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Charting cooperative pathways to net zero through the IFFDC agroforestry model

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Received: 31 December 2024 / Accepted: 22 December 2025
Published online: 27 December 2025

Abstract
Member-owned and democratically controlled collective enterprises have enormous abilities to advance community-driven sustainable practices. These collectives, through adoption of innovative approaches, can integrate cooperative values with environmental goals and can align and direct their activities towards attaining the goal of net-zero emissions. This paper uses a mixed-method and exploratory case study design to investigate the role of a VERRA certified cooperative institution—the Indian Farm-Forestry Development Cooperative (IFFDC) in low-carbon development and rural livelihood enhancement. The IFFDC's initial pilot project (2008–2013) covered 189 hectares and generated 78,000 Verified Carbon Standard (VCS) credits, of which 41,000 were sold internationally, yielding INR 67.2 million. A tri-party revenue-sharing agreement allocated INR 30 million to 120 landholding farmers (average INR 250,000 per farmer), INR 15 million to 11 forestry cooperatives (average INR 1.36 million per cooperative), and INR 22.2 million was retained by IFFDC to meet operational expenses and support future initiatives. Reinvestment supported new plantations, cooperative capacity building, and maintenance, ensuring long-term ecological and financial sustainability. The project contributed to eight Sustainable Development Goals (SDGs), SDG 1, 3, 5, 8, 10, 13, 15 and 17. Key success factors included participatory governance, structured revenue-sharing, and robust Measurement, Reporting, and Verification (MRV) practices. The study demonstrates that cooperative-led carbon farming can achieve environmental, economic, and social objectives simultaneously, offering a scalable, community-centric model for low-carbon development.

Keywords Cooperatives · Net-zero emission · SDG · IFFDC · Carbon farming · Carbon credits · Agro-forestry

1 Introduction

Climate change remains a pressing challenge with its far-reaching implications on environment, economies, and societies. Long-term climate change effects are a global menace to food security, biodiversity, and public health [1]. These challenges call for integrated and universal adaptation of mitigation strategies that combine technological innovation, sound policies, institutional frameworks, and international cooperation [2, 35]. Extreme variations in temperature, rainfall, and soil quality are impacting agricultural productivity [5], prompting the pursuit for resilient, low-carbon solutions [34].

FAO [18] emphasizes that Agriculture, Forestry, and Other Land Use (AFOLU) sectors, which contribute 13–21% of global emissions, offer substantial carbon sequestration potential through agroforestry, soil management, and conservation agriculture. Agroforestry has gained attention as a viable pathway that integrates trees with farming

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systems to provide ecological and economic benefits, including carbon sequestration, biodiversity enhancement, soil improvement, and diversified farmer incomes [15, 27, 29–31, 33, 41] particularly when ecosystem services like carbon credits are monetized [48]. Chaiya [11] examined the role of community forests in greenhouse gas emissions trading and climate resilience and highlighted the importance of local participation and climate risk management in promoting sustainable environmental development. Rao et al. [40] explores the role of carbon farming in advancing Sustainable Development Goals (SDGs) in India and highlights various strategies viz. soil carbon enhancement, agroforestry, and cover cropping to mitigate climate change, improve agricultural sustainability, and enhance farmers' livelihoods.

Carbon farming encompasses two distinct but complementary approaches: active sequestration and emission reduction. Active sequestration involves capturing and storing atmospheric carbon dioxide in soil and biomass, particularly through agroforestry and soil carbon storage [4, 46]. Emission reduction, on the other hand, focuses on minimizing greenhouse gas emissions at the source through techniques such as reduced fertiliser application, conservation tillage, and sustainable water management [36], the measures vary as per type of sector/activities. These strategies collectively contribute to lowering the overall carbon footprint of agricultural systems, making them integral to achieving net-zero targets. Climate-smart agriculture, including agro-forestry systems, can significantly mitigate adverse impacts of climate change on agriculture [43] by lowering CO_2 emissions and strengthening carbon sinks [14] as these are potent enough to aid in the adaptation and mitigation processes.

At the 26th session (November, 2021) of the United Nations Framework Convention on Climate Change (COP 26), India announced to achieve its net zero target by 2070. Its long-term low-carbon development strategy is based on the principles of equity and climate justice and the principle of common but differentiated responsibilities and respective capabilities [32]. Post-1997 Kyoto Protocol witnessed carbon commodification to combat climate change impacts through established carbon credit trading frameworks. India commits to create an additional carbon sink of 2.5 to 3 billion tons of CO_2 equivalent through additional forest and tree cover by 2030 [45]. Sustainable development demands reduction of greenhouse gas emissions and transition to a low-carbon economy. This transition requires innovative solutions to balance environmental goals with socio-economic development, particularly in vulnerable regions where livelihoods depend intensely on natural resources. Carbon farming strategies reduce greenhouse gas emissions by sequestering atmospheric carbon dioxide in soil and biomass [42].

Despite this promise, there remain gaps in research on how cooperatives engaged in agroforestry structure their governance, business models, and carbon credit mechanisms. Most existing work emphasises ecological performance or livelihood benefits but rarely examines the integration of governance, financial sustainability, and carbon credit lifecycles within cooperative frameworks.

A notable exception is the Indian Farm Forestry Development Cooperative (IFFDC), one of India's largest cooperatives in the agroforestry sector, established in 1993 under the aegis of the Indian Farmers Fertiliser Cooperative Limited (IFFCO), the National Level Cooperative Society engaging in the fertilizer production and distribution. IFFDC is a prime example of how cooperatives can use agro-forestry to effectively reduce the effects of climate change. It aims at enhancing the quality of life in rural areas via sustainable forestry and agriculture and has a strategy to combine environmental care with socio-economic development. Despite the growing recognition of carbon farming and agroforestry as climate mitigation strategies, there remains a significant knowledge gap regarding the role of collectives in facilitating these approaches.

This paper addresses that gap by analysing IFFDC as a case study of cooperative-led agroforestry for low-carbon development. The objectives of the study are to:

- analyse the organizational structure, governance, management, business model, and financial performance of IFFDC;
- assess the implementation and outcomes of IFFDC's agroforestry and carbon credit generation initiatives;
- identify the challenges, weaknesses, and operational constraints faced by IFFDC in project execution, governance, and carbon credit mechanisms; and
- derive lessons and recommendations for scaling cooperative-led agroforestry and carbon farming in similar contexts.

This paper is divided into six sections. Section 2 provides a review of existing literature examining the promises of the cooperative approach . Section 3 outlines research methodology, including data collection methods. Section 4 presents the case study of the IFFDC, delineating its governance, management, business model, financial performance, carbon credit generation and its impactful role towards SDGs. Section 5 presents analytical discussion through SWOT analysis of the IFFDC model and reflects on comparative insights. Section 6 offers concluding remarks with policy recommendations.

