



RESEARCH ARTICLE

Empowering Bonda tribal communities: Participatory networks for climate-resilient agriculture

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Abstract

The traditional farming methods used by the Bonda tribe, a particularly vulnerable tribal group (PVTG), residing in Odisha, are closely linked to ecological balance and cultural identity. However, the resilience of these practices is being undermined by climate change. This study, which adopted community-led approaches to enhance resilience, included 270 participants from 3 ecological areas of the Bonda Hills and used a sequential exploratory mixed-methods design. Six interconnected themes emerged from surveys, focus groups, key informant interviews and participatory rural appraisal (PRA) tools: reviving traditional farming methods, encouraging climate-resilient mixed farming, enhancing infrastructure and market accessibility, decentralising agricultural support, advancing inclusive agriculture and nutrition and fortifying organisational and financial ties. The results showed the incorporation of both indigenous and new knowledge to develop collaborative and culturally appropriate solutions. A comprehensive framework was provided to ensure that the recommendations, including improved market connections, local extension services and millet-based polycropping, align with Bonda priorities as well as those of other PVTGs.

Keywords: agroecology; Bonda; climate; participatory approaches; resilience

Introduction

The Bonda tribe, one of the particularly vulnerable tribal groups (PVTGs) of India, resides in the remote hilly terrains of the Malkangiri district in Odisha (1). Their agricultural practices are deeply embedded in their cultural, spiritual and ecological worldview, representing a harmonious relationship between people and nature (2, 3). For the Bonda, agriculture is not merely an economic pursuit but an integral part of their identity, tradition and survival strategy (4). Traditional systems such as *Dangar Chas* (shifting cultivation), millet-based polycropping and terrace farming have evolved over centuries, finely tuned to the climatic patterns and ecological characteristics of the Bonda Hills (5–8). These methods are based on an intricate understanding of soils, water availability, seed diversity and biodiversity conservation, enabling them to sustain their livelihoods in challenging environmental conditions (9, 10).

Over generations, these indigenous farming systems have demonstrated remarkable resilience to climatic uncertainties, ensuring both food security and ecological stability (4, 11). However, in recent decades, the resilience of Bonda agriculture has been increasingly challenged (4). Climate variability, characterised by erratic rainfall patterns, rising temperatures and shifting seasonal cycles, has disrupted cropping calendars and reduced yields (12). Ecological degradation, including soil erosion and declining soil fertility, has been

exacerbated by shorter fallow cycles and reduced access to traditional cultivation areas (13). At the same time, market exclusion, insecure land tenure and weak institutional support have marginalised the Bonda, limiting their ability to adapt effectively to new challenges (4).

In addition to environmental pressures, socio-economic and policy-related factors have intensified the vulnerability of Bonda agriculture (10). The gradual erosion of intergenerational knowledge transfer threatens the continuity of indigenous farming wisdom, as younger generations migrate in search of alternative livelihoods (2, 14). Policy frameworks often remain disconnected from the cultural realities and needs of PVTG communities, focusing instead on standardised development models that may not align with local priorities (15). This dual marginalisation—ecological and institutional—risks displacing traditional farming practices that have sustained the Bonda for centuries and threatens the cultural and ecological integrity of their homeland (16).

Against this backdrop, the present study seeks to explore community-driven strategies for enhancing climate resilience in Bonda tribal farming practices. The primary objective is to identify and articulate sustainable agricultural approaches that align with the Bonda worldview, respect their resource systems and address the emerging challenges of climate change and socio-economic transformation. The study also aims to provide policy and practice

recommendations grounded in local realities, ensuring that interventions are not externally imposed but rather co-created with the community. By focusing on people's participation and culturally sensitive strategies, the research emphasises the need for approaches that uphold agricultural dignity, strengthen food sovereignty and foster ecological harmony, offering a model that may inform sustainable tribal agriculture in other PVTG contexts as well.

