUAFS, Krishi Vigyan Kendras, Farmer Producer Organizations and farming communities exemplifies **SDG 17 (Partnerships for the Goals)**, highlighting the importance of institutional convergence in achieving sustainable agricultural development.

Overall, the findings clearly indicate that the DBT Biotech-KISAN Hub Programme successfully integrated scientific innovation, participatory extension and institutional support to improve the livelihoods of small and marginal farmers in the Aspirational Districts of West Bengal. The programme not only enhanced productivity and household income but also strengthened livelihood resilience through improvements in knowledge, technology adoption, institutional participation and human capacity. The integrated intervention model developed under the programme provides strong evidence that biotechnology-based extension systems can serve as an effective and scalable strategy for promoting inclusive agricultural growth and sustainable rural transformation in India.

5. Conclusion

The present study demonstrates that the **DBT Biotech-KISAN (Biotechnology–Krishi Innovation Science Application Network) Hub Programme** has significantly improved the livelihoods of small and marginal farmers in the five Aspirational Districts of West Bengal

through an integrated, science-based extension approach. The baseline–endline assessment clearly established that systematic capacity building, technology dissemination, quality input support and continuous technical backstopping substantially enhanced farmers' scientific knowledge, technology adoption, household income and overall livelihood security.

The programme successfully bridged the gap between research institutions and farming communities by promoting improved livestock, backyard poultry and freshwater aquaculture technologies tailored to local production systems. Scientific interventions such as superior Black Bengal goat germplasm, balanced feeding, mineral mixture supplementation, preventive animal healthcare, improved fish seed, scientific pond management, entrepreneurship development and ICT-enabled advisory services resulted in significant improvements in production efficiency and farm profitability. The observed increase in the Knowledge Score, Adoption Index and Livelihood Development Index clearly demonstrates that scientific knowledge translated into higher technology adoption, which subsequently enhanced productivity, income and livelihood resilience.

The Livelihood Development Index showed substantial improvement following programme implementation, indicating positive changes in human, financial, physical, natural and social capital. Enhanced scientific skills, diversified livelihood opportunities, increased institutional participation, strengthened Farmer Producer Organizations (FPOs) and improved access to extension services collectively contributed to sustainable livelihood development. Women farmers emerged as major beneficiaries of the programme, demonstrating increased participation in livestock and fisheries enterprises, improved technical competency and greater economic empowerment.

The statistical analyses confirmed that education, training, landholding and occupation significantly influenced knowledge enhancement, technology adoption and livelihood improvement. The strong positive relationships among knowledge, adoption, household income and livelihood development emphasize the critical role of scientific extension and farmer capacity building in accelerating rural transformation. These findings support the Sustainable Livelihood Framework and reinforce the importance of integrating technological innovation with institutional support and participatory extension systems.

The programme also made meaningful contributions to the **Sustainable Development Goals (SDGs)** by promoting poverty reduction (SDG 1), food and nutritional security (SDG 2), quality education through farmer training (SDG 4), gender equality (SDG 5), decent work and economic growth (SDG 8), climate-resilient agricultural practices (SDG 13) and multi-stakeholder partnerships (SDG 17). These outcomes demonstrate that biotechnology-based agricultural extension can serve as an effective mechanism for achieving both national development priorities and global sustainability objectives.

Overall, the DBT Biotech-KISAN Hub Programme has proven to be an effective and replicable model for translating scientific innovations into measurable socio-economic benefits for rural communities. The integrated intervention strategy substantially improved productivity, technology adoption, household income and livelihood security while strengthening institutional linkages among research organizations, extension agencies and farming communities. The experience gained from this programme provides valuable evidence for policymakers and development agencies seeking to promote science-led agricultural development in resource-constrained regions.

Future programmes should focus on expanding digital extension services, strengthening climate-smart livestock and aquaculture technologies, promoting women-led agri-enterprises, improving value addition and market integration, and enhancing collaboration among research institutions, government agencies and Farmer Producer Organizations. Scaling up the Biotech-KISAN model across other Aspirational Districts and agro-ecological regions of India has the potential to accelerate inclusive agricultural growth, improve rural resilience

and contribute significantly to the national vision of **Viksit Bharat 2047** through sustainable, technology-driven rural development.

