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Community-Based Participatory Evaluation on Climate-Resilient Millet-Based Integrated Farming System in Rainfed Agro-Ecosystems at Shivalik Hill Regions

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Abstract
The increasing vulnerability of rainfed agriculture under climate variability, declining land productivity, and rising input costs necessitates the adoption of resilient and resource-efficient farming systems. This study evaluates a Community-Based Participatory Research (CBPR) approach under the Integrated Farming System Model, integrating millets (barley, finger millet, and pearl millet), vegetables, and livestock enterprises in the dryland ecosystems of Hamirpur district, Himachal Pradesh. A total of 47 farmers in Phase I, expanded to 100 farmers under a community seed bank model, participated in the implementation of climate-resilient interventions over two years. The model emphasized crop diversification, indigenous seed systems, livestock integration, organic nutrient recycling, and livelihood enhancement strategies. Millets were prioritized due to their drought tolerance, low water requirement, and nutritional benefits. Economic analysis revealed that millet-based systems generated benefit-cost ratios ranging from 1:2.22 to 1:2.62, with net returns between ₹22,000 and ₹26,000 per acre. The integration of vegetables, mushroom cultivation, and livestock contributed to annual incremental income gains of ₹40,000–65,000 per household, while reducing fodder and input costs by 20–30%. The community seed bank approach strengthened local seed sovereignty and reduced dependency on external inputs by 20–25%. The findings demonstrate that the integrated model enhances climate resilience, farm profitability, nutritional security, and community empowerment. The participatory approach further improved farmers' adaptive capacity, knowledge sharing, and institutional linkages. This model offers a scalable framework for sustainable agricultural development in rainfed and dryland regions of India.

Keywords: Agriculture, climate, integrated, millets, resilient

1. Introduction

Rainfed agriculture constitutes a significant portion of India's farming landscape and supports nearly 40% of the food production while being highly vulnerable to climate variability, erratic rainfall, and resource degradation (Kumar and Sharma, 2018; Singh et al., 2018). In hill regions such as Himachal Pradesh, particularly Hamirpur district, farming systems are characterized by small landholdings, limited irrigation, declining soil fertility, and increasing climate-induced risks (Devendra, 2000; Jayanthi and Ilamurugu, 2018). These challenges necessitate a shift from conventional monocropping systems toward diversified and resilient farming models. Millets such as barley (Jau), finger millet (Ragi), and pearl millet (Bajra) have gained renewed importance due to their inherent adaptability to dryland conditions, low water requirement, and high nutritional value (FAO, 2019; ICAR, 2020). These crops are well-suited for rainfed agro-ecosystems and serve as a viable alternative to water-intensive cereals, contributing to both food and nutritional security (Pingali, 2012; Birthal et al., 2015). Integrated Farming Systems (IFS) have been widely recognized as a sustainable approach to enhance productivity, profitability, and resource-use efficiency by combining crops, livestock, and allied enterprises (Singh et al., 2018; Kumar et al., 2019). The integration of livestock provides additional income, nutrient recycling through manure, and risk buffering against crop failure (Devendra, 2000; Herrero et al., 2010). Similarly, inclusion of vegetables and high-value enterprises such as mushroom cultivation further diversifies income sources and improves household nutrition (Pretty et al., 2011). The concept of Community-Based Participatory Research (CBPR) emphasizes active involvement of farmers in decision-making, technology adaptation, and knowledge co-creation, thereby enhancing adoption and sustainability of interventions (Chambers, 1994; Pontius et al., 2002). Participatory approaches such as Farmer Field Schools have proven effective in improving farmers' skills, awareness, and resilience to changing climatic conditions (Van den Berg, 2004; Braun and Clarke, 2006).