Materials and Methods

The study employed a sequential exploratory mixed-method design to investigate community-driven strategies for enhancing climate resilience in Bonda tribal farming practices. A purposive sampling technique was adopted to ensure adequate representation of the ecological and cultural diversity across the Bonda Hills in Khairaput block, Malkangiri district, Odisha. The research was conducted in 3 representative hamlets, Kadamguda (Lower Bonda Hill), Badbel (Middle Bonda Hill) and Andrahal (Upper Bonda Hill), with 90 respondents from each, resulting in a total of 270 participants drawn from diverse age groups, genders and socio-economic backgrounds. Data collection combined survey-based and participatory approaches to capture both qualitative and quantitative dimensions of the research objectives. Structured interview schedules were administered to gather information on socio-economic, demographic and food security indicators. Participatory rural appraisal (PRA) tools such as social maps, resource maps, seasonal calendars and transect walks were employed to document land use patterns, cropping cycles and resource availability. Focus group discussions (FGDs) and key informant interviews (KIIs) were held with elderly farmers, women seed custodians and village leaders to document intergenerational agricultural knowledge, traditional climate adaptation practices and community priorities for agricultural development. Throughout the fieldwork, observation notes and field diaries were maintained to capture contextual details, behavioural nuances and lived farming experiences. For deriving policy and practice recommendations, a synthesis-based analytical approach was applied. This involved integrating thematic findings from qualitative analysis with descriptive statistics from quantitative data, enabling a triangulated interpretation of evidence. Atlas.ti software was used for thematic designs. Traditional wisdom, agroecological practices and food sovereignty perspectives emerging from the community were juxtaposed with empirical determinants of food security to identify viable strategies for enhancing resilience. A comparative literature review was also conducted, drawing on national and global studies on agroecology, indigenous farming systems and tribal resilience, while referencing policy frameworks such as the FAO's Indigenous Peoples Policy, the National Agroecology Framework of India and the United Nations Sustainable Development Goals (SDGs). This triangulation ensured that the recommendations generated were context-sensitive, scientifically grounded and reflective of the Bonda community's aspirations, thereby enhancing their relevance for both local-level interventions and broader policy frameworks.

Results

The Bonda community follows diversified cultivation practices that include the cultivation of finger millet, foxtail millet, barnyard millet, proso millet and pearl millet to reduce the risks associated with

unpredictable rainfall patterns (17). The cultivation of upland paddy, which can withstand drought conditions along with the incorporation of various legumes in these systems, ensures the continuous availability of food in the community (18). These diversified practices can be considered a natural protective mechanism to prevent soil erosion in the sloping topography of the hills. They also ensure internal nutrient cycling through the retention of biomass (18). In addition to this, the spatial arrangement of land follows mixed cropping patterns prevalent in other Eastern Ghats communities. These practices effectively control pest infestations while ensuring the stability of crop yields under increasingly unpredictable thermal conditions (18). Traditional agroecological systems are further enhanced through the careful preservation of seeds, focusing on the selection of climate-resilient crop landraces (19). The preservation of indigenous seed varieties, along with the use of organic fertilisers, helps maintain a high level of agro-biodiversity, which is of primary importance to the tribe's adaptive capacity (18). Besides crop management, the tribe employs indigenous water-harvesting techniques such as contour trenching and mini-irrigation systems in forests to preserve moisture during long spells of dry weather. These moisture-preservation practices are complemented by shifting cultivation, which allows for extended fallow periods and promotes forest regrowth in the rugged Malkangiri region. They are also supplemented by the use of wild forest products as nutritional buffers during lean periods or extreme meteorological events (19). Therefore, the integration of these practices is essential.

Reviving traditional agroecological practices

The thematic network sociogram (Fig. 1) illustrates how community sentiment connects to four core recommendations: (i) recognition and documentation of cropping systems such as *Dangar Chas* and *Kemagi Mandia* within agroecology and biodiversity frameworks; (ii) promotion of community-led seed festivals and indigenous ecological knowledge documentation; (iii) revival of traditional agroecological practices; and (iv) integration of traditional crops, including *black suan*, *kangu* and *bada suan* into agricultural training and extension programmes.

