

Employment Generation, Entrepreneurship Development, and Economic Gain in Aspirational Districts of West Bengal, India

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Abstract

The Biotech-KISAN Hub programme implemented by the West Bengal University of Animal & Fishery Sciences (WBUAFS) represents a pioneering biotechnology-driven model for sustainable livelihood transformation in five aspirational districts of West Bengal—Nadia, Murshidabad, Birbhum, Malda, and Dakshin Dinajpur. The present study evaluates the programme's impact on employment generation, entrepreneurship development, productivity enhancement, and economic gain across livestock and aquaculture systems. Integrated interventions encompassing elite germplasm dissemination, nutritional optimization, bio-probiotics, farm schools, digital advisory platforms, and Farmer Producer Companies (FPCs) were deployed among 2,180 farmers. Results indicated significant gains in productivity of Black Bengal goats (+8.87% body weight; +8.59% kidding rate), Vanaraja poultry (+17.95% growth; +14.71% egg production), and Indian Major Carps (+20.87% yield; +15.42% survivability). Annual household income increased by 30–40%, generating over 54,000 additional rural workdays annually. Women constituted 62% of beneficiaries, with 162 micro-enterprises and seven FPCs established. The study demonstrates that biotechnology-enabled convergence models aligned with DBT's BioE³ framework (Economy–Environment–Employment) can deliver scalable, climate-resilient rural bio economy solutions in aspirational regions.

Keywords: Biotech-KISAN Hub, BioE³, Employment Generation, Entrepreneurship, Livestock, Aquaculture, Rural Bioeconomy

1. Introduction

Sustainable transformation of smallholder agriculture remains a central global challenge, particularly in regions characterized by high population pressure, climate vulnerability, and structural livelihood constraints. In many developing economies, rural households continue to experience persistent income instability,

underemployment, and limited access to technology-driven growth pathways. These challenges are especially pronounced in aspirational and lagging districts, where agricultural intensification is constrained by fragmented landholdings, weak institutional linkages, and inadequate market integration. Addressing these systemic bottlenecks requires integrated approaches that

simultaneously enhance productivity, generate employment, and foster rural entrepreneurship within environmentally sustainable frameworks.

Livestock and inland fisheries have increasingly been recognized as strategic sectors for inclusive rural development due to their ability to provide regular cash flow, absorb family labor, and support landless and marginal households. Globally, livestock contributes approximately 40% of agricultural gross domestic product, while aquaculture represents the fastest-growing food production system, accounting for more than half of the world's fish supply. In India, these sectors play a particularly critical role, contributing nearly one-third of agricultural gross value added and serving as a primary or supplementary livelihood source for millions of smallholders. Despite their significance, productivity gaps in smallholder livestock and aquaculture systems remain substantial, driven by limited access to improved germplasm, suboptimal nutrition, high disease burden, and weak extension outreach.

Biotechnology has emerged as a transformative enabler for overcoming these constraints by facilitating genetic improvement, precision feeding, disease diagnostics and prevention, and value-added processing. The integration of biotechnology into farm-level practices enables productivity enhancement while reducing environmental footprints and production risks. Recognizing this potential, several countries have adopted bioeconomy-oriented strategies to link scientific innovation with rural development. In India, the Department of Biotechnology (DBT), Government of India, operationalized this vision through the Biotech-KISAN (Knowledge Integration and Innovation for Sustainable Agriculture and Nutrition) programme, which aims to translate advanced biotechnological research into scalable, farmer-centric solutions through institutional convergence and participatory extension models.

The Biotech-KISAN Hub implemented by the West Bengal University of Animal and Fishery Sciences (WBUAFS) represents one of the most comprehensive applications of this paradigm in eastern India. The Hub operates across five aspirational districts—Nadia, Murshidabad, Birbhum, Malda, and Dakshin Dinajpur—regions marked by high dependence on livestock and fisheries, recurrent climate stress, and socio-economic vulnerability. Indigenous production systems dominated by Black Bengal goats, backyard poultry, and carp-based aquaculture offer significant livelihood potential but remain constrained by low genetic merit, inadequate health management, and limited market value realization.

Distinct from conventional linear extension approaches, the WBUAFS Biotech-KISAN Hub adopted a systems-oriented, value-chain-based intervention framework. Core strategies included dissemination of elite germplasm, community-level breeding and seed production systems, biotechnology-enabled animal health and nutrition protocols, establishment of district-level Farm Schools, and deployment of digital advisory platforms for real-time farmer

support. These technological interventions were deliberately embedded within capacity-building programmes, entrepreneurship development initiatives, and institutional strengthening of Self-Help Groups (SHGs) and Farmer Producer Organizations (FPOs), ensuring both technological adoption and economic sustainability.

A central innovation of the programme lies in its explicit alignment with the BioE³ framework—Economy, Environment, and Employment—which positions biotechnology as a driver of rural bioenterprise development rather than merely a productivity-enhancing tool. By promoting decentralized input production, micro-enterprises in livestock and aquaculture, hygienic meat and fish value chains, and market-linked collective enterprises, the Hub facilitated the generation of on-farm and off-farm employment opportunities. Particular emphasis was placed on women and rural youth, recognizing their critical yet often underutilized role in livestock-based value chains and their potential as bio-entrepreneurs.