Acknowledgement

The authors gratefully acknowledge the **Department of Biotechnology (DBT), Ministry of Science & Technology, Government of India**, for financial support under the **Biotech-KISAN Programme**. The authors also acknowledge the **West Bengal University of Animal and Fishery Sciences, Kolkata, India**, for providing the necessary institutional, laboratory and field facilities for carrying out the study. The cooperation and support of the participating farmers and field personnel during sample collection and field investigations are sincerely acknowledged.

References

- Agresti, A. (2019). *An Introduction to Categorical Data Analysis* (3rd ed.). John Wiley & Sons.
- Anderson, J. R., & Feder, G. (2007). Agricultural extension. In R. E. Evenson & P. Pingali (Eds.), *Handbook of Agricultural Economics* (Vol. 3, pp. 2343–2378). Elsevier.
- Barrett, C. B., Reardon, T., & Webb, P. (2001). Nonfarm income diversification and household livelihood strategies in rural Africa: Concepts, dynamics and policy implications. *Food Policy*, 26(4), 315–331.
- Chambers, R., & Conway, G. R. (1992). *Sustainable Rural Livelihoods: Practical Concepts for the 21st Century*. IDS Discussion Paper No. 296. Institute of Development Studies, Brighton, UK.
- Davis, K., Swanson, B., Amudavi, D., Mekonnen, D. A., Flohrs, A., Riese, J., Lamb, C., & Zerfu, E. (2012). *In-depth Assessment of the Public Agricultural Extension System of India*. International Food Policy Research Institute (IFPRI).
- Department for International Development (DFID). (1999). *Sustainable Livelihoods Guidance Sheets*. Department for International Development, London.
- Department of Biotechnology (DBT). (2022). *Biotech-KISAN (Biotechnology–Krishi Innovation Science Application Network): Programme Guidelines*. Ministry of Science and Technology, Government of India, New Delhi.
- Ellis, F. (2000). *Rural Livelihoods and Diversity in Developing Countries*. Oxford University Press.
- FAO. (2011). *The State of Food and Agriculture 2010–11: Women in Agriculture—Closing the Gender Gap for Development*. Food and Agriculture Organization of the United Nations, Rome.
- FAO. (2017). *Guidelines for Impact Evaluation of Agricultural Projects*. Food and Agriculture Organization of the United Nations, Rome.
- FAO. (2023). *The State of Food and Agriculture 2023*. Food and Agriculture Organization of the United Nations, Rome.
- Feder, G., Just, R. E., & Zilberman, D. (1985). Adoption of agricultural innovations in developing countries: A survey. *Economic Development and Cultural Change*, 33(2), 255–298.
- Field, A. (2018). *Discovering Statistics Using IBM SPSS Statistics* (5th ed.). Sage Publications.
- Government of India. (2024). *Agricultural Statistics at a Glance 2024*. Ministry of Agriculture and Farmers Welfare, New Delhi.
- Government of West Bengal. (2024). *District Statistical Handbook*. Bureau of Applied Economics and Statistics, Kolkata.

- Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2019). *Multivariate Data Analysis* (8th ed.). Cengage Learning.
- Johnson, R. A., & Wichern, D. W. (2019). *Applied Multivariate Statistical Analysis* (7th ed.). Pearson.
- Kaiser, H. F. (1974). An index of factorial simplicity. *Psychometrika*, 39(1), 31–36.
- Kothari, C. R. (2004). *Research Methodology: Methods and Techniques* (2nd ed.). New Age International Publishers.
- Likert, R. (1932). A technique for the measurement of attitudes. *Archives of Psychology*, 140, 1–55.
- Mittal, S., & Mehar, M. (2016). Socio-economic factors affecting adoption of modern information and communication technology by farmers in India. *Journal of Agricultural Education and Extension*, 22(2), 199–212.
- Montgomery, D. C. (2020). *Design and Analysis of Experiments* (10th ed.). John Wiley & Sons.
- NITI Aayog. (2018). *Transformation of Aspirational Districts: Programme Document*. Government of India, New Delhi.
- NITI Aayog. (2023). *Aspirational Districts Programme: Annual Review*. Government of India, New Delhi.
- Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric Theory* (3rd ed.). McGraw-Hill.
- OECD. (2008). *Handbook on Constructing Composite Indicators: Methodology and User Guide*. OECD Publishing.
- OECD. (2019). *Better Criteria for Better Evaluation: Revised Evaluation Criteria Definitions and Principles for Use*. OECD Publishing.
- Rogers, E. M. (2003). *Diffusion of Innovations* (5th ed.). Free Press.
- Scoones, I. (1998). Sustainable rural livelihoods: A framework for analysis. *IDS Working Paper No. 72*. Institute of Development Studies, Brighton.
- Sen, A. (1999). *Development as Freedom*. Oxford University Press.
- Snedecor, G. W., & Cochran, W. G. (1989). *Statistical Methods* (8th ed.). Iowa State University Press.
- Steel, R. G. D., Torrie, J. H., & Dickey, D. A. (1997). *Principles and Procedures of Statistics: A Biometrical Approach* (3rd ed.). McGraw-Hill.
- United Nations. (2015). *Transforming Our World: The 2030 Agenda for Sustainable Development*. United Nations.
- United Nations Development Programme (UNDP). (2016). *Human Development Report 2016: Human Development for Everyone*. UNDP.
- United Nations Development Programme (UNDP). (2022). *Human Development Report 2021/2022: Uncertain Times, Unsettled Lives in a Changing World*. UNDP.
- World Bank. (2021). *Data Collection and Survey Design for Agricultural Development Projects*. World Bank.
- World Bank. (2023). *Transforming Agriculture for Inclusive Growth and Rural Development*. World Bank.
- World Health Organization. (2022). *One Health Joint Plan of Action (2022–2026)*. World Health Organization.

Figure 1. Improvement in Knowledge Score of Beneficiary Farmers Before and After Intervention