2 Promises of the cooperative approach

Empirical studies show that community-based, locally tailored initiatives, when designed with community participation and local knowledge, deliver sustainable development outcomes across environmental, social and economic dimensions [10, 16]. Sector-specific research confirms that community-driven interventions can achieve measurable SDG targets when interventions are aligned with local needs and capacities [52]. The cooperative and community-based models contribute directly to SDGs because they embed development in members' goals and local priorities [9, 23]. The ICA [22] statement on cooperative identity, which includes the cooperative definition, values and principles, stresses sustainability as a core aspect, particularly, through democratic governance, concern for community, and member education. Together, these perspectives position cooperatives as key instruments for inclusive, people-centered, and sustainable development.

Cooperatives and producers' organisations are member-owned and member-controlled entities. Their collective nature helps smallholders to access to finance, technology, market, technical inputs and knowledge, enhances scale production, and bargaining power [21, 54]. Beyond purely economic or environmental benefits, cooperative models have the potential to deliver social co-benefits: more equitable distribution of project benefits, shared decision-making, and stronger community resilience [12, 28]. Savari et al. [44] highlighted key dimensions of sustainability assessment of cooperatives, including governance, economic viability, social inclusion, and environmental responsibility, enabling them to identify strengths, address gaps, and enhance long-term sustainability.

Cooperatives help farmers' access resources, share knowledge, and implement sustainable practices such as agroforestry and conservation agriculture, enhancing productivity, resilience, and the overall effectiveness of climate-smart agriculture interventions [17]. In India, the Agroforestry models has not only improved farm productivity and income but also delivered environmental gains such as improved soil quality, biodiversity conservation, and carbon sequestration when compared to monocropping systems [12, 28, 41]. Institutional innovations such as cooperatives and Farmer Producer Organizations (FPOs) play a crucial role in supporting smallholder farmers under climate-smart agriculture programs. Evidence from India and China shows that these organizations not only reduce transaction costs and risks but also strengthen farmer livelihoods and promote ecological sustainability [26, 53].

Cooperatives facilitate smallholders' participation in both compliance and voluntary carbon markets by providing access to technical knowledge, financial resources, and collective governance structures, while ensuring environmental integrity and equitable socio-economic benefits [18]. Ran et al. [39] highlighted that cooperative management plays a significant role in facilitating the green and low-carbon transition of agriculture in the Western Tarim River Basin. The cooperative-led approaches contribute to reducing carbon emissions, improving environmental sustainability, and supporting the region's transition toward low-carbon agriculture. Whereas, Yu et al. [56] found that the cooperative membership positively influences farmers' interest in green production practices. Together, agroforestry practices and farmer collectives represent complementary strategies for fostering sustainable rural livelihoods and achieving climate adaptation objectives and thereby making large-scale adoption of carbon farming feasible.

Raina et al. [38] reviewed the incentive mechanisms in carbon farming contracts and categorized three mode of payments, result-based, action-based and hybrid approaches. The critical success factors for incentivising farmers participation, includes clear and transparent contract terms, appropriate compensation levels aligned with effort and risk, access to technical support and training and policy frameworks supporting carbon markets. Aggarwal and Brockington [3] examined the livelihood impacts of forest carbon projects in India and found that these projects offer potential climate mitigation and conservation benefits, but their impact on poverty reduction is mixed and context-dependent. Ajayi et al. [4] explored the potential of voluntary carbon markets as a tool for promoting sustainable agriculture and highlighted the challenges including limited awareness, inadequate infrastructure, and policy gaps that hinder effective farmers' participation in carbon markets. While these studies does not specifically address cooperatives, it notes that collective or community-based implementation models could leverage farmer participation in the carbon farming, enabling farmers to pool resources, share risks, and collectively meet emission reduction targets.

In support of this, IFAD [24] highlighted that cooperatives strengthen smallholder capacity to adopt sustainable practices, negotiate fairer carbon prices, and access climate finance. Bamanyisa et al. [6] highlighted that cooperatives can effectively mobilise members to undertake carbon enhancement activities, generate carbon credits, and participate in carbon trading, thereby, contributing to climate change mitigation and enhancing community livelihoods. Tanveer et al. [50] identified that intermediaries, including cooperatives and NGOs, have successfully connected local communities with carbon markets, enhanced transparency, and improved access to carbon finance. Grashuis [20] identified key determinants of farmers' cooperative membership, including education, experience, farm size, wealth, social capital, trust,

and market orientation, highlighting that socio-economic and behavioural factors significantly influence participation in collective action. Collectively, these studies and reports underscore that cooperative frameworks are essential for scaling climate-smart interventions, operationalising carbon farming, and linking local action with broader mitigation and development goals.

3 Research methodology

This research employed a mixed-method, exploratory case study design, with the IFFDC as the unit of analysis [13, 47, 55]. The approach was exploratory, aimed at understanding the processes followed by IFFDC and triangulating qualitative data collected through key informants' interview, semi-structured interviews and focused group discussions (FGD) with quantitative data, in terms the financial performance of the IFFDC compiled from their annual reports, ensuring both depth and breadth in analysis. While quantitative methods help measure IFFDC's impact on carbon credit generation and economic sustainability, qualitative insights provide a deeper understanding of stakeholder perceptions and operational challenges. The details of the data collection methods provided in Table 1.

The combination of these sources allowed a comprehensive, triangulated evaluation of IFFDC as a cooperative organization, ensuring methodological rigour, despite the single-unit case study design.

4 Case study: IFFDC

4.1 Organisational overview

IFFDC, a registered Multi-State Cooperative Society (MSCS) under the MSCS Act of 1984 (subsequently under the MSCS Act of 2002) with Registration No. "MSCS/CR/37/93" came into existence formally on 22nd October, 1993, although its work had begun as early as in 1986–87. IFFDC was promoted by the Indian Farmers Fertiliser Cooperative Limited (IFFCO), with the objective of promoting sustainable farm and community-based forestry among smallholders. In the early stages, IFFCO provided funds and manpower for afforestation and promotion of village-level Primary Farm Forestry Cooperative Societies (PFFCS) and Primary Livelihood Development Cooperative Societies (PLDCS). During 1995 to 2000, with IFFCO's own contribution and funds mobilised from the India-Canada Environment Facility (ICEF) via Canadian International Development Agency (CIDA), from United Kingdom's Department of International Development, and from National