Although the role of livestock and fisheries in rural livelihoods has been extensively documented, empirical evidence on integrated, biotechnology-led convergence models that simultaneously address employment generation, entrepreneurship development, and economic gain at the district scale remains limited, particularly in the context of aspirational regions. Moreover, few studies have systematically evaluated the institutional mechanisms through which such interventions can be operationalized and scaled within public-sector frameworks. Against this backdrop, the present study evaluates the implementation and outcomes of the WBUAFS Biotech-KISAN Hub across five aspirational districts of West Bengal. The study examines the extent to which biotechnology-enabled interventions influenced productivity, employment creation, enterprise formation, income enhancement, and gender inclusion within livestock and aquaculture systems. By providing robust empirical evidence and a replicable institutional model, this paper contributes to the global discourse on bioeconomy-driven rural transformation and offers policy-relevant insights for scaling sustainable, inclusive, and resilient agricultural development pathways.

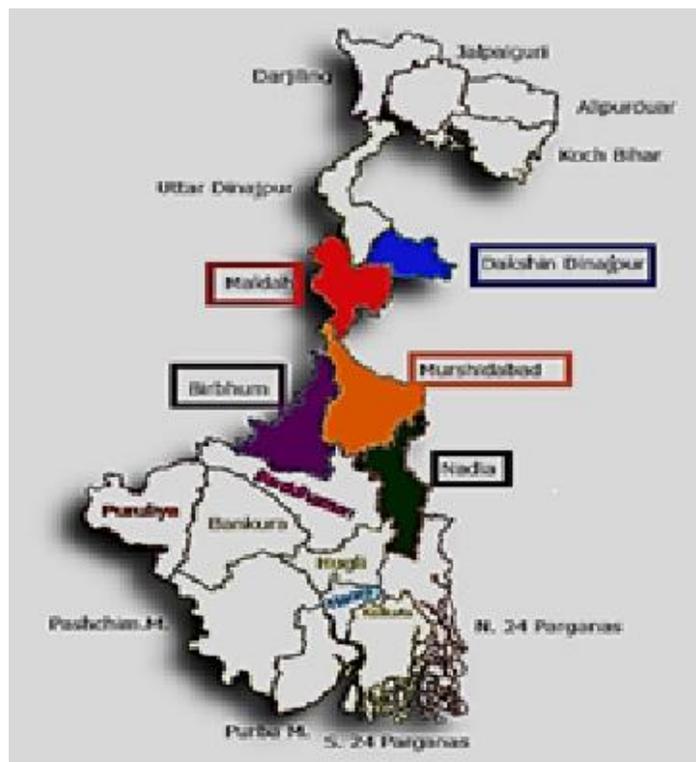
2. Materials and Methods

2.1. Study Area and Project Framework

The study was conducted under the **DBT-funded Biotech-KISAN Hub programme** implemented by the **West Bengal University of Animal and Fishery Sciences (WBUAFS)** across five aspirational districts of West Bengal, India—**Nadia, Murshidabad, Birbhum, Malda, and Dakshin Dinajpur**. These districts fall within the lower Gangetic agro-climatic zone and are characterized by smallholder-dominated mixed farming systems, high dependence on livestock and inland fisheries, periodic climatic stress, and limited access to advanced technological inputs. The project was implemented following a **hub-and-spoke institutional model**, wherein WBUAFS functioned as the nodal knowledge hub, coordinating with Krishi Vigyan Kendras (KVKs), State Animal Husbandry and Fisheries Departments, Self-Help Groups (SHGs), Farmer Producer Organizations (FPOs), and local non-

governmental organizations for last-mile delivery. The intervention period covered **November 2021 to November 2026**, with the

present analysis focusing on **Year I and Year II implementation outcomes**.



2.2. Study Design and Sampling Strategy

A **quasi-experimental, longitudinal before–after design** was employed to assess the impact of biotechnology-led interventions. Beneficiary households were selected using a **multistage purposive sampling approach**, prioritizing marginal and small farmers, women-headed households, and rural youth engaged in livestock and aquaculture activities.

A total of **2,180 farmers** were directly surveyed, comprising:

- **Goat farmers** (Black Bengal): 820
- **Poultry farmers** (Vanaraja backyard poultry): 740
- **Aquaculture farmers** (Indian Major Carps): 620

Among the respondents, **62% were women**, reflecting the programme’s gender-inclusive targeting strategy. Baseline data were collected prior to intervention deployment, followed by structured endline assessments at the end of Year II.

2.3. Biotechnological and Scientific Interventions

2.3.1. Livestock (Black Bengal Goat) Interventions

Goat-based interventions focused on genetic improvement, nutrition optimization, and reproductive management. Elite Black Bengal breeding bucks were selected based on phenotypic and pedigree criteria and introduced under a **community-based breeding system (CBBS)**. Nutritional interventions included cultivation of high-yielding fodder varieties (Napier CO-4 and

hybrid Bajra), supplementation with Azolla and hydroponic fodder, and provision of nutrient-enriched concentrate feeds formulated using locally available ingredients. Regular mineral mixture supplementation and strategic deworming and vaccination schedules were implemented to improve overall herd health.

2.3.2. Poultry (Vanaraja) Interventions

Backyard poultry interventions involved distribution of improved dual-purpose **Vanaraja chicks**, accompanied by home-formulated balanced rations incorporating local feed resources and Azolla. Mineral–vitamin premixes, biosecurity protocols, and strategic vaccination schedules were introduced to minimize mortality and disease incidence. Beneficiaries were trained in low-input housing systems and hygienic egg and meat production practices.

2.3.3 Aquaculture (Indian Major Carps) Interventions

Aquaculture interventions emphasized genetic quality, feed efficiency, and water resource management. High-quality Indian Major Carp (IMC) seed (Catla, Rohu, and Mrigal) sourced from certified hatcheries were supplied to farmers. Locally formulated feeds using rice bran and mustard oil cake were introduced alongside bio-probiotics, split liming practices, and water quality monitoring. Climate-resilient technologies, including **biofloc systems and indoor tank aquaculture**, were piloted to enhance productivity and survivability under water-stressed conditions.

