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Advancing women's empowerment through climate-resilient natural farming

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Abstract

This study aimed to examine how climate-resilient natural farming (NF) contributed to women's empowerment, farm profitability, and ecological sustainability, within the framework of gender-responsive agricultural extension in red and laterite zone of West Bengal. The research employed a narrative synthesis approach combined with an in-depth case study, integrating field-based insights with farm level economics data to document women empowerment alongside agro economic performance under NF systems. The study was conducted during 2021-25 in Bankura district of West Bengal and involved a detailed case study of a tribal woman farmer, Mrs. Gainamoni Murmu, from the Taldangra block. A comparative economic assessment of NF with conventional farming (CF) systems was conducted using season-wise data on cost of cultivation and net returns. The findings were triangulated with relevant empirical studies to ensure consistency with documented gender empowerment outcomes and agroecological performance trends. NF reduced cultivation costs by about 7-25% and increased net returns by 14-28% compared to CF, with the highest gains observed in diversified crop combinations and protected cultivation systems using on-farm bio inputs. Farm income records showed a consistent upward trend, reflecting improved profitability, reduced input dependence, and greater income stability. In parallel, women's empowerment outcomes improved markedly, with enhanced decision-making authority, control over farm income and leadership roles in SHGs/FPOs. The study demonstrates that NF, when supported by gender-responsive extension and institutional linkages, functions as both an environmentally regenerative and socially transformative pathway, advancing women's empowerment and contributing to Sustainable Development Goals (SDG 2, 5, 12, 13, 15) in resource-constrained regions.

Keywords: Women empowerment, natural farming, red and lateritic zone, Bankura, sustainable agriculture

1. Introduction

Women have historically formed the backbone of Indian agriculture, sustaining rural livelihoods through their roles in crop production, livestock care, seed preservation, and household food security. Yet their contributions remain under recognized due to ingrained land titling patterns, gendered norms, and limited access to institutional support and extension services (Panda *et al.*, 2025) ^[1]. Recent shifts in rural labour markets driven by male out-migration, mechanization, and diversification into non-farm sectors have further intensified the feminization of agriculture. Today, women constitute nearly two-fifths of India's agricultural workforce but continue to face restricted decision-making authority, asset ownership, and visibility in formal policy spaces (Menon, 2025) ^[2]. Their expanded responsibilities therefore coexist with structural constraints, reinforcing the need for gender-responsive agricultural strategies. Presently the challenges in chemical-driven conventional agriculture practices intersect with climate change, which is reflected in more erratic rainfall, prolonged dry spells, extreme temperatures (Lawson *et al.*, 2020) ^[3] have increased vulnerability of small and marginal farmers, particularly the farm women whose adaptive capacities are

limited. In this context, the transition toward organic and natural farming resonates not only as an agronomic alternative but as a socio ecological imperative aligned with India's commitments to the Sustainable Development Goals (SDGs), particularly SDG 2 (Zero Hunger), SDG 5 (Gender Equality), SDG 12 (Responsible Consumption and Production), SDG 13 (Climate Action), and SDG 15 (Life on Land).

Eastern India's red and lateritic zone typified by districts such as Bankura, West Bengal makes these transitions even more compelling. The region is characterized by inherently low nutrient availability, coarse-textured soils prone to erosion, and seasonal water stress (Mandal *et al.*, 2022) ^[4]. Under such conditions, natural and organic approaches emphasize soil regeneration through composting, mulching, on-farm bio-input production, mixed cropping, and biological pest regulation (Gamage *et al.*, 2023) ^[5]. These practices support ecological resilience by improving soil structure, enhancing moisture retention, increasing biodiversity, and reducing dependence on volatile agrochemical markets (Altenbuchner *et al.*, 2017) ^[6]. Organic and natural farming therefore offer pathways that resonate deeply with their aspirations for safe food,

household nutrition, secure livelihoods, and reduced health hazards, while also increasing their recognition as stewards of agroecological knowledge (Kiliç *et al.*, 2020) [7]. While gender-responsive extension reshapes local power dynamics through women participation, improving gender equity in farm productivity and addressing wage disparity in agrifood employment could potentially cut global food insecurity by around 2 percent (FAO 2023) [8].