Table 1 Methods of data collection and analysis

Key informant interviews	• Semi-structured interviews were conducted with IFFDC officials, selected member representatives, and personnel involved in the carbon credit evaluation • The purpose was to understand institutional strategies, governance practices, agroforestry interventions, and processes related to carbon credit mechanisms, sustainability strategies, and regulatory challenges
Structured questionnaires	• A structured questionnaire was administered to key stakeholders to gather factual details about IFFDC's members, governance structure, management practices, business model, activities undertaken, financial performance, and carbon credit mechanisms. This allowed for a data-driven evaluation of farmer-member support, financial sustainability, environmental impact, and institutional effectiveness and competitiveness • A factsheet was prepared using secondary records from IFFDC to document membership growth, financial trends, and geographic expansion
Focus group discussions (FGDs)	• FGDs with farmers of primary cooperative member societies of IFFDC were conducted to capture collective experiences, perspectives and challenges related to participation in IFFDC's activities, and carbon farming
Document analysis	• IFFDC annual reports (2000–2023–24), project evaluation documents were analysed to validate primary data, track institutional performance, and triangulate findings
SWOT analysis	• A SWOT analysis was conducted to systematically assess the internal strengths and weaknesses of the IFFDC model, as well as the external opportunities and threats that influence its effectiveness in promoting carbon farming and sustainable development • This approach helped to identify strategic advantages that can be leveraged and challenges that need to be addressed for improving the scalability and sustainability of the model

Table 2 IFFDC's shareholders. Source: IFFDC25 Annual Report 2023–24

Value of each share (INR)	Shareholders	No. of shares
50,000	Indian Farmers Fertiliser Cooperative Limited	2507
	National Cooperative Development Corporation	8
10,000	Uttar Pradesh Sahakari Gram Vikas Bank Ltd	1
	Madhya Pradesh State Cooperative Marketing Federation Ltd	1
1000	Primary Farm Forestry Cooperative Societies Ltd. and Primary Livelihood Development Cooperative Societies Ltd	7935

Fig. 1 Business processes of IFFDC

Wasteland Development Board (NWDB) of Ministry of Rural Development, Government of India, the IFFDC expanded afforestation, promoted PFFCS and PLDCS and undertaken rural livelihood development projects.

IFFDC's governance structure consists of a General Body representing 172 member cooperatives from over 9570 villages across 18 states (Andhra Pradesh, Assam, Bihar, Chhattisgarh, Gujarat, Haryana, Himachal Pradesh, Jammu & Kashmir, Jharkhand, Karnataka, Kerala, Maharashtra, Odisha, Punjab, Tamil Nadu, Telangana, Uttarakhand, and West Bengal) and 13 members on its board of directors, comprises of elected cooperators, as well as nominated and co-opted members. These member cooperatives operating at different levels, such as IFFCO as chief promoter, works as national level cooperative society, then National Cooperative Development Corporation (NCDC), State Cooperative Federations, and village level PFFCS and PLDCS. As on March 31, 2023, IFFDC had 172 cooperative societies as its members, subscribed INR 133.7 million, against an authorised share capital of INR 1000 million. Table 2 presents the shareholders categories including their number of subscribed shares vis-à-vis value of each share.

On the operational front, IFFDC's management team of 219 employees and a Managing Director had evolved toward a hybrid model combining professional expertise with cooperative governance. Senior managers coordinated project planning, resource mobilisation, and performance monitoring, while regional field teams facilitated participatory implementation and capacity-building activities. The management team operated under the strategic guidance of the Board of Directors, ensuring coherence between policy formulation and field-level implementation. The organizational structure fostered participatory planning, decentralized decision-making, and continuous feedback from member cooperatives, thereby strengthening accountability and institutional adaptability.

The business model of IFFDC is illustrated in Fig. 1 and briefly summerised in Table 3, highlighting the cooperative's integrated framework that links cooperative governance, community participation, and sustainable agroforestry outcomes.

It was observed that IFFDC initially promoted large-scale farm forestry by planting long-gestation tree species such as *Teak* and *Indian Rosewood* (*Dalbergia sissoo*) on selected wastelands. However, due to slow growth, long maturity periods, and legal restrictions on harvesting, member cooperatives saw limited financial benefits, leading to their reduced participation. In order to address this, IFFDC then introduced agro-forestry, integrating tree planting with traditional farming. Short-rotation commercial species like *Melia composita* (Burma Neem) and *Ailanthus excelsa* (Adusa) were selected for boundary plantations and intercropping. This allowed farmers to cultivate crops alongside trees, following models such as Melia-Wheat, Melia-Mustard, etc. This approach provided both environmental and economic benefits**,** enhancing soil fertility, reducing erosion, and offering an additional income stream through timber and carbon credits.

Unlike conventional agroforestry models, IFFDC integrated cooperative principles into its practice, ensuring democratic governance, equitable benefit-sharing, and long-term community involvement. Traditional agroforestry models primarily focus on individual or corporate-led afforestation initiatives, whereas IFFDC emphasised collective ownership through PFFCS/ PLDCS. Additionally, IFFDC aligned its projects with international carbon credit mechanisms such as VERRA, offering financial incentives for afforestation efforts. Unlike many other agroforestry initiatives that rely on subsidies, IFFDC promoted self-sustaining afforestation by reinvesting carbon credit earnings into new projects.

The financial performance of IFFDC reflected a gradual transition from project-based funding dependence to a more diversified and self-sustaining model. Table 4 provides a detailed overview of IFFDC's financial performance over different

Table 3 Business processes of IFFDC. Source: Author's representation based on primary data collection

Land acquisition and agreement	Barren/waste land acquired from village panchayats, local authorities, or individuals on a 30-year lease, ensuring clarity in rights, and benefit-sharing mechanisms
Formation of cooperative	PFFCS/PLDCS are formed with local farmers, landless labourers, women, and poor individuals as its members. These operational units are responsible for project implementation and participatory decision-making
Development and maintenance	Encompassed plantation establishment, soil and water conservation, maintained by the PFFCS/PLDCS under the existing technical support and guided by participatory planning and field-level supervision
Livelihood enhancement	PFFCS/PLDCS were supported in creating alternative livelihood opportunities, including the formation of Self-Help Groups (SHGs), providing micro credit, and developing micro-enterprises in order to improve household resilience and community well-being
Forest growth and profit generation	Over 5–7 years, the forest grows, and thereby, realises the economic and environmental benefits of the initiative, including timber and non-timber products, as well as carbon credit revenues, which then equitably shared among members

time periods, highlighting key trends in working capital, total deposits, fixed assets, and profitability. Analysis of IFFDC's audited reports indicated that between 2000–01 and 2020–21, over a half-decadal growth trajectory, the cooperatives' annual turnover and net profit increased steadily. The cooperative's financial health was shaped by multiple factors, including policy support, membership expansion, and diversification of revenue streams.