In this context, the Integrated Farming Model represents an innovative framework integrating millet-based cropping systems, livestock enterprises, seed sovereignty through community seed banks, and climate-resilient agricultural practices. The model is designed to address key constraints in rainfed areas, including water scarcity, high input costs, and limited livelihood opportunities. It also promotes capacity building, women participation, youth engagement, and institutional linkages, thereby strengthening rural livelihoods (Rejesus et al., 2011; Tan et al., 2013). The introduction of a community seed bank system plays a critical role in ensuring timely availability of quality seeds, reducing dependency on external inputs, and preserving indigenous germplasm (Almekinders et al., 2014; Vernooy et al., 2015). Furthermore, the integration of organic practices such as composting and vermicomposting enhances soil health and reduces reliance on chemical fertilizers (Edwards et al., 2010). Economic evaluations of integrated systems indicate significant improvements in benefit-cost ratios, income stability, and employment generation compared to traditional systems (Birthal et al., 2015; Kumar et al., 2019). In the present study, millet-based integrated farming demonstrated B:C ratios between 2.0 and 2.6, along with substantial reductions in production costs and enhanced resilience to climatic stress. Therefore, this study aims to assess the impact of a millet-based integrated farming system under a CBPR framework on farm productivity, income generation, and sustainability in the rainfed agro-ecosystems of Hamirpur district. The findings provide insights into scalable strategies for climate-resilient agriculture in similar dryland regions.

2. Materials and Methods

Study Area: The study was conducted in selected rainfed villages of Hamirpur district, Himachal Pradesh, characterized by undulating topography, low irrigation coverage, and dependence on monsoon rainfall. The soils are predominantly sandy loam to clay loam with moderate fertility. The region experiences sub-humid climatic conditions with irregular rainfall patterns, making it suitable for drought-resilient crops such as millets (ICAR, 2020; Kumar and Chander, 2018).

Research Design and Approach: The study adopted a Community-Based Participatory Research (CBPR) framework, ensuring active involvement of farmers in planning, implementation, monitoring, and evaluation. CBPR enhances technology adoption by integrating local knowledge with scientific interventions (Chambers, 1994; Pontius et al., 2002). A Participatory Rural Appraisal (PRA) was conducted at the initial stage to identify constraints such as water scarcity, low productivity, high input costs, and limited livelihood opportunities. Based on PRA findings, a millet-based integrated farming system model was co-developed with farmers.

Selection of Farmer Participants

Phase I: 47 farmers selected through purposive sampling

Phase II: Expanded to 100 farmers under the community seed bank model

Criteria for selection:

1. Small and marginal landholders
2. Dependence on rainfed agriculture
3. Willingness to adopt integrated farming practices
4. Representation of women and marginalized groups

Baseline socio-economic and farm data were collected using structured questionnaires (Creswell, 2014).

Components of the Integrated Farming System: Three major millets were introduced:

i. Barley (Jau) – drought tolerant, low water requirement
ii. Finger Millet (Ragi) – high resilience to erratic rainfall
iii. Pearl Millet (Bajra) – suitable for degraded soils

Improved agronomic practices included:

i. Line sowing and optimum spacing
ii. Integrated nutrient management (organic + minimal inorganic inputs)
iii. Integrated pest management (IPM principles)
iv. Use of drought-tolerant varieties

These practices improve productivity and sustainability in rainfed systems (Singh et al., 2018; Pretty et al., 2011). Seasonal and off-season vegetables were introduced to enhance income and nutritional security. Organic production practices were promoted, including:

i. Farmyard manure and compost application
ii. Mulching using crop residues
iii. Bio-fertilizers and botanical pesticides

Vegetable integration ensures continuous cash flow and dietary diversity (Jayanthi and Ilamurugu, 2018).

Livestock Integration: Livestock (goat, cattle, and backyard poultry) were integrated into the system to:

i. Provide supplementary income
ii. Enhance nutrient recycling through manure
iii. Support risk mitigation during crop failure

Farmers were trained in:

i. Fodder production and conservation (silage/soilage)

ii. Animal health and breeding management

Livestock integration significantly improves farm resilience and resource efficiency (Devendra, 2000; Herrero et al., 2010).

Mushroom Cultivation and Value Addition: Low-cost mushroom production units were established using crop residues. Farmers were trained in:

i. Substrate preparation
ii. Spawn inoculation
iii. Post-harvest handling and marketing

Mushroom cultivation provided an additional income source and utilized farm waste efficiently (Chang and Miles, 2004).