Responses from all three demographic clusters—elders, women farmers and youth/community leaders—showed consistent endorsement of these measures. Elders emphasised safeguarding indigenous knowledge, women farmers highlighted their roles in seed management and food diversity and youth stressed opportunities for integrating traditional crops into training and policy initiatives. The network structure demonstrates multiple linkages between participant groups and recommendation nodes, signifying a distributed consensus rather than a top-down directive.

Climate-resilient and mixed farming systems

The theme of climate-resilient and mixed farming systems was anchored in community sentiment, prompting the need for adaptive strategies. The network sociogram (Fig. 2) demonstrates linkages between this sentiment and practical interventions, including intercropping of millets, legumes and tubers; installation of community rain gauges and climate boards informed by indigenous indicators; and training local youth in agroecological monitoring and seasonal forecasting. Elders, women farmers and youth leaders all expressed strong, overlapping support for these measures, underscoring the necessity of diversified, adaptive farming systems in the face of climate variability.

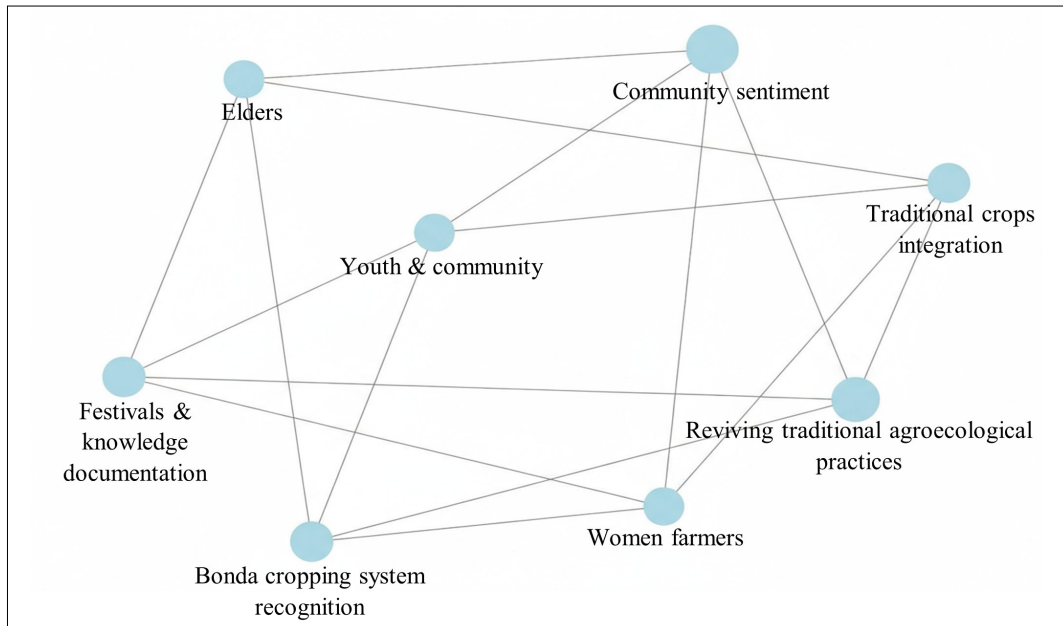


Fig. 1. Network sociogram of Bonda community on reviving traditional agroecological practices.