Analysis of the financials revealed an interesting interplay between various indicators, particularly in working capital and profitability. While total expenditure shown a downward trend from INR 30,966.0 million in 2020–21 to INR 25,664.3 million in 2023–24, net profit consistently increased over the years, reaching INR 157.3 million in 2023–24. The analysis suggested that consistent increase in profitability was accompanied by improved cost efficiency and effective revenue optimisation strategies. The rise in total deposits from INR 447.5 million in 2015–16 to INR 975.7 million in 2023–24 reflected growing stakeholders' confidence and cooperative's expanding financial credibility. However, a temporary decline in working capital between 2020–21 and 2022–23 indicated short-term liquidity pressures, possibly due to pandemic-induced disruptions and delayed project cycles. The subsequent recovery in 2023–24 demonstrated IFFDC's capacity to restore financial balance through adaptive management practices. Overall, these trends underscored the cooperative's financial resilience and highlighted the need for strong liquidity management and strategic reinvestment to ensure sustained and inclusive growth.

The analysis of IFFDC's financial data revealed a steady expansion in business turnover since inception, indicating the cooperative's growing operational scale and financial stability. Turnover, which began at INR 0.009 million, rose sharply to an all-time high of INR 31,057.1 million in 2020–21, driven by project expansion and favorable market conditions. A subsequent decline to INR 27,460.2 million in 2021–22 reflected the adverse effects of the COVID-19 pandemic, including disruptions in supply chains and project execution. Although a partial recovery occurred in 2022–23 with turnover reaching INR 28754.8 million, a further fall to INR 25,821.5 million in 2023–24 suggested continuing market volatility

Table 4 Financials of IFFDC (trend over the years) in INR million. Source: Author's compilation from IFFDC's Annual Reports

Financials	Half-decadal growth						Last three financial year		
	Inception (1995–96)	2000–01	2005–06	2010–11	2015–16	2020–21	2021–22	2022–23	2023–24
Share capital	0.118	56.2	57.5	131.4	132.3	132.7	133.7	133.7	133.7
Working capital	–	–	76.3	92.7	147.5	110.6	68.5	80.2	340.6
Total reserves	0.013	2.3	–	–	176.7	415.0	481.9	577.8	686.7
Total expenditure	–	13.2	1462.9	2119.7	10,226.2	30,966.0	27,360.0	28,613.9	25,664.3
Total deposits	–	36.2	48.4	35.7	447.5	604.6	604.6	735.7	975.7
Fixed assets	–	0.7	1.6	6.8	1039.2	195.9	216.8	223.0	222.3
Gross profit	–	1.0	5.0	15.2	119.1	150.8	156.6	203.4	269.5
Net profit	0.009	2.1	13.6	15.0	59.3	91.1	100.2	140.9	157.3
Total business turnover	0.009	15.3	1476.4	2134.7	10,285.4	31,057.1	27,460.2	28,754.8	25,821.5

and the influence of external factors such as carbon-market fluctuations. As shown in Fig. 2, this fluctuating pattern illustrates both the resilience and sensitivity of IFFDC's business model to external shocks. Overall, while IFFDC's long-term growth remained strong, the recent variability highlighted the need for adaptive financial strategies and diversification to sustain performance under changing market conditions. In particular, there is a need to enhance farmer mobilisation and awareness about IFFDC business model to facilitate the formation of PFFCS and PLDCS across IFFDC's operational network in 18 states, thereby expanding project coverage and local participation.

4.2 Key project activities and achievements

Analysis of IFFDC's project portfolio indicated that the cooperative implemented a diverse range of initiatives aimed at promoting sustainable development, enhancing rural livelihoods, and advancing environmental conservation. These projects were implemented in partnership with multiple stakeholders, including IFFCO, the National Bank for Agriculture and Rural Development (NABARD), state governments, and corporate social responsibility (CSR) collaborators, reflecting the cooperative's multi-dimensional approach and wide geographic reach.

IFFCO-supported projects included social forestry initiatives in Uttar Pradesh, Madhya Pradesh, Rajasthan, and Uttarakhand, as well as a Rural Livelihood Development Project (RLDP) in Odisha and West Bengal. These interventions primarily focused on afforestation, natural resource management, and improving livelihood opportunities for rural communities, integrating environmental objectives with local economic development.

NABARD-supported initiatives encompassed three projects in the Madhya Pradesh State viz. watershed development, rural livelihood entrepreneurship, and a climate-proofing project. IFFDC also promoted FPOs across six states, namely Bihar, Haryana, Madhya Pradesh, Maharashtra, Uttarakhand and Uttar Pradesh under the Central Sector Scheme for the promotion of 10,000 FPOs. In addition, in 2022–23, watershed development project was started in the Cuttack district of Odisha, which demonstrate IFFDC's continuing efforts to expand its operational scope and strengthen rural infrastructure and sustainability initiatives. Collectively, these interventions aimed to strengthen institutional capacity, enhance agricultural productivity, and build climate resilience among rural populations.

State government-supported projects included the promotion of FPOs in Bihar, Gujarat, Uttarakhand and Uttar Pradesh, under the Central Sector Scheme implemented by the National Cooperative Development Corporation (NCDC), targeting the formation and scaling of farmer collectives to improve market linkages and cooperative governance.

CSR-supported projects highlighted the cooperative's engagement with corporate partners to implement socially impactful programmes. Notable initiatives included IFFCO's one of the subsidiary—IFFCO-Tokio's Integrated Rural Development Project in Bihar and Chhattisgarh, a research study on the adaptability of Melia composita (Burma Neem) in semi-arid regions of Haryana funded by the Meet Trust of Mitsui & Co. Ltd., and green belt development projects in Delhi NCT parks under the Horticulture Department, also supported by Mitsui & Co. Ltd. These projects combined research, environmental restoration, and livelihood enhancement objectives.

Overall, the analysis of these initiatives indicates that IFFDC has implemented a wide spectrum of projects across different states, funding mechanisms, and thematic areas. Table 5 summarizes the key projects, categorises them under broader themes, and presents their major achievements, illustrating the cooperative's multi-pronged approach to rural development, environmental sustainability, and cooperative strengthening.