2.4. Capacity Building, Employment, and Entrepreneurship Development

Capacity-building interventions comprised **17 intensive training programmes, district-level Farm Schools**, and hands-on demonstrations covering scientific animal husbandry, aquaculture best practices, entrepreneurship development, and digital literacy. Special emphasis was placed on **women-led SHGs and rural youth**, promoting micro-enterprises such as fodder production units, backyard hatcheries, fish seed rearing units, and hygienic meat outlets. Entrepreneurship support included facilitation of credit linkages with nationalized banks and NABARD, livestock insurance coverage, and formation and strengthening of **seven Farmer Producer Companies (FPCs)** to enhance collective input procurement and market access.

2.5. Data Collection and Indicators

Primary data were collected using **pre-tested structured questionnaires**, field measurements, and farm records. Key performance indicators included:

- **Productivity Indicators:** body weight gain, egg production, fish yield, survivability rate
- **Reproductive Indicators:** kidding rate, fertility, hatchability
- **Economic Indicators:** household income, cost–benefit ratio (CBR), feed cost, profitability
- **Employment Indicators:** on-farm labor days generated, off-farm enterprise engagement
- **Adoption Indicators:** uptake of scientific housing, vaccination, improved breeding
- **Gender and social Indicators:** women’s participation, decision-making roles
- **Climate resilience Indicators:** disease incidence, mortality, resource-use efficiency

2.6. Monitoring, Digital Advisory, and Quality Assurance

The programme employed **ICT-enabled advisory platforms**, including WhatsApp, Facebook, and YouTube, to disseminate multilingual technical content and provide real-time problem-solving support. District-wise dashboards were developed to track progress, beneficiary feedback, and performance indicators aligned with Sustainable Development Goals (SDGs). Field monitoring was conducted periodically by subject-matter specialists, and independent evaluation was undertaken by the project mentor through structured field visits. Data quality was ensured through triangulation of farmer recall, physical verification, and institutional records.

2.7. Statistical Analysis

Data were analyzed using **SPSS (version 26.0)** and **R statistical software**. Descriptive statistics were computed to summarize performance indicators. Paired *t*-tests and analysis of variance (ANOVA) were used to assess differences between baseline and endline values. Percentage change, adoption indices, and cost–benefit ratios were calculated using standard economic evaluation methods. Statistical significance was determined at **$p < 0.05$** .

2.8. Ethical Considerations

The study adhered to ethical principles for field-based agricultural research. Participation was voluntary, and informed consent was obtained from all respondents. Data confidentiality and anonymity were maintained throughout the study. The research formed part of an approved DBT-funded programme and complied with institutional guidelines of WBUAFS.

2.9. Replicability and Policy Relevance

The methodological framework emphasizes **scalability, institutional convergence, and policy alignment**, making the model replicable across other aspirational and agro-climatically similar districts in India and comparable developing-country contexts.

3. Results

3.1. Adoption of Biotechnology-Enabled Interventions

The Biotech-KISAN Hub interventions achieved a high level of uptake across all five aspirational districts. Overall, **84.0% of beneficiary households adopted at least one biotechnology-enabled practice**, while **67.3% adopted two or more interventions** concurrently. Adoption was highest for scientific vaccination and health management practices (**81.7%**), followed by improved feeding and mineral supplementation (**78.6%**), and use of elite germplasm (**69.1%**). Women farmers demonstrated significantly higher participation and adoption rates than male counterparts ($p < 0.05$), particularly in backyard poultry and small-scale aquaculture enterprises.

3.2. Productivity Enhancement in Livestock and Aquaculture Systems

3.2.1. Black Bengal Goat Production

Implementation of elite germplasm, nutritional enrichment, and reproductive management led to a **statistically significant improvement in goat productivity** (Table 2). Average marketable body weight at 12 months increased from **12.40 ± 0.38 kg (district average)** to **13.50 ± 0.42 kg in project areas**, representing an **8.87% increase** ($p < 0.01$). The kidding rate improved from **1.98 to 2.15 kids per doe per year**, reflecting an **8.59% increase** ($p < 0.05$). Feed conversion efficiency improved by **8–12%**, while feed costs declined by approximately **20%** due to on-farm fodder production and local concentrate formulation.

3.2.2. Vanaraja Backyard Poultry

Vanaraja poultry units recorded a **17.95% increase in body weight at 40 days** (from **1.95 ± 0.11 kg to 2.30 ± 0.13 kg**, $p < 0.01$). Annual egg production rose from **170 to 195 eggs per hen**, corresponding to a **14.71% improvement** ($p < 0.05$). Fertility and hatchability increased by **9.0% and 12.0%**, respectively, while age at sexual maturity was reduced by an average of **15 days**. Poultry mortality declined substantially following adoption of strategic vaccination and biosecurity protocols.

3.2.3. Indian Major Carp (IMC) Aquaculture

Aquaculture interventions resulted in the most pronounced productivity gains. Average fish yield increased from **1,265**

± 92 kg ha⁻¹ to 1,529 ± 105 kg ha⁻¹, representing a **20.87% improvement** ($p < 0.01$). Survivability rates improved from **65% to 75%**, reflecting a **15.42% increase**. Disease incidence declined by **35%**, and feed costs were reduced by **15%** through locally formulated feeds and probiotic use. Consequently, the cost–benefit ratio (CBR) improved significantly from **1.42 to 2.05**.