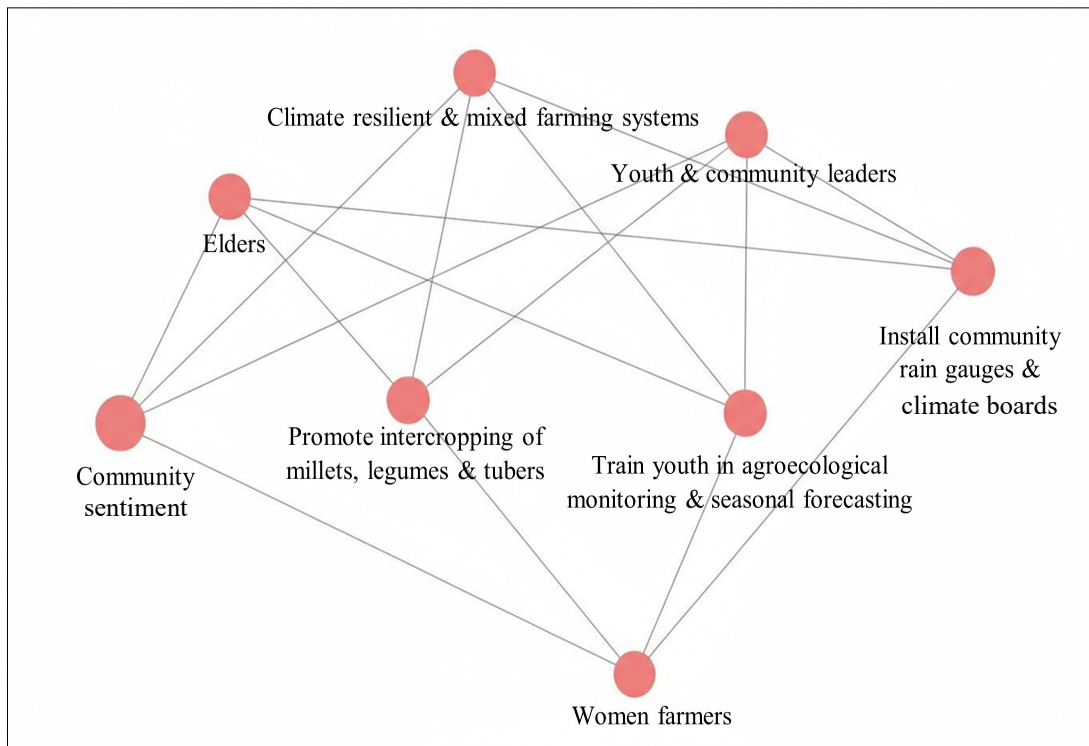


Fig. 2. Climate-resilient and mixed farming systems.

Infrastructure and market access improvement

The sociogram for infrastructure and market access (Fig. 3) reflects the community's frustration. Key recommendations include road construction linking remote hamlets to market hubs, establishment of cold storage and threshing floors and direct procurement of tribal crops under schemes such as Minimum Support Price (MSP) for millets. Across all clusters, there was agreement that improved infrastructure would directly enhance income stability, reduce post-harvest losses and reconnect farmers with abandoned farmlands.

Decentralised agricultural extension and training

Participants articulated the need for agricultural extension systems that are linguistically accessible and culturally resonant. The network sociogram (Fig. 4) links this sentiment with recommendations such as training Bonda youth as para-extension workers, creating

community knowledge hubs with visual and oral learning tools and facilitating seasonal exposure visits. Elders valued oral traditions, women farmers sought accessible and time-sensitive training and youth expressed readiness to serve as cultural and agroecological knowledge facilitators.

Gender-inclusive agriculture and nutrition

The gender-inclusive agriculture and nutrition theme (Fig. 5) centres on the recognition that women, while central to seed storage, cooking and food preservation, are often excluded from decision-making forums. Recommendations include recognising women's agricultural roles through leadership opportunities, providing joint land rights under the Forest Rights Act and promoting kitchen gardens and nutrition literacy via self-help groups (SHGs) and integrated child development services (ICDS) interventions. All clusters supported these reforms, emphasising structural inclusion,