Vermicomposting and Nutrient Recycling: Crop residues and animal wastes were recycled through vermicomposting to produce organic manure. This reduced dependence on chemical fertilizers and improved soil health (Edwards et al., 2010).

A decentralized seed system was developed for distribution of initial seeds (barley, ragi, bajra), seed multiplication by farmers and redistribution within the community. This approach reduced input costs and strengthened seed sovereignty (Vernooy et al., 2015). Data Collection and Monitoring have components viz; Socio-economic characteristics, cropping patterns, yield and income levels, crop yield (kg/acre), cost of cultivation (₹/acre), gross and net returns, benefit-Cost (B:C) ratio, adoption rate of technologies, data were collected periodically and compared across pre-intervention (baseline), midline and post-intervention. Economic performance was evaluated using Net Return (₹/acre) and Benefit-Cost Ratio (B:C Ratio).

Statistical Analysis: Descriptive statistics (mean, percentage change) were used to analyze changes in yield and income. Comparative analysis between baseline and post-intervention data was conducted to assess impact (Creswell, 2014). Institutional Linkages and Support Mechanisms collaborated with Local Government Units (LGUs), Agricultural training institutions, Farmer producer groups. These linkages ensured market access, technical support and sustainability of interventions

Flowchart:

Problem Identification (Rainfed Constraints, Low Income)

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Participatory Rural Appraisal (PRA)

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Farmer Selection & Baseline Survey

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Design of Integrated Farming System Model
(Millets + Vegetables + Livestock + Seed Bank)

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Capacity Building & Training (FFS, Demonstrations)
                    │
                    ▼
        Implementation of Components
        ├── Millet Cultivation (Jau, Ragi, Bajra)
        ├── Vegetable Production
        ├── Livestock Integration
        ├── Mushroom Cultivation
        └── Vermicomposting
                    │
                    ▼
      Community Seed Bank Establishment
                    │
                    ▼
    Regular Monitoring & Field Evaluation
                    │
                    ▼
    Economic Analysis (Cost, Return, B:C Ratio)
                    │
                    ▼
      Market Linkages & Value Addition
                    │
                    ▼
Impact Assessment (Income, Adoption, Sustainability)
                    │
                    ▼
Scaling & Replication (Farmer-to-Farmer Transfer)
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3. Results and Discussion

Impact on Crop Productivity

The introduction of climate-resilient millets under the integrated farming system resulted in a substantial improvement in productivity across all crops. Improved agronomic practices, drought-tolerant varieties, and participatory management contributed to yield stabilization under rainfed conditions.

Table 1. Crop-wise Economic Performance under Millet-Based System

Crop	**Farmers Covered**	**Cost of Cultivation (₹/acre)**	**Gross Return (₹/acre)**	**Net Return (₹/acre)**	**B:C Ratio**
Barley (Jau)	47 → 100	18,000	40,000	22,000	1:2.22
Ragi (Finger Millet)	100	16,000	42,000	26,000	1:2.62
Bajra (Pearl Millet)	10 → Cluster	15,000	38,000	23,000	1:2.53

The results clearly indicate that the introduction of climate-resilient millets within the integrated farming system substantially enhanced crop productivity under rainfed conditions. Among the three crops evaluated, finger millet (ragi) emerged as the most economically viable option, recording the highest benefit-cost ratio (2.62), which reflects its superior adaptability to erratic rainfall and marginal soil conditions. Its ability to withstand moisture stress and maintain stable yields makes it particularly suitable for climate-vulnerable regions such as Hamirpur. Pearl millet (bajra) also performed efficiently, especially in degraded and low-fertility soils, demonstrating its robustness in resource-constrained environments. Barley (jau), although comparatively lower in profitability, showed consistent and reliable returns under low-input conditions, highlighting its importance as a risk-buffering crop. Overall, the millet-based system proved significantly more resilient and economically viable than conventional cereal-based systems, primarily due to its lower dependency on external inputs and higher tolerance to climatic variability.