In Bankura, these transformations are already visible. Supported by the local Krishi Vigyan Kendra (KVK), over 400 farmers have shifted away from chemical dependence, embracing community driven, low-cost natural farming practices. These initiatives not only help rehabilitate degraded soils and reduce input-related financial stress but also enhance local biodiversity and contribute to climate-resilient rural development. By empowering women farmers within these transitions, Bankura's emerging organic and natural farming movement illustrates how gender equity and ecological sustainability can reinforce each other laying the groundwork for more inclusive, resilient, and environmentally sound agricultural futures.

2. Methodology

This study follows a narrative synthesis approach combining: (i) secondary literature (peer-reviewed and grey) on women in agriculture, gender-sensitive extension, and organic/natural farming models; (ii) field derived documentation from WBCADC KVK Bankura, including the detailed case narrative of Mrs. Gainamoni Murmu (Pakurdiha, Taldangra); and (iii) comparative economic tables for natural farming (NF) versus conventional farming (CF) drawn from local KVK datasets.

2.1 Case study: Mrs. Gainamoni Murmu's journey in Bankura

This case study presents a ground-level account of how natural farming empowered a woman farmer in Bankura, illustrated through the journey of Mrs. Gainamoni Murmu from Pakurdiha village, Taldangra block. What began as a childhood familiarity with farming evolved into a passion-driven profession, transforming her from a conventional, chemical-dependent vegetable grower into a pioneer of natural farming and women's empowerment in her community. Health concerns, rising input costs, and exposure to Natural Farming concepts through the local Krishi Vigyan Kendra (KVK), Sonamukhi, became key turning points that reshaped her agricultural practices and

life trajectory. The participant was informed that all original records, interview notes, and supporting documentation have been stored securely and gave consent for publication.

2.2 The turning point: Embracing natural farming

During an awareness program conducted by WBCADC KVK Sonamukhi in 2021, Mrs. Murmu was introduced to the alarming effects of chemical pesticides and fertilizers on human health and the environment. This eye-opening experience, coupled with escalating production costs in her farm, inspired her to pivot toward Natural Farming as a solution. Determined to offer safe, chemical-free produce to her family and community, she took proactive steps to change her approach. She eagerly gathered knowledge, attended every training program available, and sought continuous technical support. Under the mentorship of the KVK scientists, she began transitioning her vegetable plots to a natural farming protocol. This approach allowed her to maintain crop quality, increase productivity, and eventually overcome the limitations of seasonal farming by improving soil resilience.

2.3 Building entrepreneurial strength

Despite limited formal education, Mrs. Murmu's keen observation, adaptability, and determination made her a natural agricultural innovator. Recognizing her potential, the KVK provided intensive hands-on training in Natural Farming, including bio-fertilizer and bio-pesticide preparation, vermicomposting, and the use of indigenous inputs such as *Beejamrit*, *Jeevamrit*, and botanical extracts such as *Neemastra*, *Brahmastra*, and *Agniastra* for pest management. Through continuous trainings, field demonstrations, and exposure visits, she quickly mastered these practices and further strengthened her enterprise by adopting protected cultivation techniques to improve yield and quality.

2.4 Natural farming in practice

By 2022, Mrs. Murmu had established a consistent NF routine that included treating all seeds with *Beejamrit* to enhance germination, applying *Jeevamrit* regularly to enrich soil microbial activity, and managing pests through homemade botanical formulations such as *Agniastra* and *Neemastra*. To address water scarcity, she adopted soil moisture conservation practices like wide spacing and heavy mulching based on the principle of *Vapasa*, which improved soil structure and reduced irrigation requirements.