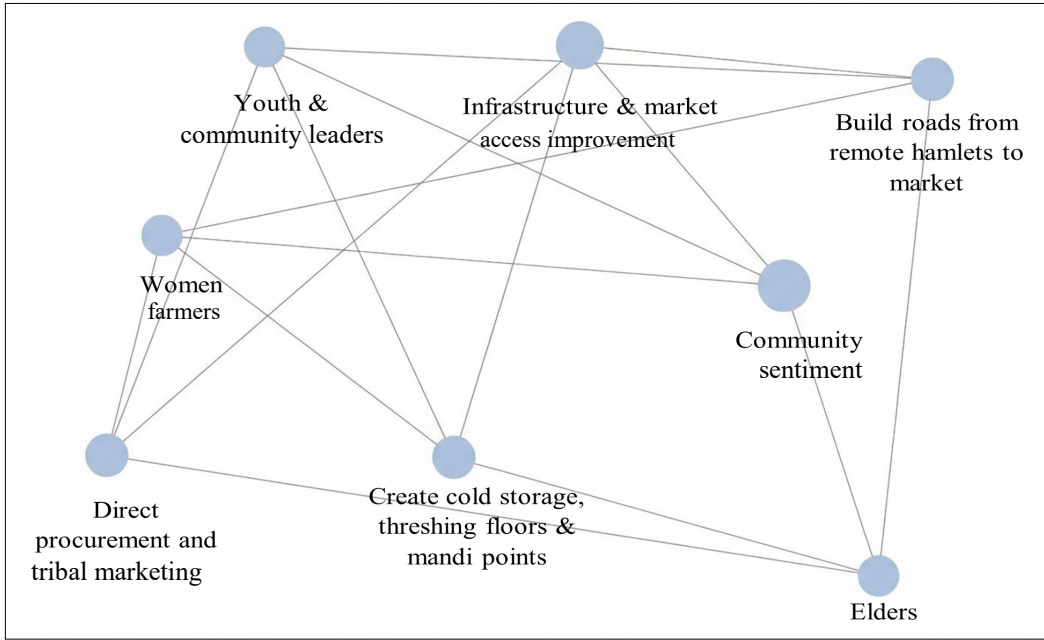


Fig. 3. Infrastructure and market access improvement.

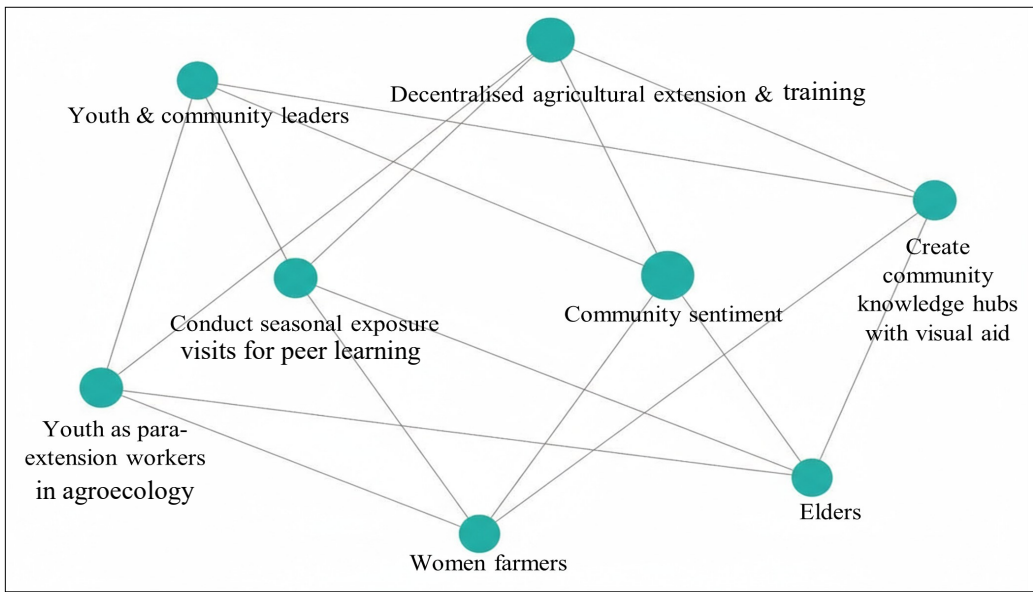


Fig. 4. Decentralised agricultural extension and training.