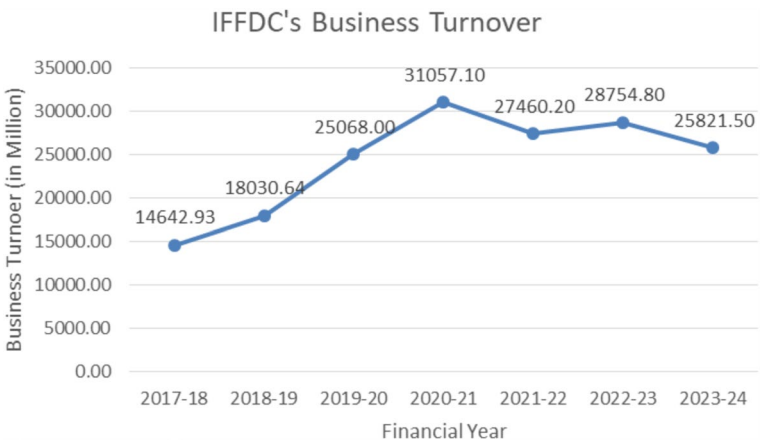

Fig. 2 IFFDC's business turnover

Table 5 Achievements of key projects. Source: Author's representation based on primary data collection

Projects theme	Achievements
Livelihood Development	Livelihood improvement was achieved for over 570,000 families, reflecting the project's broad socio-economic impact
Wadi Development	Fruit orchard were established covering 8515 tribal families across 3406 hectares of land, demonstrating the initiative's contribution to both income generation and land-use optimisation
Social Forestry and Climate Change	A total of 29,421 hectares of wasteland afforested, resulting in an existing tree cover of 1.09 million trees, demonstrating IFFDC's contribution to environmental restoration and climate mitigation
Water resource Development	The initiative successfully constructed 273 check dams, 1176 ponds, 1327 wells, and 326 LDPE tanks, enhancing water availability and supporting agricultural productivity in target areas
Watershed Management	An area of 18,837 hectares was treated under watershed management interventions, improving soil conservation, water retention, and overall ecosystem resilience
Formation of SHGs	A total of 1907 SHGs were formed, comprising 19,529 members, of whom 94% were women, indicating the cooperative's focus on women's empowerment and community participation
Promotion of Farmer Producers Organisation	Eighty-eight FPOs were established, encompassing 56,832 members, alongside the development of 2868 community institutions with 111,688 members, highlighting the cooperative's efforts to strengthen farmer collectives and enhance their market linkages

4.3 Carbon credits generation: lifecycle, challenges, and impact

IFFDC's carbon credit programme represents one of the earliest cooperative-led initiatives in India to integrate community forestry with carbon markets. A pilot project was implemented on 189 hectares between 2008 and 2013. This attempt served as a crucial test for IFFDC, to assess the feasibility and potential of scaling similar initiatives. The project successfully generated 78,000 carbon credits under the Verified Carbon Standards (VCS) for the period from 2008 to the first quarter of 2022. These credits were formally registered with VERRA in April 2023. The initiative demonstrates how a cooperative model can effectively integrate environmental objectives with community participation and financial mechanisms.

The carbon offset projects followed a structured and participatory approach throughout their design, implementation, and verification stages, ensuring compliance with internationally recognised standards. Rigorous assessment, stakeholder consultation, and monitoring processes were applied to maintain transparency and credibility.

The major stages of the project lifecycle are summarised in Table 6, illustrating the stepwise approach from baseline assessment to credit issuance and sale. This systematic approach allowed IFFDC to not only generate measurable carbon benefits but also to strengthen member engagement, promote sustainable agroforestry practices, and enhance financial sustainability through carbon revenue sharing.

This step-wise approach demonstrates how IFFDC successfully combined cooperative governance, community participation, and internationally recognised carbon standards to generate measurable climate benefits. Participatory design and rigorous monitoring were the key factors in ensuring credibility, sustainability, and financial returns for member cooperatives.

The calculation of carbon credits in the IFFDC model follows standard methodologies based on verified emissions reductions, following internationally recognised methodologies such as those of the Verified Carbon Standard (VCS) under VERRA. Each tonne of carbon dioxide (CO_2) sequestered or emission reduced is equivalent to one carbon credit. The process consists of several key steps:

- Determining the baseline: The first step involves establishing the carbon stock of the land prior to project implementation. This includes measuring existing vegetation, soil carbon, and land use patterns. The baseline scenario represents what would have occurred without the project and provides a reference for estimating emissions reductions;

Table 6 Major stages of IFFDC carbon credit project lifecycle. Source: Author's representation based on primary data collection

Stage	Description
Feasibility Studies and Baseline Data Collection	Initial assessments were conducted to evaluate project viability and establish baseline environmental data, including land use, soil quality, and existing vegetation cover
Project Description Document (PDD) Preparation	A detailed PDD was prepared, documenting project objectives, methodology, expected outcomes, and monitoring procedures
GPS Mapping of Project Sites	Consulting firms were engaged to capture precise GIS data. The coordinates (longitude and latitude) of every plantation site were recorded to compare land status and plantation growth before and after interventions. Accredited auditors validated and verified plantation development
Validation Audit and Project Registration	Independent audits confirmed the project's potential to generate carbon credits. The project was subsequently registered with global certification bodies, including VERRA, with audits conducted by M/S Rainforest Alliance, Indonesia
Sample Plot Preparation and Monitoring	Sample plots were established across the plantation sites to systematically monitor growth, survival rate, and development of trees over time
Carbon Credit Validation	Accredited auditors conducted formal validation of carbon credits, and the auditor's report was submitted to the registry for review
Verification and Certification of Carbon Credits	Subsequent verification audits were conducted by M/s Carbon Check (India) Pvt. Ltd. Certified credits were issued, and carbon credit accounts were opened with the registry
Post-Certification Monitoring	Ongoing monitoring ensured long-term project success. Activities included training members of PFFCS cooperatives in fire management, plantation care, and adaptive management practices
Market Exploration	Generated carbon credits were marketed and sold in international carbon markets to generate revenue for member cooperatives and sustain project activities

- Comparing emissions: Project emissions, including carbon sequestration from afforestation and agroforestry activities, are compared against the baseline. This ensures that only additional carbon captured by the project is counted;
- Calculating emissions reductions: Net emissions reductions are calculated by subtracting project emissions from baseline emissions. Conservativeness deductions are applied as per VERRA methodology to avoid overestimation. These methodologies provide guidance on estimating carbon in biomass, soil organic carbon, and other relevant pools; and
- Issue carbon credits: After validation and verification, each tonne of CO_2e reduced is issued as a carbon credit. For the IFFDC pilot project (2008–2013, 189 hectares), 78,000 carbon credits were successfully generated.

4.3.1 Challenges in carbon credit validation and market participation

While the methodology is well-defined, practical implementation faces several challenges:

- Validation and verification costs: Audits require substantial financial investment and time. Accredited audit firms for forestry-based carbon credits are limited in India, making the selection of auditors a critical step for each credit issuance;
- Market volatility and buyer orientation: Voluntary carbon markets are largely buyer-driven, where buyers determine prices. Sellers often lack transparency regarding actual buyers and prevailing market prices;
- Standardisation and integrity issues: Variability in methodologies, lack of standardisation, and limited market transparency can reduce confidence in carbon credit transactions. Some intermediaries or trading agencies retain significant margins, further complicating revenue flows for cooperatives; and
- Operational and technical challenges: Accurate monitoring requires GPS mapping, sample plots, and regular measurement of tree growth. Ensuring compliance with Measurement, Reporting, and Verification (MRV) protocols and long-term monitoring adds operational complexity.