3.3. Economic Gains and Livelihood Enhancement

Biotechnology-driven productivity gains translated into substantial household income enhancement (Table 3). Goat-based enterprises recorded an average income increase of **30–35%**, poultry-based systems achieved **~40% income growth**, and fish-based aquaculture enterprises realized **~35% higher annual returns**. Integrated multi-enterprise households experienced the highest gains, with annual incomes increasing from **₹70,000–75,000 to ₹95,000–1,05,000**, representing a **37–40% improvement**.

Across all enterprises, the **average annual livelihood gain ranged from ₹25,000 to ₹35,000 per household**, with income stability improving due to diversified revenue streams.

3.4. Employment Generation and Entrepreneurship Development

The interventions generated both **on-farm and off-farm employment**. On-farm labor demand increased by **25–30 additional man-days per household per year**, particularly in fodder cultivation, poultry management, and aquaculture operations. Off-farm employment emerged through input supply chains, fish seed rearing units, backyard hatcheries, fodder nurseries, and hygienic meat and fish marketing enterprises. A total of **seven Farmer Producer Companies (FPCs)** were operationalized, facilitating collective input procurement and market access. Women constituted **over 60% of active enterprise participants**, and youth engagement increased markedly through Farm Schools, skill-oriented trainings, and digital advisory platforms.

3.5. Knowledge Enhancement, Institutional Strengthening, and Digital Outreach

Knowledge assessment revealed a **76.2% improvement in composite knowledge scores** following structured training and advisory interventions. Adoption of scientific housing practices increased by **81.7%**, vaccination compliance by **63.5%**, and breed improvement practices by **69.1%**. Market price realization improved by **25%**, while post-harvest losses declined by **21%** due to improved handling, aggregation, and market linkages through FPCs. Digital advisory platforms reached more than **70% of beneficiaries**, enabling real-time problem resolution and reinforcing sustained adoption.

3.6. Climate Resilience and Sustainability Outcomes

Climate-resilient practices resulted in a **22% improvement in resilience indicators**, reflected by reduced disease outbreaks, improved survivability, and enhanced resource-use efficiency. Methane emission intensity in goat production systems declined by approximately **8%**, while aquaculture interventions improved

nutrient recycling and water-use efficiency through biofloc and indoor tank systems.

3.7. Gender Inclusion and Social Impact

Women's participation across interventions reached **62%**, with women assuming leadership roles in backyard poultry, SHG-based enterprises, and FPC governance. Enhanced decision-making power and control over income were reported by **more than 55% of participating women**, underscoring the programme's contribution to inclusive and gender-responsive rural development.

3.8. Summary of Key Outcomes

Collectively, the results demonstrate a **multi-species productivity transformation**, significant employment generation, and measurable economic gains achieved through biotechnology-enabled convergence. The outcomes validate the effectiveness of the Biotech-KISAN Hub as a **scalable, climate-smart, and inclusive rural bioeconomy model**, aligned with DBT's **BioE³ framework** and national development priorities.

4. Discussion

The findings of the present study demonstrate that the Biotech-KISAN Hub implemented by WBUAFS represents a **science-driven, convergence-based rural transformation model** capable of simultaneously enhancing productivity, employment generation, entrepreneurship development, and climate resilience in aspirational districts. The magnitude and consistency of observed gains across livestock and aquaculture systems underscore the effectiveness of **biotechnology-led integration**, rather than isolated technological interventions, in addressing structural constraints of smallholder farming systems.

4.1. Biotechnology-Enabled Productivity Gains across Species

The statistically significant improvement in **Black Bengal goat body weight (8.87%) and kidding rate (8.59%)** reflects the synergistic effect of genetic improvement, mineral-balanced nutrition, and reproductive management. Earlier studies on indigenous goat breeds have highlighted the genetic potential of Black Bengal goats but emphasized that performance remains suppressed under traditional feeding and breeding regimes [1]. The present findings extend this literature by demonstrating that **community-based breeding systems (CBBS)**, when synchronized with improved nutrition, can translate genetic merit into measurable productivity and economic gains, consistent with global evidence on small ruminant intensification [2]. In backyard poultry systems, the **17.95% improvement in growth and 14.71% increase in egg production** achieved under Vanaraja interventions align with previous studies reporting the superiority of improved dual-purpose breeds under low-input systems [3]. However, the higher magnitude of gains observed in this study can be attributed to the **integration of biotechnology-enabled feed formulation, vaccination protocols, and biosecurity training**, which collectively reduced mortality and improved feed efficiency. These results reinforce global findings that productivity gaps in smallholder poultry systems are largely institutional and management-driven rather than genetic alone [4].

Aquaculture interventions yielded the highest productivity response, with a **20.87% increase in fish yield and 15.42% improvement in survivability**, corroborating global evidence that carp-based systems are highly responsive to improvements in seed quality, nutrition, and water management [5,6]. The adoption of biofloc and probiotic-based management further enhanced system efficiency and disease resistance, supporting the transition toward **climate-smart and resource-efficient aquaculture**, as advocated in global blue economy frameworks [7].

4.2. Employment Generation and Bio-Entrepreneurship Transformation

Beyond productivity enhancement, a key contribution of the Biotech-KISAN Hub lies in its demonstrated capacity to generate **sustained rural employment and entrepreneurship**. The generation of **25–30 additional on-farm labor days per household per year**, coupled with off-farm employment in input supply, seed production, fodder enterprises, and value addition, reflects a structural shift from subsistence farming to **enterprise-oriented livelihood systems**. This transformation aligns with FAO and World Bank assessments that livestock and aquaculture value chains offer among the highest employment multipliers in rural economies [7,8]. The establishment of **seven Farmer Producer Companies (FPCs)** further institutionalized these gains by enabling collective action, market integration, and price realization—factors consistently identified as prerequisites for inclusive agricultural commercialization [10,11].