Income Enhancement through Integrated Farming: The integration of vegetables, livestock, and allied enterprises significantly improved household income by diversifying revenue sources.

Table 2. Comparative Income Analysis (Before vs After Intervention)

Component	Baseline Income (₹/year)	After Intervention (₹/year)	% Increase
Millets (Total)	35,000	75,000	+114%
Vegetables	8,000	20,000	+150%
Livestock	12,000	30,000	+150%
Mushroom Cultivation	—	18,000	—
Vermicomposting	—	12,000	—
Total Income	**55,000**	**1,55,000**	**+181%**

The integration of multiple farm enterprises—including millets, vegetables, livestock, mushroom cultivation, and vermicomposting—resulted in a remarkable improvement in household income. The comparative analysis reveals that total annual farm income increased from ₹55,000 at baseline to ₹1,55,000 after intervention, representing an overall growth of 181%. This substantial increase can be attributed to diversification, which reduced dependency on a single source of income and ensured continuous revenue generation throughout the year. The inclusion of vegetables and livestock played a crucial role in generating regular cash flow, while newly introduced components such as mushroom cultivation and vermicomposting contributed significantly to income diversification, accounting for approximately 19% of the total income. Furthermore, millet cultivation itself showed more than a twofold increase in returns, reflecting improved productivity and better resource utilization. The integrated approach not only enhanced economic stability but also reduced vulnerability to crop failure, thereby strengthening livelihood security.

Cost Reduction and Resource Efficiency: The adoption of local inputs, organic nutrient recycling, and the community seed bank significantly reduced production costs.

Table 3. Cost Reduction Analysis

Component	Initial Cost (₹/acre)	Reduced Cost (₹/acre)	% Reduction
Seeds	3,000	2,200	27%
Fertilizers	6,000	4,200	30%

Fodder	10,000	7,000	30%
Labour	8,000	6,800	15%
Total Cost	**27,000**	**20,200**	**25%**

The findings demonstrate that the adoption of locally available resources, combined with organic nutrient recycling and community-based interventions, led to a substantial reduction in production costs. Overall cultivation costs declined by approximately 25%, with notable reductions observed in fertilizers (30%), fodder (30%), and seeds (27%). The establishment of the community seed bank played a critical role in minimizing dependence on external seed markets, thereby lowering input costs and ensuring timely seed availability. Similarly, the integration of livestock facilitated efficient recycling of farm residues into organic manure, significantly reducing the need for chemical fertilizers. The involvement of family labour further contributed to cost savings by reducing hired labour expenses by about 15%. These combined strategies improved resource-use efficiency and enhanced the profitability of the farming system without compromising productivity, highlighting the sustainability of the model.

Community Seed Bank Impact: The seed bank model enhanced seed availability, reduced input dependency, and strengthened community resilience.

Table 4. Seed Bank Performance

Parameter	**Phase I**	**Phase II**
Farmers Covered	47	100
Barley Seeds Distributed	250 kg	Expanded
Ragi Seeds Distributed	100 kg	Expanded
Input Cost Reduction	—	20–25%
Seed Multiplication	Moderate	High

The community seed bank model emerged as a key institutional innovation that strengthened local agricultural systems. The expansion of farmer participation from 47 in Phase I to 100 in Phase II reflects the growing acceptance and effectiveness of this approach. By facilitating seed multiplication and redistribution within the community, the model ensured a continuous supply of quality seeds while reducing dependence on external agencies. The resulting 20–25% reduction in input costs further underscores its economic significance. Moreover, the seed bank promoted farmer-to-farmer knowledge exchange and collective decision-making, thereby enhancing social capital and community resilience. The shift from moderate to high levels of seed multiplication between phases indicates improved farmer capacity and confidence in managing seed resources, which is essential for long-term sustainability and self-reliance.