4.3.2 Impact of carbon credits on IFFDC

The carbon credit programme significantly influenced IFFDC's financial sustainability, community engagement, and long-term strategic direction. The initiative not only validated the economic viability of cooperative-led carbon farming but also positioned IFFDC as a national model for integrating environmental and livelihood goals.

The establishment of a tri-party agreement among IFFDC, its member forestry cooperatives, and the landowner farmers created a transparent and equitable revenue-sharing model. After deducting expenses associated with project development, such as validation and verification audits, GPS mapping, and VERRA registration fees, the remaining revenue from carbon credit sales was distributed among stakeholders. The participating farmers viewed carbon credits as a new and sustainable source of income. The programme enabled them to earn additional revenue without harvesting their trees, as ownership of the plantations remained with the farmers, the members of PFFCS. This arrangement provided both financial and ecological incentives, allowing farmers to benefit economically while contributing to environmental restoration. Importantly, forestry-based carbon credits were perceived as a complementary income stream rather than the primary objective of afforestation efforts. The central aim of IFFDC's forestry initiatives remained the enhancement of forest cover, ecological balance, and environmental conservation. Nevertheless, the revenue generated through the sale of verified carbon credits constituted a direct financial return for the participating tree growers, reinforcing the viability of community-driven climate action.

Out of 78,000 carbon credits generated under the project, 41,000 carbon credits were successfully sold in the international voluntary carbon market, generating a total revenue of INR 67.2 million. The sale demonstrated the commercial feasibility of cooperative-led carbon trading and validated IFFDC's compliance with international certification standards. As per the revenue-sharing agreement, after deducting project development and administrative costs, the income from the sale of carbon credits was equitably distributed among stakeholders. Out of the total revenue of INR 67.2 million generated from the sale of 41,000 carbon credits, INR 15.0 million was shared among 11 forestry cooperatives (averaging INR 1.36 million per cooperative), and INR 30.0 million was disbursed to 120 participating farmers (averaging INR 250,000 per farmer) on whose land the plantations were established. The remaining INR 22.2 million was retained by IFFDC to cover operational expenses, monitoring, verification (INR 7.2 million), and to support the scaling of future carbon credit initiatives (INR 15 million). Approximately 45% of the net income was allocated to landowner farmers, 22% to the respective forestry cooperatives, and 33% to IFFDC for project management and reinvestment. The remaining portion covered administrative and transaction costs. This structured framework ensured that all parties benefited proportionally from the carbon credit proceeds. It fostered a sense of collective ownership and accountability, encouraging continued participation, maintenance of plantations, and compliance with environmental standards. By aligning financial incentives with ecological responsibilities, the tri-party arrangement reinforced the cooperative ethos of shared prosperity and long-term sustainability.

In terms of financial sustainability and return on investment (ROI), the carbon credit programme provided immediate financial returns to farmers and cooperatives, while its long-term viability depended on maintaining a balance between project costs and recurring benefits. IFFDC's carbon credit initiative involved substantial upfront investment in plantation development, validation, monitoring, and certification processes. The project development expenditure, estimated at around INR 35 million, covered GPS mapping, third-party verification, and VERRA registration fees. These costs were deducted prior to the distribution of revenue.

From the sale of 41,000 verified carbon credits, the initiative generated INR 67.2 million in revenue, demonstrating strong financial performance with a financial sustainability ratio of 192% and a robust return on investment (ROI) of 92%. This corresponds to an early return ratio of nearly 2:1 within the first credit issuance cycle, underscoring the economic viability of cooperative-led carbon offset initiatives. Given the project's 30-year lifespan (till 2038), subsequent issuance cycles are expected to enhance overall profitability and strengthen financial resilience. The extended lifespan until 2038, ensures that the participating forestry cooperatives and farmers will continue to receive benefits from periodic carbon credit issuances. This arrangement provides a sustained source of income and acts as a powerful financial incentive for farmers to expand forestry operations, adopt sustainable land management practices, and reinvest in tree-based livelihoods. The model, thus, reinforces the dual objectives of economic empowerment and ecological restoration, demonstrating how cooperative structures can align local incentives with global climate action.

The financial sustainability of forestry-based carbon credit models depends on consistent credit generation, favourable market conditions, and transparent reinvestment practices. By aggregating carbon credits from member cooperatives, IFFDC reduced transaction costs and enhanced bargaining power in the voluntary carbon market.

Moreover, reinvesting part of the revenue into new plantations ensured a self-sustaining afforestation cycle, enabling continuous income generation for cooperatives and farmers while maintaining ecological benefits over the long term.

4.3.3 Strategic reinvestment and expansion of carbon credit projects

IFFDC Is strategically reinvesting the revenue generated from its carbon credit programme to develop new projects in collaboration with their member cooperatives. These cooperatives are utilising the funds to expand plantation areas, thereby enhancing overall carbon sequestration capacity and scaling the cooperative-led model of sustainable forestry.

Building on the success of the initial pilot project, IFFDC has planned and registered a second project with the VERRA Registry in Washington, DC. This project covers 455.25 hectares, cultivated between 2015 and 2023 across 30 PFFCS in Uttar Pradesh and 6 PFFCS in Madhya Pradesh. It is projected to generate an annual production of 10,370 carbon credits, equivalent to sequestering 10,370 tonnes of CO_2, and is expected to accumulate a total of 207,447 carbon credits over two decades.

According to the 2023–24 annual report, a total of 290 hectares has been planted across four states, 119 ha in Uttar Pradesh, 22 hectares in Uttarakhand, 38 hectares in Madhya Pradesh, and 111 hectares in Rajasthan. In total, 292,000 saplings were planted by various PFFCS (116,000 in Uttar Pradesh, 21,000 in Uttarakhand, 34,000 in Madhya Pradesh, and 121,000 in Rajasthan). The validation audit, a critical step for carbon credit generation, has been successfully completed by accredited auditors, confirming the project's compliance with international standards.

Capacity building remains an integral component of the project. PFFCS in Madhya Pradesh and Uttar Pradesh conducted seven mock drills on plantation fire management, while the chairpersons of 30 PFFCS attended a three-day leadership development program at KVK, Badgaon, Udaipur. The project is now advancing towards the verification phase, which will enable the issuance of carbon credits through the VERRA Registry. These activities reinforce IFFDC's commitment to sustainable environmental practices, strengthen the technical and managerial capabilities of member cooperatives, and underscore its role in global carbon reduction efforts.