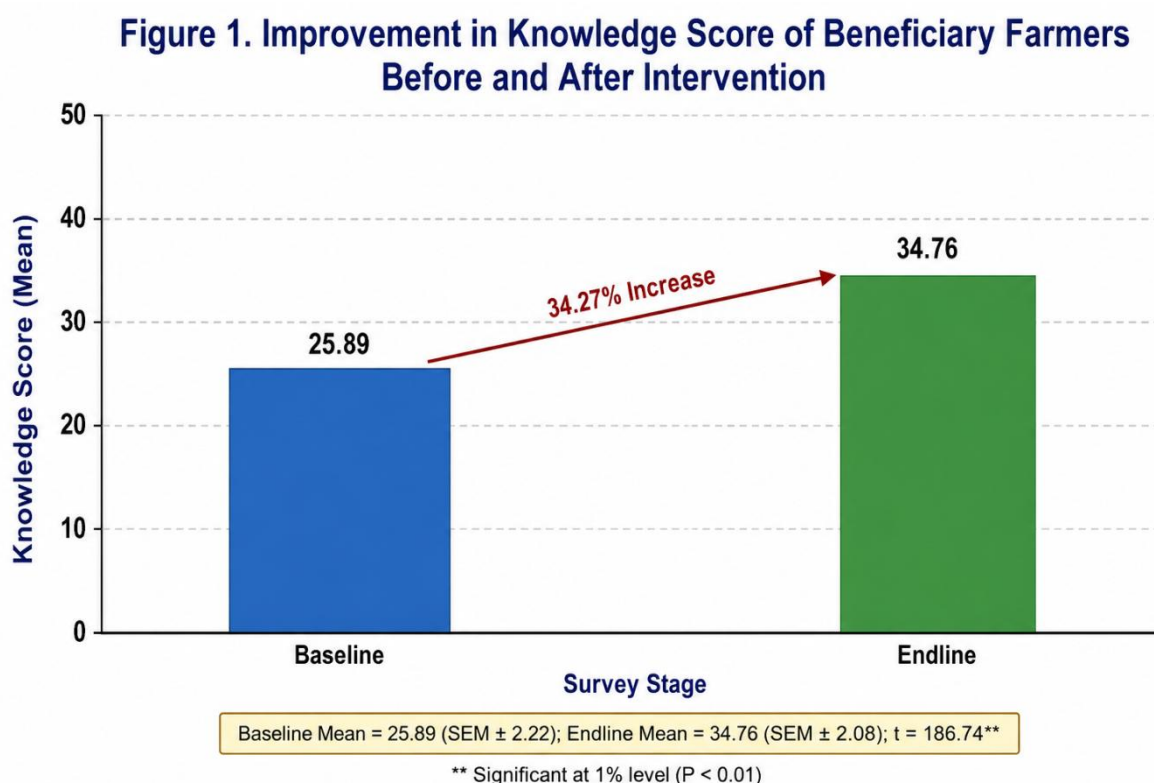


Figure 2. Technology Adoption Index Before and After Intervention

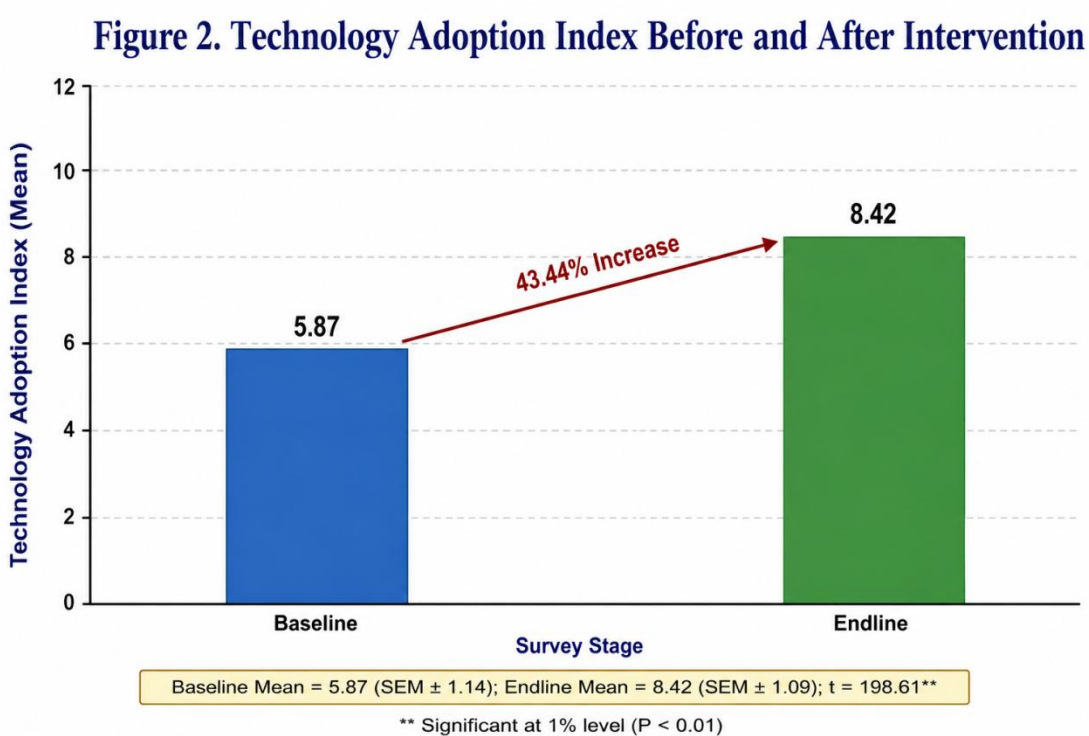


Figure 3. Source-wise Monthly