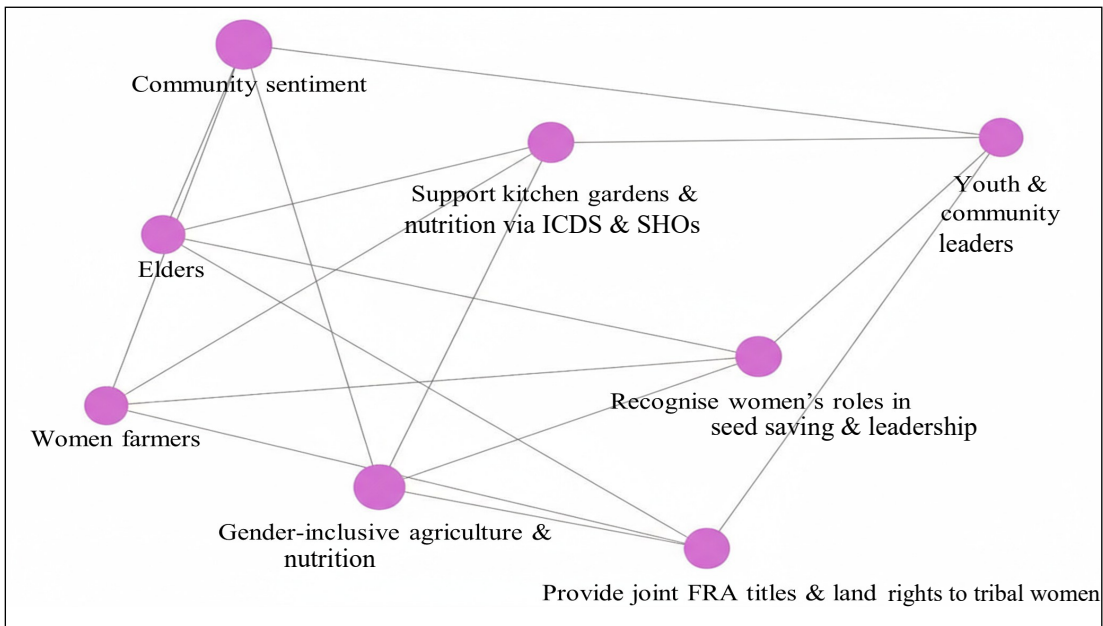


Fig. 5. Gender-inclusive agriculture and nutrition.

rights recognition and improved household nutrition.

Financial and institutional linkage strengthening

The final thematic sociogram (Fig. 6) reflects mistrust towards formal credit systems and reliance on informal moneylenders. Recommendations focused on simplifying access to crop insurance and tribal credit, training SHGs in financial literacy and agro-based entrepreneurship and promoting tribal-specific Farmer-Producer Organisations (FPOs) with sustained mentorship. Elders, women and youth each supported strategies to bridge financial gaps, reduce dependence on predatory lending and strengthen institutional linkages for economic resilience.

Community sentiments

The study revealed a strong, community-wide consensus among the 270 Bonda respondents on the urgent need to revive and sustain traditional agroecological systems, which are deeply tied to their cultural identity and ecological sustainability. The shared sentiment, “*We trust our old ways. Mandia and suan have fed us for generations. We need support to preserve them, not replace them*”, reflects a collective determination to safeguard heritage crops and farming techniques. Three core recommendations emerged from the discussions: the recognition and documentation of systems such as *Dangar Chas* and *Kemaaji Mandia* within agroecology and biodiversity frameworks; the promotion of community-led seed festivals and indigenous ecological knowledge documentation; and the integration of heritage crops, including *blacksuan*, *kangu* and *bada suan*, into agricultural training and extension programmes. Elders emphasised preserving indigenous wisdom, women highlighted their role in seed preservation and food diversity and youth sought opportunities to embed these traditions within policy and capacity-building initiatives. The sociogram analysis confirmed that this consensus emerged organically across demographic groups, indicating a bottom-up approach rather than externally imposed directives.

Climate variability has disrupted traditional cropping patterns, prompting adaptive responses under the theme of climate-resilient and mixed farming systems. The unifying sentiment, “*rain does not follow the old rhythm*”, underscores awareness of shifting seasonal patterns. Practical interventions proposed by the community included intercropping of millets, legumes and tubers to improve soil fertility and yield stability; installation of community rain

gauges and climate boards blending scientific and indigenous indicators; and training local youth in agroecological monitoring and seasonal forecasting. Elders contributed time-tested climate indicators, women stressed crop diversification for household food security and youth demonstrated readiness to acquire technical skills for environmental monitoring. The consistency of support across age and gender groups reflects the community’s openness to hybrid knowledge systems that merge tradition with innovation.