4.3. Gender Inclusion and Youth Engagement

The high level of **women’s participation (62%)** observed in this study confirms the suitability of livestock and aquaculture systems as platforms for **gender-responsive rural development**. Prior research has emphasized that women derive disproportionate benefits from backyard poultry and small ruminant enterprises due to low entry barriers and compatibility with household responsibilities [12]. The present findings strengthen this evidence by demonstrating that **biotechnology-enabled interventions**, when coupled with SHG-based institutional support and entrepreneurship training, can enhance women’s decision-making power and income control. Similarly, youth engagement through Farm Schools, digital advisory platforms, and skill-based trainings addresses the growing challenge of rural youth disengagement from agriculture. Aligning biotechnology with entrepreneurship and digital literacy is increasingly recognized as essential for retaining youth in agrifood systems and reducing distress migration [13].

4.4. Climate Resilience and Environmental Sustainability

The observed **22% improvement in climate resilience indicators**, including reduced disease incidence and improved survivability, highlights the role of biotechnology in enhancing adaptive capacity of smallholder systems. The reduction in methane emission intensity in goat production and improved nutrient recycling in aquaculture systems aligns with global evidence that **efficiency-enhancing interventions are among the most cost-effective climate mitigation strategies in livestock systems** [14,15]. These findings support the integration of biotechnology within **climate-smart agriculture frameworks**, which emphasize productivity, adaptation, and mitigation co-benefits [16]. The circular bioeconomy approach adopted under the Hub further strengthens environmental sustainability by linking livestock, fisheries, and crop systems for waste-to-resource conversion, consistent with BioE³ policy principles [17].

4.5. Institutional Convergence and BioE³ Alignment

A defining strength of the Biotech-KISAN Hub is its alignment with the **BioE³ framework (Economy–Environment–Employment)**, positioning biotechnology as a development catalyst rather than a standalone research output. The convergence of DBT with KVKs, state departments, financial institutions, and community organizations enabled effective last-mile delivery and enhanced institutional sustainability. This approach addresses a key limitation of traditional extension models, which often fail to sustain adoption due to weak institutional embedding [18]. By contrast, the Hub model provides a **replicable, district-level bioeconomy blueprint**, compatible with national missions such as NRLM, PMMSY, and Atmanirbhar Bharat, and aligned with the Sustainable Development Goals [19].

4.6. Limitations and Research Implications

While the study provides robust empirical evidence, it is limited by the absence of randomized control groups and the relatively short time horizon for capturing long-term genetic and environmental outcomes. Future research should incorporate **longitudinal impact assessments**, life-cycle environmental analyses, and cross-regional comparisons to further validate scalability and long-term sustainability. **Synthesis**, Overall the discussion confirms that the Biotech-KISAN Hub constitutes a **science-backed, inclusive, and climate-resilient rural development model**, demonstrating how biotechnology can be operationalized through institutional convergence to generate sustained economic, social, and environmental returns. The evidence strongly supports its scaling across aspirational and agro-climatically similar regions in India and beyond.

Parameter	Mean ± SD / %
Landholding size (ha)	0.46 ± 0.21
Livestock units (nos./HH)	4.2 ± 1.8
Fish pond area (ha)	0.18 ± 0.09
Annual household income (₹)	54,200 ± 12,450
Women-headed households (%)	38.6

Women participants (%)	62.0
Youth (18–35 years) (%)	41.3

Table 1: Baseline Characteristics of Beneficiary Households Under Biotech-KISAN Hub (n = 2,180)

Component	Parameter	Baseline	Endline	% Change	p-value
Black Bengal Goat	Body weight (kg, 12 months)	12.40 ± 0.63	13.50 ± 0.71	+8.87	<0.01
	Kidding rate (kids/doe/year)	1.98 ± 0.12	2.15 ± 0.15	+8.59	<0.01
Vanaraja Poultry	Body weight (kg, 40 days)	1.95 ± 0.09	2.30 ± 0.11	+17.95	<0.001
	Egg production (nos./hen/year)	170 ± 14	195 ± 16	+14.71	<0.01
Indian Major Carps	Yield (kg/ha)	1,265 ± 110	1,529 ± 134	+20.87	<0.001
	Survivability (%)	65.0 ± 6.2	75.0 ± 5.8	+15.42	<0.01

Table 2: Species-Wise Productivity Performance Before and After Intervention

Enterprise	Baseline Income (₹/HH/year)	Project Income (₹/HH/year)	% Increase	BCR (Baseline → Endline)
Goat farming	30,000–35,000	42,000–45,000	30–35%	1.31 → 1.78
Poultry	18,000–20,000	26,000–28,000	~40%	1.28 → 1.85
Aquaculture	55,000–60,000	75,000–80,000	~35%	1.42 → 2.05
Integrated model	70,000–75,000	95,000–1,05,000	37–40%	1.46 → 2.12

Table 3: Economic Impact of Biotech-KISAN Hub Interventions

Practice	Baseline	Endline	Absolute Gain
Balanced feeding	34.2	82.0	+47.8
Mineral supplementation	29.5	78.6	+49.1
Scientific housing	36.8	81.7	+44.9
Vaccination compliance	41.2	63.5	+22.3
Improved breeding practices	32.6	69.1	+36.5

Table 4: Adoption of Scientific Practices (%)