Table 1: Season-wise major crop combinations under natural farming (NF) system (multi- cropping on the same land)

Particulars	Kharif (monsoon)	Rabi (winter)
Vegetables	Tomato + Beans + Cucumber	Cauliflower + Pea + Radish
Vegetables-Cereals	Tomato + Rice + Beans	—
Vegetables-Oilseeds	—	Cauliflower + Mustard + Fenugreek + Cabbage + Radish

Table 2: Season-wise major crop combinations under conventional farming (CF) system (prior monocropping approach)

Particulars	Kharif	Rabi
Vegetables	Tomato	Cauliflower
Vegetables-Cereals	Rice	—
Vegetables-Oilseeds	—	Mustard

Table 1 and Table 2 compare cropping patterns under NF and CF adopted by Gaynamoni Murmu, highlighting clear differences in system design. NF emphasized diversified and integrated cropping across Kharif and Rabi seasons, combining vegetables with cereals and oilseeds, often within the same plot. In contrast, CF showed a tendency toward monocropping. The NF approach, promoted by

KVK, enhanced crop diversity, system resilience, and efficient resource use.

3. Results and Discussion

3.1 Crops and economics under NF system

Diversification under NF (Table 1) enables better resource utilization (e.g., nutrients, water), pest control via crop rotation, weed suppression, and improved year-round productivity (Altenbuchner *et al.*, 2017) ^[6]. The shift toward diversified, mixed cropping under NF is proven to provide superior resource-use efficiency, economic stability, and environmental sustainability. The variety in cropping systems also enhances soil organic matter and ecosystem resilience, factors critical in the resource constrained red and lateritic soils typical of Bankura (Mandal *et al.*, 2022) ^[4]. Contrastingly, the CF system in Table 2 largely characterized by the cultivation of single crop per season (monocropping), with little integration of different crop groups on the same plot or across the year. Such monocropping can increase vulnerability to pests, diseases, erratic weather, and market fluctuations, and is associated with higher input costs, lower resource use efficiency, and diminished ecosystem services compared to diversified systems (Laishram *et al.*, 2022) ^[9].

Table 3 depicts economic outcomes from the Bankura case that indicate input cost reductions of ~7-25% across seasons and crop combinations as shown in, driven by substitution of purchased fertilizers/pesticides with on-farm bio-inputs

(Jeevamrit, Beejamrit, botanical extracts) and diversified intercropping (based on KVK Bankura case records). Net returns under NF exceeded those under CF by ~14-28% (Table 4), supported by the adoption of protected cultivation for high-value vegetables and staggered harvests (case data). These gains are consistent with studies of Farnworth and Hutchings, (2009) ^[10]. The case demonstrates notable empowerment outcomes, including improved decision-making in farming, greater control over income, and increased social leadership. While challenges such as pest spillover, water scarcity, labor demands, and market access persist, these reflect broader regional constraints faced by women farmers (Alvi *et al.*, 2021) ^[11]. Sustained KVK support, collective action through women-led self-help groups (SHGs) and FPOs, and local certification approaches like Participatory Guarantee System (PGS) helped mitigate these barriers, reinforcing agronomic, economic, and social benefits (Altenbuchner *et al.*, 2017) ^[6]. Overall, aligning agroecology with gender-responsive institutions generates a virtuous cycle in which agronomic, economic, and social benefits reinforce one another.

3.2 Financial turnaround: A comparative edge

Mrs. Murmu's shift to Natural Farming not only improved soil and crop health but also enhanced her income by significantly reducing input costs. A comparative analysis of her farm economics before and after adopting natural practices highlights these benefits (Table 3-4).

Table 3: Cost of cultivation of various crop combinations under NF and CF systems (Rs per hectare)

Crops Combination	Kharif NF cost	Kharif CF cost	NF vs CF (%)	Rabi NF cost	Rabi CF cost	NF vs CF (%)
Vegetables	59,056	78,516	-24.78%	54,785	63,000	-13.03%
Vegetables + Cereals	62,152	72,001	-13.67%	—	—	—
Vegetables + Oilseeds	—	—	—	55,500	59,550	-6.8%

*Negative percentages indicate cost reduction under NF relative to CF.

Table 4: Net returns of various crop combinations under NF and CF systems (profit per hectare, Rs)

Crops Combination	Kharif NF net return	Kharif CF net return	NF vs CF (%)	Rabi NF net return	Rabi CF net return	NF vs CF (%)
Vegetables	272,579	228,009	19.54%	56,815	45,037	26.15%
Vegetables + Cereals	255,858	224,214	14.11%	—	—	—
Vegetables + Oilseeds	—	—	—	29,846	23,229	28.48%

*Positive percentages indicate higher returns under NF relative to CF (Relative Economic Efficiency).