4.4 IFFDC farm forestry project: advancing sustainable development goals

The IFFDC farm forestry project addressed climate change mitigation while promoting socio-economic development in rural communities. Plantations were established on wastelands and marginal lands, providing additional income to farmers and strengthening the sustainability of forestry cooperatives. Out of the 17 UN SDGs, the project contributed to eight goals, spanning environmental restoration, economic empowerment, and social inclusion (Table 7).

Key impacts included carbon sequestration (SDG 13), enhanced biodiversity and restoration of degraded lands (SDG 15), income generation and poverty reduction (SDG 1), improved nutrition through fruit plantations (SDG 3), women's empowerment through SHGs (SDG 5), promotion of decent work and local economic growth (SDG 8), reduced inequalities by including marginalised groups (SDG 10), and strengthened partnerships with member cooperatives and SHGs (SDG 17).

These findings demonstrate that cooperative-led carbon farming effectively integrates environmental and socio-economic objectives, offering a replicable model for achieving multiple SDGs in rural contexts.

4.5 Community-centric approach, challenges and mitigation strategies

A key factor in IFFDC's success was its active engagement with rural communities, who participated in planning and implementing forestry initiatives. This participatory approach, supported by the cooperative structure, fostered ownership and ensured long-term sustainability. The project faced operational and technical challenges, including plantation maintenance, carbon credit validation, and market uncertainties. IFFDC addressed these through targeted interventions, such as fire management training, leadership programs, and partnerships with accredited auditors. Details of the challenges and solutions are summarized in Table 8, highlighting the strategies that enabled effective and sustainable project execution.

IFFDC ensured the long-term maintenance of afforested areas through a structured framework involving PFFCS and PLDCS as key community institutions. These bodies managed and maintained the plantations on a sustainable basis, with IFFDC providing support for protection, monitoring, and watch-and-ward activities. Financial grants were provided to PFFCS for need-based maintenance, including irrigation, hoeing, weeding, pruning, and barbed-wire fencing to safeguard the plantations. Additionally, IFFDC trained member cooperatives in sustainable forestry practices, fire

Table 7 Impact on sustainable development goals (SDGs). Source: Author's representation based on primary data collection

SDGs	Project activities/interventions	Observed impact
SDG 1—No Poverty	Employment and income generation through project activities	Improved livelihoods and reduced poverty among participating farmers
SDG 3—Good Health and Well-Being	Fruit plantations under agro-horticulture systems	Increased access to nutritious food, contributing to better health outcomes
SDG 5—Gender Equality	Support to 1900 + SHGs with 19,529 members (94% women)	Empowered women through income-generating activities, enhancing family livelihoods
SDG 8—Decent Work and Economic Growth	Employment and income from project operations	Promoted economic growth and offered decent work opportunities
SDG 10—Reduced Inequalities	Inclusion of women and marginalised groups in project activities	Ensured equitable distribution of income, employment, and resources
SDG 13—Climate Action	Forest plantations for carbon sequestration	Mitigated climate change by reducing atmospheric CO_2
SDG 15—Life on Land	Restoration of waterlogged areas and biodiversity plantations	Enhanced biodiversity, transformed lands into bird sanctuaries, and improved ecosystems
SDG 17—Partnership for the Goals	Promotion and formation of PFFCS and PLDCS and SHGs	Strengthened partnerships for ecological restoration, economic development, and capacity building

Table 8 IFFDC projects implementation challenges and mitigation strategies. Source: Author's representation based on primary data collection

Challenges	Mitigation
Managing forest fire	
• Frequent and severe forest fires during hot summer months posed risks to forest sustainability and community safety	• Implemented fire protection trenches/strips as firebreaks to contain and control the spread of fires by about 50%, limiting tree loss to around 10% per hectare compared to 30–40% in unprotected areas
• Rapid spread of fires in dense forested areas increased potential damage	• Strategically placed trenches to slow down fire progression, minimising ecological damage effectively
Training and preparedness	
• Limited knowledge and skills among community members regarding fire behaviour and firefighting techniques	• Conducted comprehensive training programmes that include understanding fire behaviour, using firefighting equipment, and safety protocols
• Insufficient emergency response capabilities and inability to execute safety measures during incidents	• Equipped cooperatives with firefighting tools and practical drills to ensure members are prepared for emergencies
Identification of genuine buyers	
• Identification of genuine buyer of forestry-based carbon credits in the international market and assessing of fair prices of the carbon credits	• IFFDC hired consulting firm which is dealing in carbon credit sale since long time in the international market to overcome this challenge

prevention, and resource management. The use of GPS mapping and periodic satellite monitoring enabled tracking of forest health, minimizing risks such as degradation or encroachment, and ensured accountability and long-term viability of the afforested regions.

5 Analytical discussion

5.1 SWOT analysis

The IFFDC model is an innovative approach that combines environmental conservation with socio-economic development through cooperative principles. A SWOT analysis of the model was conducted to evaluate its internal strengths and weaknesses, along with external opportunities and threats. The analysis is presented in Table 9.

5.2 Comparative insights and broader lessons

A comparison of IFFDC's model with other agroforestry and carbon credit initiatives in India revealed its distinct cooperative and community-driven character. While several projects have emerged to integrate agroforestry with carbon markets, such as the Punjab State Agroforestry Project by *ClimateSeed*, IFFDC's approach differed significantly in structure, ownership, and sustainability.

The Punjab initiative promoted tree planting alongside crops to improve soil health, reduce emissions, and generate carbon credits. However, it relied heavily on private partnerships and corporate sustainability investments, which, though effective in mobilising resources, often limited farmers' participation in governance and decision-making. In contrast, IFFDC was owned and governed by the farmers themselves, organised through farm forestry cooperatives. The member-based structure enabled direct involvement of tree-growing farmers in planning, policy formulation, and benefit sharing, ensuring long-term ownership and accountability.

Another major distinction lay in the revenue-sharing mechanism. IFFDC implemented a transparent and structured model, in which revenue from carbon credit sales was equitably distributed among farmers, cooperatives, and IFFDC, with a portion reinvested into new plantation projects. This ensured financial self-reliance and sustainability, unlike the Punjab model, where financial flows depended largely on external corporate funding and voluntary buyers, making income streams less stable.

Moreover, IFFDC's scope extended beyond carbon forestry. It supported agricultural input supply, women's empowerment through SHGs, and livelihood diversification, integrating environmental, social, and economic outcomes within a single cooperative framework.