Household Income Before and After Intervention

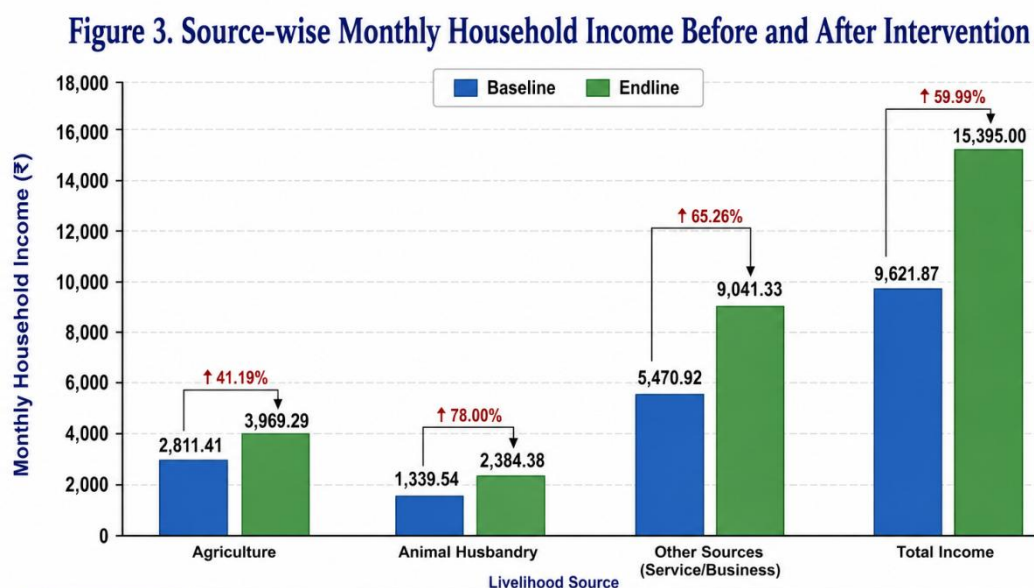


Figure 4. District-wise Household Income before and After Programme Intervention