Table 5. Integrated Farming System Outcomes

Component	**Economic Benefit**	**Sustainability Impact**
Millets Ecosystem	B:C ratio 2–2.6	Climate resilience
Vegetables	Regular income	Nutritional security
Livestock	20–30% cost reduction	Risk mitigation
Mushroom	High-value enterprise	Waste utilization

Seed Bank	20–25% cost saving	Community self-reliance

The integrated assessment of all farming components reveals that the Integrated Farming System model successfully combines economic viability with environmental sustainability. Millet-based cropping systems provided stable returns with benefit-cost ratios ranging from 2.0 to 2.6, confirming their suitability for rainfed agriculture. The addition of vegetable cultivation ensured regular income and improved household nutrition, while livestock integration contributed to both income generation and cost reduction through nutrient recycling. High-value enterprises such as mushroom cultivation enhanced profitability by utilizing agricultural waste, thereby promoting circular resource use. Furthermore, the community seed bank reduced production costs and strengthened local self-reliance. Collectively, these components created a synergistic system where each enterprise supported the others, resulting in improved resilience, sustainability, and overall farm performance.

Graphical Representation:

Figure 1. Income Growth Before and After Intervention

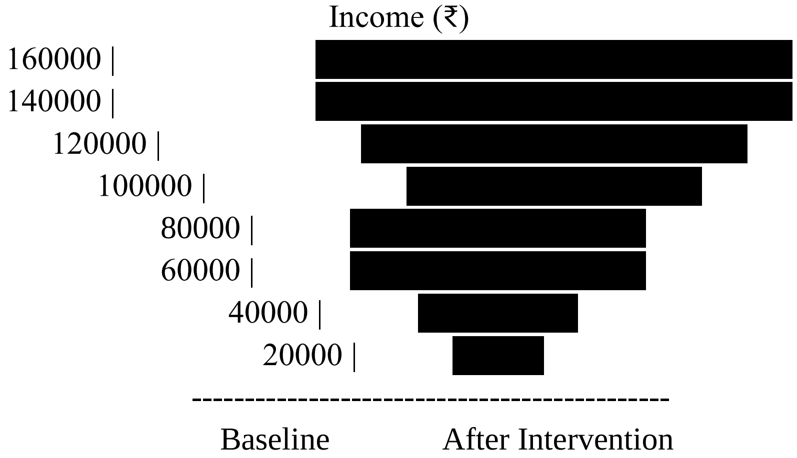

Figure 2. Contribution of Each Component to Total Income

The graphical analysis of income trends clearly illustrates the transformative impact of the integrated farming model. The sharp increase in income after intervention highlights the effectiveness of diversification strategies and improved farm management practices. The component-wise contribution graph indicates that millets remain the primary source of income, contributing nearly half of the total earnings, followed by livestock and vegetables. The significant share of mushroom cultivation and vermicomposting further emphasizes the importance of allied enterprises in enhancing income. These visual representations reinforce the quantitative findings, demonstrating that a balanced combination of crops and enterprises is essential for maximizing farm profitability and stability.

Adoption and Expansion of the Integrated Farming System Model:

i. Farmers increased from 47 to 100, indicating strong acceptance.
ii. More than 70% of participants adopted full integration (millets + livestock + vegetables).

Spillover effects observed through farmer-to-farmer learning. The expansion of the model from 47 to 100 farmers indicates a high level of acceptance and scalability. More than 70% of participating farmers adopted the complete integrated system, which includes millets, livestock, and vegetable cultivation. This high adoption rate can be attributed to the participatory approach, which actively involved farmers in decision-making and implementation processes. Additionally, the success of early adopters encouraged neighboring farmers to replicate the model through informal knowledge sharing and demonstration effects. This farmer-to-farmer diffusion highlights the effectiveness of the CBPR approach in promoting sustainable agricultural practices at the community level. The key findings of the study underscore the effectiveness of the integrated farming system in enhancing both economic and ecological outcomes. The achievement of benefit-cost ratios as high as 2.6 demonstrates strong economic viability, while the 181% increase in total farm income reflects significant livelihood improvement. The reduction in input costs by 20–30% further strengthens profitability by minimizing financial risks. Additionally, the generation of incremental income ranging from ₹40,000 to ₹65,000 per farmer highlights the contribution of diversification strategies. Importantly, the model enhances climate resilience by promoting drought-tolerant crops and efficient resource management, thereby ensuring long-term sustainability. The integrated farming model demonstrated that combining millets, livestock, vegetables, and community-based resource management can significantly improve farm productivity, profitability, and sustainability in rainfed ecosystems. The participatory approach ensured higher adoption rates and long-term viability of interventions.