Table 9 SWOT analysis of IFFDC model. Source: Author's representation based on primary data collection

	Strengths	Weaknesses
Internal factors	• Structured governance and transparent revenue-sharing mechanisms promoted trust and long-term sustainability; • Strong community engagement, reduced resistance and ensured participatory decision-making and ownership; • Proven financial viability; • Diversified initiatives include SHGs with 94% female participation; • Aligned with total of eight SDGs; • Technical expertise and capacity building	• Limited awareness and knowledge among community members regarding carbon credit management; • High initial investment and validation costs posed challenges for scaling without external support; • Dependence on limited accredited auditors and carbon registries created bottlenecks in validation and verification processes
	Opportunities	**Threats**
External factors	• Rising global carbon credit demand can support project expansion and thereby can increase carbon sequestration and income for more farmers • Partnerships with international voluntary carbon markets could enhance revenue and bargaining power • Growing global interest in low-carbon development and sustainable forestry offers opportunities for replication of the cooperative-led model • Integrating technology for monitoring • Potential for employment generation • Nurturing farming community for sustainable farming	• Risks of forest degradation, encroachment, and climate events like forest fires, droughts, extreme weather, could impact long-term carbon sequestration • Volatility and lack of standardisation in voluntary carbon markets may affect predictable revenue streams • Competition from other land-use initiatives or market intermediaries might reduce market transparency and affect stakeholder benefits

From these comparisons, several broader lessons emerged for scaling up cooperative-led low-carbon development:

- Community ownership and participatory governance build trust, accountability, and continuity;
- Transparent revenue-sharing systems reinforce equitable benefit distribution and encourage member participation;
- Integrated livelihood and sustainability components strengthen social inclusion and resilience;
- Reinvestment in new plantations ensures long-term viability and ecological regeneration;
- Aggregation through cooperatives enhances bargaining power and reduces transaction costs in voluntary carbon markets.

Overall, IFFDC's agroforestry model demonstrated that cooperatives can effectively align climate action with rural development, offering a replicable, financially sustainable, and community-centric pathway for advancing India's low-carbon transition.

6 Conclusion and recommendations

The IFFDC's farm forestry and carbon credit initiative demonstrated that cooperative-led models can effectively combine environmental restoration with socio-economic empowerment, validating principles of collective action and participatory governance [8, 37]. Through structured ownership, transparent revenue sharing, and reinvestment in community forestry, IFFDC created a replicable framework for inclusive low-carbon rural development.

Empirical findings revealed that long-term engagement with rural communities was central to IFFDC's success. The participatory approach fostered a sense of ownership among farmers, enhanced trust, and ensured continuity of plantation maintenance. Furthermore, reinvestment of carbon revenue into new plantations and cooperative capacity building sustained ecological and financial outcomes. These findings reaffirm the cooperative theory premise that collective ownership and local agency strengthen institutional sustainability and equitable distribution of benefits [7].

Drawing on these insights, the following policy and strategic recommendations are proposed aiming to enhance sustainability, impact, and scalability of cooperative-led carbon farming:

- A national cooperative with pan-India sub-operations should be promoted to coordinate renewable energy and carbon market participation. Such an institution can streamline registration and trading processes, provide technical and financial assistance, support R&D, and recognize cooperatives demonstrating excellence in ESG practices.
- Efforts should be made to develop robust domestic and international carbon markets through partnerships with public and private entities. Expanding market accessibility would enhance income potential for cooperatives and attract greater investment in green initiatives.
- Regular workshops, training programmes, and seminars on renewable technologies, carbon accounting, and sustainability management should be organized to build technical and managerial capacities of cooperatives.
- Government agencies, private investors, and international organizations should work collaboratively, governments providing policy and financial support, the private sector offering technology and market linkages, and international partners facilitating capacity building and access to global carbon mechanisms. Such partnerships would ensure the long-term sustainability and scalability of cooperative-led low-carbon development models.
- Cooperatives should establish clear, equitable revenue-sharing agreements that are determined ex-ante, as IFFDC did with the tri-party agreement. This aligns incentives and reduces conflicts. Theoretical literature underscores that profit or revenue sharing mitigates free riding and sustains long-term participation in agroforestry programs [19, 49].
- IFFDC's use of GPS, satellite imagery, third-party verification, and periodic audits offered both credibility and accountability. To scale up, cooperatives need policy support for MRV infrastructure, capacity building, and recognition in carbon market regulations. Studies show that collective action regimes with more rigorous MRV deliver better environmental outcomes [8, 51].
- High initial costs (plantation establishment, validation, auditing) were a challenge for IFFDC. Policymakers should facilitate subsidised grants, soft loans, or matching funds to help cooperatives and farmers in managing financial burdens until carbon credit revenue kicks in.
- IFFDC's success relied on inclusive participation, women's SHGs, marginalized farmers, aligning with cooperative theory which holds that inclusive institutions yield stronger collective identity and commitment. Policies should mandate or incentivize inclusion, gender balance, and marginalised section participation in cooperative structures.

- Cooperative initiatives should be integrated with governmental climate policies and rural development schemes. IFFDC's cooperative model could be embedded in national carbon market frameworks or rural climate programs to leverage greater resources and institutional support.
- Part of the carbon credit revenue should be consistently reinvested into forest protection, new afforestation, capacity building, and community institutions.

Overall, IFFDC's case underscores that climate action through cooperatives is not merely an environmental strategy but a socio-economic transformation pathway. Compared with corporate-led or privately managed agroforestry initiatives, IFFDC's member-owned model proved more sustainable, transparent, and inclusive.

Future research should explore longitudinal carbon sequestration trends under cooperative management and assess how institutional design influences market participation and equity outcomes. From a policy perspective, enabling frameworks that recognise cooperatives as key actors in India's carbon economy could accelerate the transition toward inclusive, community-driven, low-carbon development.

Acknowledgements We sincerely thank the Managing Director of IFFDC and her team for their invaluable support in providing relevant data and information and facilitating discussions with their member cooperative societies essential for the successful completion of this research paper.

Author contributions All authors contributed to the study conception and design. The work is our original contribution and has not been taken from anywhere.

Funding We declare that no external funding was received for this study.

Data availability The authors confirm that all data generated or analysed during this study are included in this published article.

Declarations

Ethics approval and consent to participate The study was reviewed and approved by the Ethics Committee of the National Cooperative Union of India. All procedures involving human participants were conducted in accordance with institutional ethical guidelines and the principles of the Declaration of Helsinki. Informed consent was obtained from all participants, and confidentiality was strictly maintained. All IFFDC representatives who participated in the study were fully informed about the objectives, methodology, and their rights. Written informed consent was obtained from each representative, ensuring voluntary participation on behalf of their organization.

Consent for publication All participants provided written consent for the anonymised use of data from their organisation in publications and presentations arising from this research.

Competing interests The authors declare no competing interests.

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