Market isolation and poor infrastructure emerged as critical bottlenecks. The sentiment, “*even when our crops grow well, they rot or get low prices because we cannot carry them*”, captured the community’s frustration with inadequate transport and storage facilities. Recommended measures included road construction to connect remote hamlets with market hubs, the establishment of cold storage and community threshing floors to minimise post-harvest losses and direct procurement of tribal crops through schemes such as MSP for millets. Participants agreed that improved infrastructure could stabilise income, reclaim abandoned farmland and enhance the viability of cultivation. Women linked better storage facilities with improved household nutrition, while youth emphasised the potential for market-linked entrepreneurship.

Agricultural extension services were widely perceived as inaccessible and culturally disconnected. The prevailing sentiment, “*we need our own people to teach us*”, translated into a preference for decentralised, locally led extension models. Recommendations included training Bonda youth as para-extension workers, establishing community knowledge hubs using oral narratives, visual tools and demonstration plots and organising seasonal exposure visits for peer learning. Elders valued oral and experiential learning methods, women preferred flexible and time-efficient training formats and youth expressed enthusiasm for becoming cultural and agroecological knowledge facilitators.

Gender inequality was another prominent theme. While women play a central role in seed storage, cooking and food preservation, they remain excluded from most decision-making forums. Recommendations to address this imbalance included granting women leadership opportunities, ensuring joint land rights under the Forest Rights Act and promoting kitchen gardens alongside nutrition literacy through SHGs and ICDS. Elders supported recognising women’s contributions to agricultural heritage, women themselves sought structural inclusion and youth viewed gender

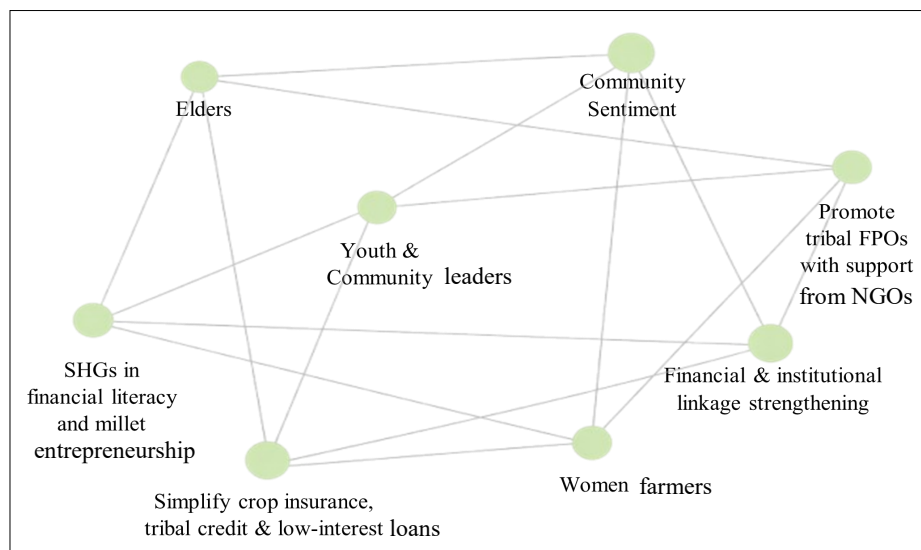


Fig. 6. Financial and institutional linkage strengthening.

equality as essential to household and community resilience.

The study found that financial exclusion severely limits agricultural resilience. Mistrust of formal credit systems has driven reliance on informal moneylenders, increasing vulnerability to debt cycles. The community recommended simplifying access to crop insurance and tribal-specific credit schemes, training SHGs in financial literacy and agro-based entrepreneurship and establishing FPOs tailored to tribal needs with sustained mentorship. All these can be achieved through decentralised extension, as decentralisation promotes socio-economic development and through the formation of village-level organisations, which also amplify farmer-led innovations (20–22). Women highlighted the need for credit to expand small-scale processing and kitchen gardening, youth saw opportunities for agro-enterprise development and elders connected financial stability with the preservation of farming traditions.