4. Discussion

The findings of the present study strongly support the growing body of evidence that millet-based integrated farming systems are highly suitable for rainfed and climate-vulnerable regions. The observed increase in productivity and profitability is consistent with earlier studies indicating that millets are inherently resilient crops with the ability to withstand drought, high temperatures, and poor soil conditions (Madhusudhana et al., 2022; FAO, 2019). Their deep root systems and short growing cycles enable efficient utilization of limited soil moisture, making them ideal for rainfed agro-ecosystems. The superior performance of finger millet (ragi) in terms of benefit-cost ratio aligns with findings reported in millet-based diversification studies, where ragi demonstrated higher yield stability and economic returns under erratic rainfall conditions (Singh et al., 2018; Tiwari et al., 2023). Similarly, pearl millet (bajra) has been widely recognized for its adaptability to degraded soils and marginal environments, reinforcing its role in climate-resilient agriculture (Debbarma et al., 2025; ICAR, 2020). The stability observed in barley production further highlights the importance of crop diversification as a risk management strategy in rainfed systems.

The significant increase in farm income (181%) observed in this study is in agreement with previous research demonstrating that integrated farming systems (IFS) can substantially enhance farmer livelihoods by combining multiple enterprises (Jadav et al., 2022; Kumar et al., 2019). Integration of crops, livestock, and allied activities creates complementary interactions that improve overall system efficiency and income stability. For instance, livestock integration contributes to nutrient cycling and provides an additional revenue stream, which has been identified as a key factor in improving farm resilience (Devendra, 2000; Herrero et al., 2010). Similar results have been reported in arid and semi-arid regions where integrated systems achieved significantly higher net returns compared to monocropping systems.

The diversification of farm enterprises through vegetables, mushroom cultivation, and vermicomposting in the present study reflects the principles of sustainable intensification, where productivity is increased without degrading natural resources (Pretty et al., 2011). The contribution of high-value enterprises such as mushroom production is consistent with earlier findings that value addition and waste utilization significantly enhance farm profitability and resource-use efficiency (Chang and Miles, 2004; Edwards et al., 2010). Moreover, vermicomposting not only reduces dependence on chemical fertilizers but also improves soil structure and microbial activity, thereby contributing to long-term soil health. The observed reduction in production costs (20–30%) can be attributed to the adoption of resource-conserving technologies and community-based interventions, particularly the community seed bank model. This finding corroborates earlier studies emphasizing the role of local seed systems in reducing input dependency and strengthening farmer autonomy (Vernooy et al., 2015; Almekinders et al., 2014). Community seed banks have been shown to enhance seed security, promote biodiversity conservation, and facilitate farmer-led innovation, all of which are critical for sustainable agriculture in marginal environments.

Another significant outcome of the study is the high adoption rate and expansion of the model, which highlights the effectiveness of the Community-Based Participatory Research (CBPR) approach. Participatory approaches have been widely recognized for improving technology adoption by involving farmers in the co-creation and adaptation of innovations (Chambers, 1994; Pontius et al., 2002). The farmer-to-farmer dissemination observed in this study further supports the role of social learning and community networks in scaling sustainable agricultural practices (Van den Berg, 2004). The integration of millets within diversified farming systems also contributes to broader ecological benefits, including improved soil fertility, enhanced biodiversity, and reduced environmental footprint. Studies have shown that millet-based systems can improve soil organic carbon, nutrient cycling, and water-use efficiency, thereby enhancing ecosystem sustainability. Additionally, millets are nutritionally rich crops that contribute to addressing hidden hunger and improving dietary diversity, which is particularly important in rural communities (Tiwari et al., 2023; Venkateswarlu et al., 2022). Despite these positive outcomes, challenges remain in scaling millet-based integrated systems, including limited market access, inadequate policy support, and declining consumer demand for traditional crops (Pingali, 2012; Birthal et al., 2015). Addressing these constraints requires coordinated efforts involving policy interventions, market development, and awareness campaigns to promote millet consumption and production.