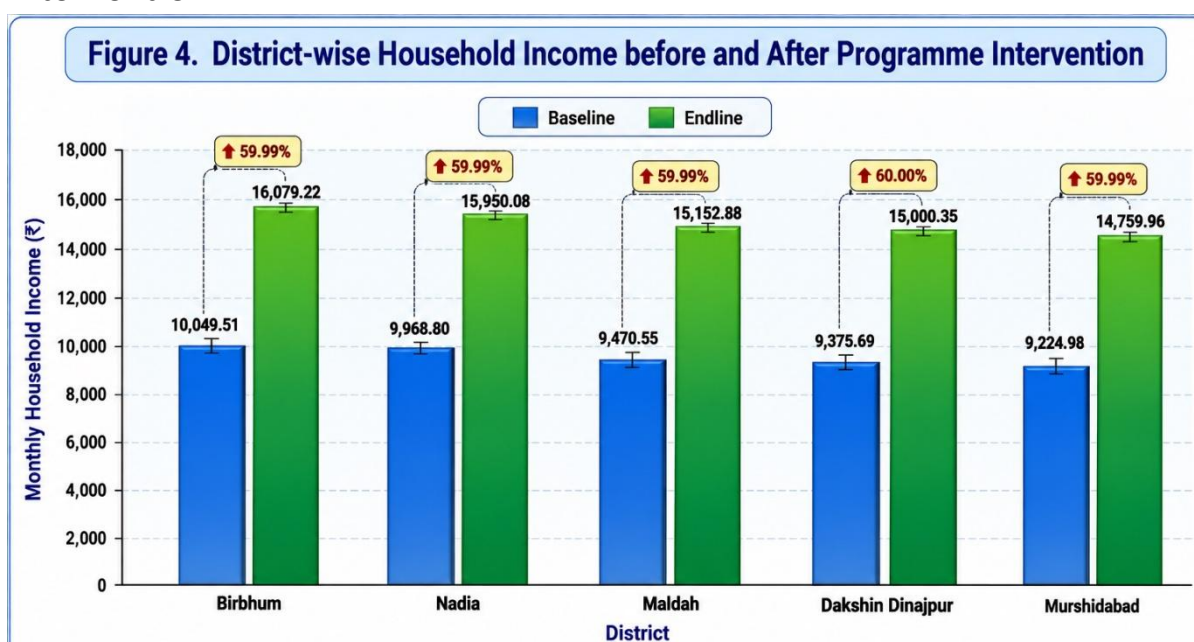


Figure 5. Livelihood Development Index Before and After Intervention

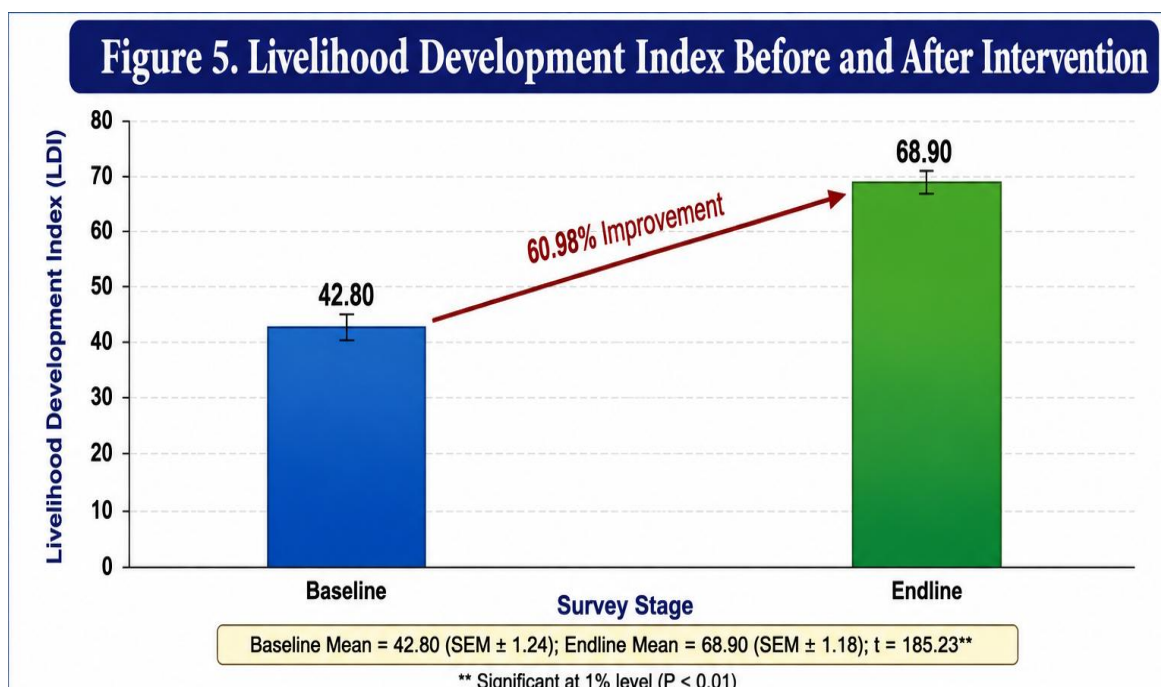
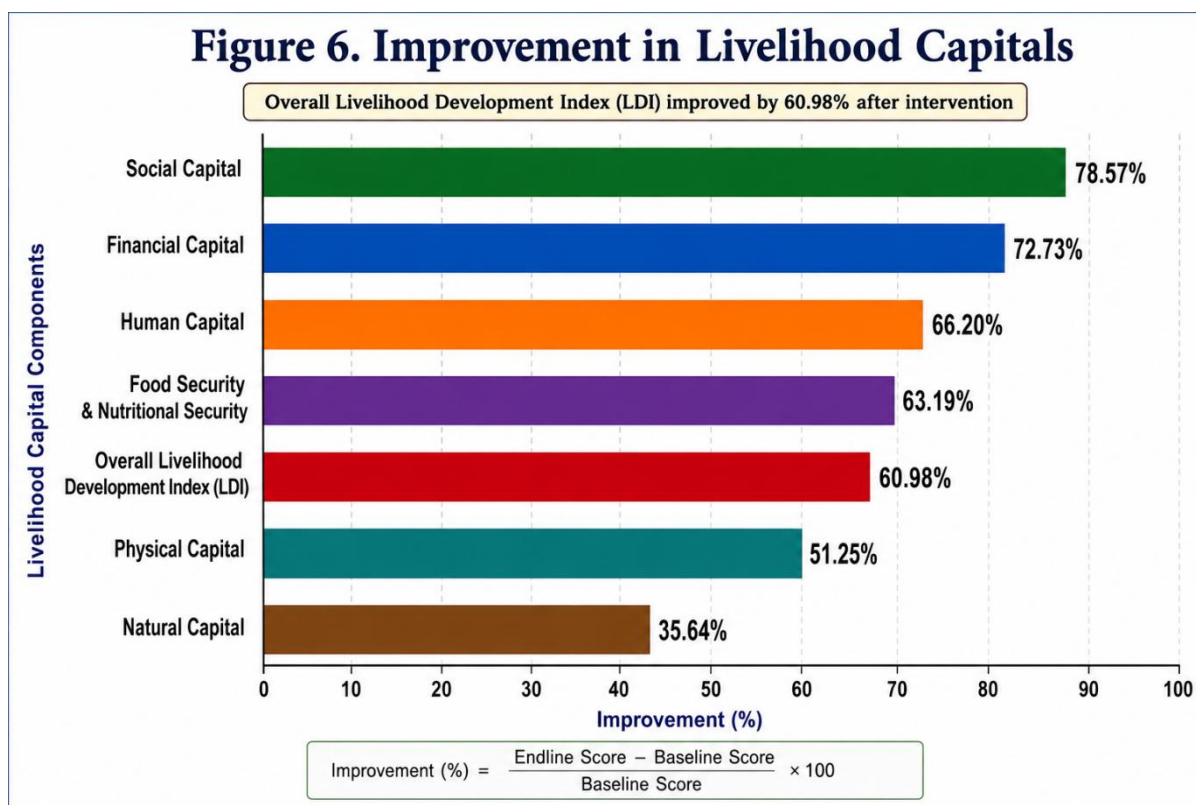