Discussion

The participatory findings revealed that the Bonda community can clearly articulate strategies for sustainable and climate-resilient agriculture when engaged through inclusive dialogue. The six themes reflect both a deep cultural attachment to traditional agroecological systems and a practical understanding of current challenges. Central to the recommendations is the revival of millet-based polycropping, shifting cultivation (*Dangar Chas*) and seed preservation practices, viewed as essential for food sovereignty, ecological resilience and cultural continuity, as millet retains higher nutrient content and are easily adaptable. This aligns with global evidence that protecting crop genetic diversity and traditional farming systems enhances adaptive capacity in the face of climate change (23). Preserving heritage crops such as *Mandia* and *suau* also safeguards intergenerational knowledge and a worldview in which agriculture is closely tied to ritual and identity.

The call for diversified, climate-resilient mixed farming systems, supported by indigenous and scientific weather forecasting, demonstrates readiness to integrate hybrid knowledge systems for risk management. Training youth in agroecological monitoring indicates a proactive approach to preparing future generations for climatic uncertainty. Infrastructural and market constraints remain major barriers, with poor road connectivity, limited storage and a lack of procurement channels restricting the ability to secure fair returns from production. The prioritisation of roads, cold storage and local procurement hubs directly addresses these bottlenecks and aligns with integrated rural development needs. The importance of road connectivity and the need for cold storage with procurement chains have been highlighted (24, 25).

Conventional agricultural extension systems have little impact to effectively engaging the Bonda, leading to strong support for decentralised, culturally grounded training led by local para-extension workers and delivered through oral traditions, visual tools and peer learning networks. Gender inequality remains a significant concern, as women contribute substantially to seed saving, food preparation and household nutrition but are excluded from decision-making. The demand for joint land titles, leadership roles and nutrition initiatives reflects the link between gender equity and agricultural sustainability.

Financial exclusion is another constraint. Mistrust of formal institutions and bureaucratic barriers pushes farmers towards

informal moneylenders. Simplifying credit access, strengthening SHGs and forming tribal-specific FPOs were identified as key solutions. Similar approaches in other indigenous contexts have improved financial inclusion and bargaining power (26).

The six themes highlight that sustainable tribal agriculture cannot be achieved through isolated interventions. A holistic strategy integrating indigenous knowledge revival, climate adaptation, infrastructure, localised extension, gender empowerment and financial inclusion is essential. The participatory approach ensured that the recommendations were co-created, grounded in lived experience and aligned with the community's long-term vision. The need for participatory approaches for sustainable agricultural development was also identified (27). The integration of local wisdom into development efforts and indigenous knowledge systems into sustainable practices are necessary for these livelihoods (28, 29). These findings align with the FAO's Indigenous Peoples Policy and the United Nations SDGs, particularly those on zero hunger, gender equality and climate action, as these organisations clearly emphasise the recognition of the rights of indigenous people, support for gender equity and the building of strong, sustainable and inclusive food systems that leave no one behind (30). The thematic framework developed here offers guidance for policy and practice not only for the Bonda but also for other PVTGs in India and globally.

Conclusion

The Bonda community holds a clear, coherent vision for sustaining their agriculture and livelihoods when engaged through participatory approaches. The six interlinked themes—reviving traditional agroecological practices, promoting climate-resilient mixed farming, improving infrastructure and market access, decentralising extension, advancing gender inclusion and strengthening financial linkages—reflect both cultural priorities and practical strategies for resilience. These recommendations highlight the importance of integrating indigenous knowledge with adaptive innovations. Sustainable agricultural transformation for the Bonda requires a holistic, multi-actor framework embedded in cultural and ecological realities. It can be suggested that by decentralising these locally grounded priorities through ground-level organisations within practice and aligning them with policy, development efforts can enhance food security, strengthen climate resilience and protect cultural heritage, thereby securing future generations. The participatory framework of six different and interlinked themes applied here offers a transferable model for other PVTGs across India and beyond, providing a huge scope for implementing regenerative agriculture strategies and assessing their impacts.

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Authors' contributions

DSR participated in sequence alignment, conceived the study and drafted the manuscript. AD participated in the study design and

performed the statistical analysis. PB contributed to the discussion of the results. AN participated in figure preparation and coordination. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used Grammarly to check for grammatical errors. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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