As evident from the farm records summarized above, all crop combinations achieved significantly lower cultivation costs and higher profits under Natural Farming compared to conventional practices. In Kharif season, the cost of cultivation under NF was 13.7-24.8% lower than under CF for the multi-crop systems, and in Rabi the cost reduction ranged from 6.8-13.0% (Table 3).

NF showed clear economic superiority over CF across crops and seasons. NF recorded higher net returns in pure vegetables during both Kharif (+19.5%) and Rabi (+26.2%). Diversified systems also favored NF, with higher returns in vegetables + cereals (+14.11%) during *kharif* and vegetables + oilseeds (+28.48%) during *rabi*. Overall, NF consistently delivered greater profitability by reducing costs while sustaining or improving yields. Overall, the results confirm that natural farming offers a clear profitability advantage by lowering costs while sustaining or increasing returns, consistent with findings of Laishram *et al.*, (2022) ^[9].

Furthermore, mixed cropping systems such as vegetables with cereals or oilseeds significantly enhance agronomic efficiency by promoting complementary nutrient uptake and internal nutrient cycling, conserving soil moisture through year-round ground cover that minimizes evaporation and enriches soil organic matter, and suppressing pests by disrupting their life cycles through greater biological diversity (Ratnadass *et al.*, 2012) ^[12]. Collectively, these ecological synergies markedly reduce dependence on external inputs by relying on farm-derived biological preparations, thereby lowering overall cultivation costs while sustaining, and often enhancing, system-level productivity (Walker *et al.*, 2025) ^[13]. By practicing mixed cropping and utilizing every part of the growing season, Mrs. Murmu made more efficient use of her farm area than with solo crops, thereby boosting overall net profit and also increasing the variety of produce available throughout the year.

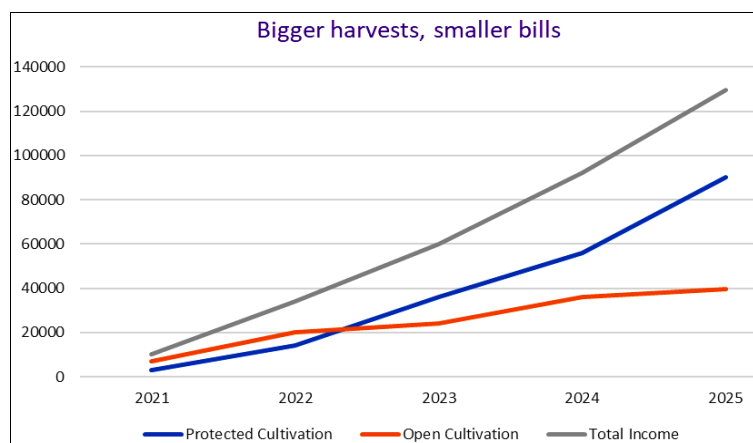


Fig 1: Graphical representation of annual farm income

The line graph (Fig. 1) illustrates the annual farm income of Mrs. Gainamoni Murmu over a five-year period (2021-2025), comparing earnings from protected cultivation, open field cultivation, and the resulting total farm income under NF practices. The data show a consistent upward trajectory, that reflects the increasing contribution of protected cultivation, whose income curve rises more sharply than that of open cultivation. While open cultivation shows gradual and moderate improvement, protected cultivation demonstrated accelerated gains, particularly from 2023 onward, indicating higher productivity, better crop quality, and improved market returns under controlled conditions. The rapid increase in the total income line further confirms that as Mrs. Murmu expanded her protected cultivation area and refined her regenerative farming techniques, her farm became more economically resilient and profitable. Overall, the graph underscores how the integration of natural farming with protected cultivation can transform smallholder farming economics showing enhanced income stability and substantial year-on-year financial growth.