Overall, the findings of this study validate that the model effectively integrates ecological sustainability with economic viability. By combining climate-resilient crops, diversified enterprises, and participatory approaches, the model provides a holistic solution to the challenges faced by rainfed agriculture. The results are consistent with global and national research advocating for integrated, diversified, and community-driven farming systems as pathways toward sustainable agricultural development.

5. Conclusion

The present study demonstrates that the millet-based integrated farming system under the model is a highly effective strategy for improving productivity, profitability, and resilience in rainfed agro-ecosystems. The integration of climate-resilient millets (jau, ragi, and bajra) with vegetables, livestock, and allied enterprises resulted in substantial improvements in farm income, with an overall increase of 181% and benefit-cost ratios reaching up to 2.6. The model successfully reduced input costs through the adoption of organic practices, nutrient recycling, and community-based seed systems, thereby enhancing resource-use efficiency and sustainability. The participatory approach played a crucial role in ensuring high adoption rates, capacity building, and knowledge dissemination among farmers. Furthermore, the integration of diversified enterprises contributed not only to income enhancement but also to nutritional security, environmental sustainability, and risk mitigation under changing climatic conditions. The study confirms that such integrated and community-driven models can serve as scalable solutions for transforming rainfed agriculture in dryland regions. Government programs should prioritize millets as climate-resilient crops in rainfed regions through incentives, subsidies, and inclusion in public distribution systems. Support for community seed banks should be enhanced to ensure seed sovereignty, reduce input costs, and preserve indigenous germplasm. Expansion of Farmer Field Schools and participatory training programs is essential to improve farmers' technical knowledge and adoption of integrated farming practices. Establishment of dedicated markets, processing units, and branding strategies for millet-based products can improve profitability and demand. Policies should encourage crop-livestock integration and support small-scale enterprises such as mushroom cultivation and vermicomposting. Provision of credit facilities, insurance schemes, and infrastructure support (irrigation, storage, transport) is necessary for scaling integrated farming systems. Integration of climate-resilient practices into agricultural policies will help farmers adapt to climate variability and reduce environmental risks. Further research is needed to develop improved millet varieties, optimize integrated farming models, and assess long-term sustainability impacts.

References

1. Chambers, R. (1994) 'Participatory rural appraisal', World Development, 22(10), pp. 1437–1454.
2. Chang, S.T. and Miles, P.G. (2004) Mushrooms: Cultivation, Nutritional Value. CRC Press.
3. Creswell, J.W. (2014) Research Design. Sage Publications.
4. Devendra, C. (2000) 'Animal production and rainfed agriculture', Outlook on Agriculture, 29(3), pp. 161–175.
5. Edwards, C.A. et al. (2010) Vermiculture Technology. CRC Press.
6. Herrero, M. et al. (2010) 'Smart investments in sustainable food production', Science, 327, pp. 822–825.
7. ICAR (2020) Vision 2050 for Indian Agriculture.
8. Jayanthi, S. and Ilamurugu, K. (2018) 'Farming systems approach', Indian Journal of Agronomy, 63.
9. Kumar, G. and Chander, H. (2018) Integrated Farming Strategies. CSKHPKV.
10. Kumar, S. et al. (2019) 'Economic evaluation of farming systems', Agricultural Systems, 173.
11. Pontius, J. et al. (2002) Farmer Field School Approach. FAO.
12. Pretty, J. et al. (2011) 'Sustainable intensification', International Journal of Agricultural Sustainability

13. Singh, R. et al. (2018) 'Integrated farming systems', International Journal of Tropical Agriculture, 36.
14. Van den Berg, H. (2004) IPM Farmer Field Schools.
15. Vernooy, R. et al. (2015) Community Seed Banks. Routledge.