Figure 6. Improvement in Livelihood Capitals



Declarations

Funding

The authors declare that no specific grant or financial support was received from any funding agency in the public, commercial, or not-for-profit sectors for the conduct of this study or preparation of the manuscript.

Ethics Approval

The study protocol was reviewed and approved specifically for this study by the Institutional Ethics Committee, Directorate of Research, Extension and Farms, West Bengal University of Animal & Fishery Sciences (WBUAFS), Kolkata, India, under Approval No. DREF/224/26, dated 22 April 2026. The study was conducted in accordance with the ethical requirements of the Institutional Ethics Committee, Directorate of Research, Extension and Farms, West Bengal University of Animal & Fishery Sciences (WBUAFS) and the applicable principles of the Indian Council of Medical Research (ICMR) National Ethical Guidelines for Biomedical and Health Research Involving Human Participants (2017).

Consent to Participate

Informed consent was obtained from all individual participants before their participation in the study. Before conducting the questionnaire-based face-to-face interviews, the participants were informed about the purpose of the study, the voluntary nature of their participation, the confidentiality of the information collected, and their right to withdraw at any stage without any adverse consequences. Only participants who voluntarily agreed to participate were included in the study.

Consent for Publication

Not applicable. The manuscript does not contain any identifiable personal information, images, or other details requiring individual consent for publication. All participant data have been presented in anonymized and aggregated form.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this manuscript.

Availability of Data and Materials

The datasets generated and/or analysed during the present study are available from the corresponding author upon reasonable request. The data are not publicly available because they contain information collected from individual participants, and public disclosure could compromise participant privacy and confidentiality.

Author Contributions

All authors contributed to the conception and design of the study, acquisition and/or analysis of data, interpretation of the findings, and preparation or critical revision of the manuscript. All authors read and approved the final manuscript.

Declaration of Competing Interests

The authors declare that there are no competing interests associated with this work.