The steady increase in income was driven by multiple reinforcing factors. Protected cultivation enabled off-season production of high-value crops that fetched premium prices, while the use of on-farm bio-inputs significantly reduced production costs. Diversified intercropping further optimized land use, ensured staggered harvests, and minimized risk. Together, these strategies led to higher, more stable net returns each year.

These trends are consistent with findings from other smallholder organic farming contexts, where low-external-input practices improve cost efficiency and stabilize or enhance farm incomes (Sithole and Olorunfemi, 2024) ^[14]. In Mrs. Murmu's case, NF generated approximately 20-30% higher net returns compared to conventional practices, reinforced by continuous KVK mentoring and collective marketing through women-led SHGs/FPOs. Such institutional support and group-based enterprises are widely recognized as critical for sustaining income gains and economic resilience among women smallholders.

Beyond the numbers, Mrs. Murmu has fundamentally changed her farming economics by becoming self-reliant in inputs. She now prepares all her bio-inputs on-farm (from compost to plant extracts), further reducing recurring costs. The only external purchases she makes are basic ingredients like jaggery and gram flour for brewing preparations like

Jeevamrit. Thus, the NF model has insulated her from volatile agrochemical prices and debt cycles, while improving her soil's fertility for long-term productivity. In subsequent years, as Mrs. Murmu expanded into protected cultivation (using low-cost polyhouses for nursery raising and off-season vegetables), her annual farm income showed a steady upward trend. By focusing on high-value crops such as bell pepper, seedless cucumber, tomato, cauliflower, and peas under organic management in these protected structures, she further enhanced her profitability while maintaining soil health. These high-value produce fetch premium prices (Heinrichs *et al.*, 2021) ^[15] and are less prone to weather shocks, contributing to a more resilient income stream.

3.3 Challenges and overcoming with innovation and grit

Mrs. Gainamoni Murmu faced early challenges in adopting NF due to pest pressure, water scarcity, and social skepticism. With support from KVK experts, she standardized practices, conserved moisture through Vapasa based methods, and improved soil health. Despite marketing difficulties from her remote location, she gradually built direct consumer links and accessed niche markets for chemical-free produce.

3.4 Rise as a leader and trainer

Today, Mrs. Gainamoni Murmu has emerged as a rural leader and trainer, serving as the Director of the women-led Haridhan Farmer Producer Company Limited in Taldangra and actively mentoring farmers across the district. Her farm has become a model learning site, attracting farmers, agricultural students, interns, and extension officials interested in practical exposure to Natural Farming. As a certified KVK Master Trainer, she conducts hands-on trainings and demonstrations on her own farm, inspiring confidence and encouraging widespread adoption of chemical-free farming through her proven success and relatable teaching style.

3.5 Lessons for aspiring agri-entrepreneurs

Mrs. Murmu's journey exemplifies the transformative potential of sustainable agricultural practices and community-based rural entrepreneurship. Her experience highlights the power of sustainable and regenerative farming practices in enhancing crop resilience and improving

profitability through reduced dependence on external inputs. Her journey demonstrates that formal education is not a prerequisite for success in agripreneurship; instead, experiential learning, innovation, and strong leadership particularly among women can catalyze meaningful rural transformation. The integration of protected cultivation technologies further illustrates the potential for income diversification and year-round production for small and marginal farmers. Crucially, her sustained collaboration with institutions such as Krishi Vigyan Kendras underscores the importance of scientific extension, collective action, and women-led producer organizations in building scalable and inclusive agricultural enterprises.

4. Conclusion

The experience of NF in Bankura's red and lateritic zone illustrated how ecological regeneration, institutional support, and women's leadership can jointly drive sustainable rural development. Mrs. Gainamoni Murmu's journey reflects reduced input costs, stable incomes and enhanced women's decision-making and leadership at the community level. Her farm has evolved into a living classroom and symbol of resilience, demonstrating the power of blending traditional wisdom with scientific guidance. Scaling such models will require strong policy support, gender-responsive extension, collective marketing, and improved rural infrastructure, positioning women at the forefront of agroecological transformation for a more sustainable future.

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Declaration of conflict of Interest

The authors declare that they have no known conflicts of interest regarding the publication of this manuscript.

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