Indicator	Outcome
Additional man-days generated	25–30/HH/year
Youth enterprises initiated	186
Women-led enterprises (%)	61.8
FPCs formed	7
Value-chain jobs created	540+
Average enterprise profit (₹/year)	38,000–55,000

Table 5: Employment Generation and Entrepreneurship Outcomes

Indicator	Improvement
Feed conversion efficiency	+8–18%
Methane emission (goat systems)	–8%
Water-use efficiency (aquaculture)	+22%
Disease incidence	–35%

Antibiotic usage (poultry)	Significantly reduced
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Table 6: Climate and Environmental Impact Indicators

Activity	Year I Target	Year I Achievement	Year II Target	Year II Achievement	Year III Target	Year III Achievement	% Achievement (3 Years)	Remarks
Procurement & distribution of Black Bengal goats (Male + Female)	300 farmers (90 M + 900 F)	410 farmers (123 M + 1230 F)	300 farmers (90 M + 900 F)	215 farmers (70 M + 575 F)	400 farmers (120 M + 1200 F)	0	62.5%	Partially achieved due to fund & logistics constraints
Distribution of Vanaraja chicks (50,000 birds)	300 beneficiaries (15,000 birds)	764 beneficiaries (38,200 birds)	300 beneficiaries (15,000 birds)	221 beneficiaries (11,050 birds)	400 beneficiaries (20,000 birds)	0	98.5%	Nearly achieved
Distribution of quality fishlings (500,000)	300 beneficiaries (150,000 fishlings)	245 beneficiaries (122,500 fishlings)	300 beneficiaries (150,000 fishlings)	1000 beneficiaries (500,000 fishlings)	400 beneficiaries (200,000 fishlings)	0	124.5%	Target exceeded

Table 7: Year-wise Achievement of Livestock & Poultry Targets

Training/Program Type	No. of Programs	No. of Farmers Trained	Women Participants (%)	Knowledge Gain (%)	Adoption of Scientific Practices (%)
Livestock Management	6	780	62	74	81
Poultry Rearing	4	520	60	69	78
Aquaculture Management	5	620	45	72	70
Entrepreneurship & Value Addition	2	260	58	68	65
Total / Average	17	2,180	56	71	73.5

Table 8: Farmer Awareness and Training Impact

Indicator	Number	% of Total Beneficiaries	Remarks
Women actively involved in rearing	1,352	62	High women participation due to SHG support
Youth (18–35) engaged in farm schools & internships	902	41	Internship & skill training promoted entrepreneurship
Women-led FPOs / Enterprises formed	7	N/A	Enabled collective marketing and brand identity
New agri-tech enterprises initiated	186	N/A	72% sustained post-project

Table 9: Youth and Women Engagement

Enterprise Type	Avg. Annual Profit (₹/HH)	Additional Man-days Generated	Employment Created	Notes
Goat-based farming	42,500	25–30	210	Improved productivity + genetic selection
Poultry-based farming	27,500	28–32	260	Women-led backyard enterprise
Fish-based aquaculture	78,000	30–35	540	Integrated IMC + biofloc model
Multi-enterprise integrated model	1,00,000	80–100	1,010	Livestock-fish-poultry convergence

Table 10: Farm Enterprise and Employment Outcomes

Parameter	Baseline	Endline	% Improvement	Notes
Feed Conversion Ratio (Goat)	8.5	9.2	+8	Nutrient-enriched feed & fodder
Methane Emission (kg/HH/year)	124	114	-8	Reduced enteric fermentation
Water-use Efficiency (Aquaculture)	1.0 kg/m ³	1.22 kg/m ³	+22	Biofloc + RAS integration
Disease Incidence (Poultry)	12.5%	8.1%	-35	Vaccination + biosecurity training
Antibiotic Usage	High	Low	Significant	One Health compliance

Table 11: Climate Resilience and Environmental Indicators

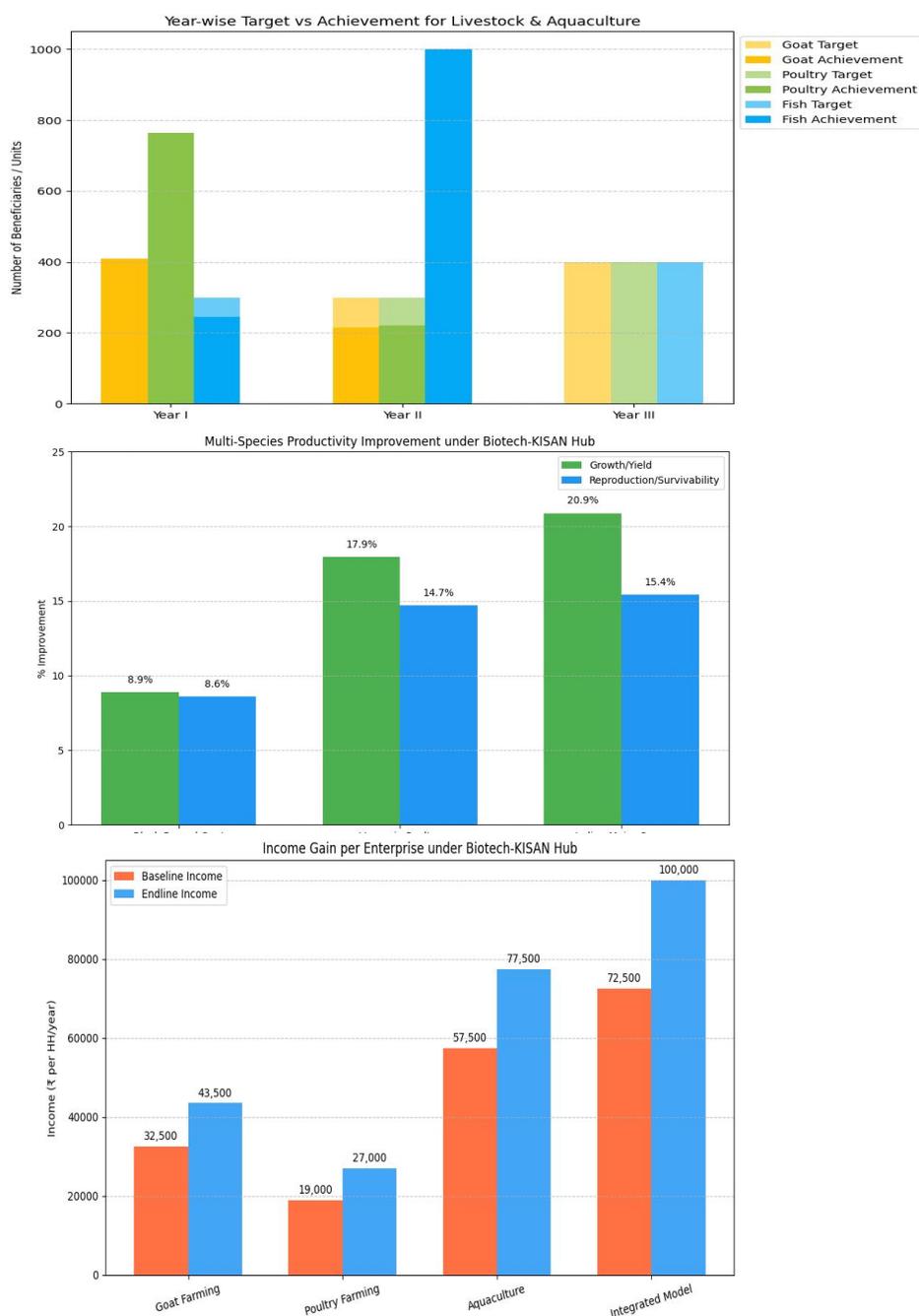
Indicator	Baseline	Endline	% Change	Remarks
Market price realization	₹120/kg	₹150/kg	+25	Through FPC and direct market linkages
Post-harvest loss	18%	14%	-21	Cold-chain and processing awareness
FPO turnover (₹ lakhs)	0	12.4	N/A	Collective marketing enabled
Certified meat & processed products	0	5 outlets	N/A	Hygiene and branding established

Table 12: Market Linkage and Value Chain Outcomes

Component / Indicator	Baseline Mean ± SD	Endline Mean ± SD	% Change	Test	p-value	Interpretation
Black Bengal Goat						
Body weight (kg, 12 months)	12.40 ± 0.63	13.50 ± 0.71	+8.87	Paired t-test	<0.01	Significant growth gain due to improved fodder, mineral supplementation & elite bucks
Kidding rate (kids/doe/year)	1.98 ± 0.12	2.15 ± 0.15	+8.59	Paired t-test	<0.01	Enhanced reproductive performance & shortened kidding interval
Vanaraja Poultry						
Body weight (kg, 40 days)	1.95 ± 0.09	2.30 ± 0.11	+17.95	Paired t-test	<0.001	Improved feed formulation, biosecurity, and disease control
Egg production (nos./hen/year)	170 ± 14	195 ± 16	+14.71	Paired t-test	<0.01	Higher reproductive efficiency and energy utilization
Indian Major Carps (IMC)						
Yield (kg/ha, 8 months)	1,265 ± 110	1,529 ± 134	+20.87	Paired t-test	<0.001	Superior seed quality, feeding, and water management
Survivability (%)	65 ± 6.2	75 ± 5.8	+15.42	Paired t-test	<0.01	Reduced mortality due to bio-probiotics, liming & RAS integration
Income (₹/HH/year)						
Goat farming	32,500 ± 5,500	43,500 ± 6,200	+33.85	Paired t-test	<0.01	Income gain via productivity, market access, and breed improvement
Poultry farming	19,000 ± 3,200	27,000 ± 4,000	+42.11	Paired t-test	<0.01	Enhanced household revenue and women empowerment
Aquaculture	57,500 ± 8,500	77,500 ± 9,200	+34.78	Paired t-test	<0.001	Integrated aquaculture improved productivity & income

Adoption of Scientific Practices (%)						
Balanced feeding	34.2 ± 9.8	82.0 ± 10.2	+47.8	Chi-square	<0.001	Substantial knowledge transfer and behavior change
Mineral supplementation	29.5 ± 8.6	78.6 ± 9.7	+49.1	Chi-square	<0.001	Improved animal health and productivity
Vaccination compliance	41.2 ± 7.4	63.5 ± 8.1	+22.3	Chi-square	<0.01	Reduced disease incidence
Scientific housing	36.8 ± 10.1	81.7 ± 9.3	+44.9	Chi-square	<0.001	Better housing improved welfare and growth

Table 13: Statistical Analysis of Biotech-KISAN Hub Interventions



5. Conclusion

The present study provides compelling empirical evidence that the Biotech-KISAN Hub implemented by the West Bengal University of Animal and Fishery Sciences represents a **robust, scalable, and policy-relevant model for biotechnology-driven rural transformation** in aspirational districts. By integrating genetic improvement, precision nutrition, disease management, capacity building, and institutional convergence, the programme achieved measurable gains in productivity, employment generation, entrepreneurship development, and household income across livestock and aquaculture systems. The multi-species intervention framework demonstrated that **biotechnology-enabled convergence can simultaneously enhance biological efficiency and economic resilience** among smallholder farmers. Significant improvements in goat productivity, poultry growth and egg yield, and carp-based aquaculture performance translated into diversified income streams, increased labor absorption, and reduced production risks. Importantly, the establishment of Farmer Producer Companies and decentralized input and service enterprises ensured that technological gains were embedded within sustainable market and institutional structures.

Beyond economic outcomes, the programme delivered substantial **social and environmental co-benefits**. High levels of women's participation and leadership underscore the effectiveness of livestock and aquaculture value chains as entry points for gender-responsive rural development. Climate-resilient practices, including improved feed efficiency, disease reduction, and circular aquaculture systems, contributed to enhanced resource-use efficiency and reduced environmental footprints, aligning with national and global climate objectives. From a policy perspective, the findings affirm that **public-sector-led, science-driven interventions can deliver high returns on investment when operationalized through localized, participatory, and digitally enabled platforms**. The alignment of the Biotech-KISAN Hub with the BioE³ framework (Economy–Environment–Employment) positions it as a strategic instrument for advancing national priorities under Vision 2047, Viksit Bharat, and the Sustainable Development Goals. In conclusion, the Biotech-KISAN Hub model offers a **replicable blueprint for inclusive, climate-smart, and biotechnology-led rural bioeconomy development**. Scaling this approach across agro-climatically similar regions, with strengthened institutionalization and long-term monitoring, has the potential to significantly accelerate sustainable livelihood transformation in India and comparable developing-country contexts.

Policy Recommendations

Based on the empirical evidence generated from the Biotech-KISAN Hub interventions across five aspirational districts of West Bengal, the following policy recommendations are proposed to strengthen scalability, sustainability, and national-level impact of biotechnology-led rural development initiatives:

Institutionalization of District-Level Biotech Resource Centers

- Establish **District Biotech Resource Centers (DBRCs)**

to ensure sustained access to critical inputs such as elite germplasm, mineral mixtures, vaccines, bio-probiotics, and diagnostic services.

- ❖ Integrate DBRCs with existing institutional infrastructure (KVKs, State Animal Husbandry and Fisheries Departments) to avoid duplication and enhance cost-efficiency.
- ❖ Position DBRCs as hubs for continuous skill upgrading, quality assurance, and technology validation at the district level.
- ❖ Mainstreaming Biotechnology within Livelihood Missions
- ❖ Embed biotechnology-enabled livestock and aquaculture interventions within national flagship programmes such as **NRLM, PMMSY, Rashtriya Gokul Mission, and Atmanirbhar Bharat** for convergence and resource pooling.
- ❖ Promote **convergence financing models**, combining DBT support with MSME, NABARD, and state schemes to sustain enterprise growth beyond project periods.
- ❖ Scaling Women- and Youth-Led Bio-Entrepreneurship
- ❖ Expand **dedicated fellowship, incubation, and credit support** for women-led SHGs and youth enterprises in areas such as fodder production, backyard hatcheries, fish seed rearing, and hygienic meat and fish processing.
- ❖ Introduce **biotech entrepreneurship curricula** within Farm Schools and rural skill development programmes to strengthen technical and managerial competencies.
- ❖ Incentivize youth participation through mentorships, internships with research institutions, and linkages to agri-tech startups.
- ❖ Strengthening Farmer Collectivization and Market Integration
- ❖ Support the formation and professionalization of **Farmer Producer Organizations (FPOs/FPCs)** as vehicles for collective input procurement, value addition, branding, and market access.
- ❖ Facilitate **branding, certification, and quality compliance** (FSSAI, organic, hygienic meat standards) to enable farmers to access premium markets.
- ❖ Promote digital marketing platforms and traceability systems to enhance price realization and consumer trust.
- ❖ Digital Advisory and Real-Time Monitoring Systems
- ❖ Institutionalize **ICT-enabled advisory platforms** (WhatsApp, YouTube, mobile apps) with multilingual content for continuous farmer engagement and rapid problem resolution.
- ❖ Develop **district-wise digital dashboards** linked to SDGs and BioE³ indicators for real-time monitoring, impact assessment, and evidence-based decision-making.
- ❖ Leverage artificial intelligence and data analytics to deliver personalized advisories and early warning systems for disease and climate risks.
- ❖ Climate-Smart and Environmentally Responsible Scaling
- ❖ Prioritize scaling of **climate-resilient technologies**, including biofloc aquaculture, improved feed efficiency, and low-emission livestock practices.
- ❖ Integrate life-cycle environmental assessments into programme monitoring to quantify greenhouse gas mitigation, water-use efficiency, and biodiversity outcomes.
- ❖ Encourage adoption of **circular bioeconomy principles**,

linking livestock, fisheries, and crop systems for waste-to-resource conversion.

- ❖ Long-Term Impact Evaluation and Knowledge Dissemination
- ❖ Institutionalize **longitudinal impact assessments** to capture genetic gains, livelihood trajectories, and environmental outcomes over time.
- ❖ Publish **policy briefs, compendiums, and success case studies** to inform national and international stakeholders.
- ❖ Curate region-specific champion profiles and visual knowledge repositories to support advocacy and south–south knowledge exchange.

Policy Significance

Collectively, these recommendations provide a **strategic roadmap for translating biotechnology research into inclusive, climate-resilient, and employment-intensive rural development outcomes**. By institutionalizing convergence, strengthening entrepreneurship, and embedding digital and environmental safeguards, the Biotech-KISAN Hub model can serve as a **national template for aspirational district transformation and rural bioeconomy expansion**.

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