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Women and Carbon Farming Cooperatives: A Model for Climate-Smart Agriculture

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ABSTRACT: The intersection of gender empowerment, cooperative farming, and climate resilience offers a promising model for sustainable agriculture. This review explores the role of women-led carbon farming cooperatives as a vehicle for promoting climate-smart agriculture (CSA). By synthesizing recent empirical studies and theoretical advancements, the article illustrates how gender-inclusive cooperative models contribute to soil carbon sequestration, climate resilience, and sustainable livelihoods. It underscores structural and institutional challenges while advocating for policy interventions that enhance women's participation and leadership in CSA cooperatives. The review reveals that empowering women through cooperatives not only bridges gender gaps in agriculture but also accelerates the global transition to climate-resilient food systems.

KEYWORDS: Agriculture, Climate, Development, Gender, Resilience, Rural, Sustainability.

INTRODUCTION

Climate change poses an unprecedented threat to global food systems, particularly in low- and middle-income countries where agricultural production is largely dependent on rainfall and traditional practices. The growing unpredictability of weather patterns, prolonged droughts, and soil degradation have exacerbated food insecurity and rural poverty. In response, there has been a surge in interest around climate-smart agriculture (CSA) - a transformative approach that integrates agricultural development and climate responsiveness by simultaneously increasing productivity, enhancing resilience, and reducing greenhouse gas emissions (FAO, 2021).

Among CSA strategies, carbon farming-which involves adopting agricultural practices that increase the storage of carbon in the soil and biomass-has garnered attention for its dual benefits of environmental mitigation and improved soil health. Practices such as agroforestry, conservation tillage, cover cropping, and biochar application not only sequester atmospheric carbon but also enhance soil fertility and water retention, improving farm yields sustainably (Lee, 2017; Migadde, 2020).

However, the success of carbon farming depends not just on the availability of technologies but also on institutional arrangements that enable equitable access and implementation. This is where cooperatives play a critical role. Farmer cooperatives offer a collective platform for members to access training, financing, and markets. More importantly, they allow marginalized voices-including those of rural women-to be amplified in agricultural decision-making and innovation processes (Kahsay&Endalew, 2025; Barooah*et al*., 2023).

Despite women's central role in food production-constituting over 40% of the global agricultural labor force-they often face systemic challenges: limited land rights, restricted access to credit and inputs, exclusion from extension services, and underrepresentation in leadership roles (World Bank, 2022). These gender disparities not only undermine the efficacy of CSA interventions but also widen existing social inequities. Recognizing this, scholars and development practitioners are increasingly advocating for gender-responsive approaches to CSA, with a particular focus on women-led or women-inclusive cooperatives (Simelton*et al*., 2021; Cacchiarelli*et al*., 2024).

Recent studies suggest that carbon farming cooperatives led by or inclusive of women can serve as catalytic institutions-accelerating CSA adoption while empowering women economically and socially. Such cooperatives can foster innovation through peer-to-peer learning, enable collective bargaining for climate finance (e.g., carbon credits), and embed climate resilience within community-based adaptation strategies (Acosta et al., 2021; Olumba&Olumba, 2025).

However, gaps remain in systematically understanding how and under what conditions these cooperatives thrive, especially in diverse agro-ecological and socio-cultural contexts. There is a need to critically examine the interplay between gender, cooperative governance, CSA adoption, and carbon outcomes.

This review article addresses that gap by synthesizing recent empirical research (2020–2025) to explore the potential of women's participation in carbon farming cooperatives as a model for climate-smart agriculture. By doing so, it contributes to gender and climate justice discourses, offering insights for policy formulation, program design, and future research.

2.0 Theoretical Framework

Understanding the transformative role of women in carbon farming cooperatives within the context of climate-smart agriculture (CSA) requires grounding in interdisciplinary theories that span environmental governance, gender studies, and institutional economics. This section elaborates on two interlocking theoretical lenses that guide this review: Feminist Political Ecology and Collective Action Theory. These frameworks offer a holistic understanding of how structural power, gendered institutions, and community cooperation intersect in rural agricultural systems under climate stress.

2.1 Feminist Political Ecology (FPE)

Feminist Political Ecology (FPE) is a critical theoretical framework that interrogates the gendered nature of environmental access, control, and decision-making. FPE holds that environmental issues are not gender-neutral; rather, they are deeply embedded in and shaped by patriarchal systems, colonial histories, and socio-economic inequalities (Rocheleau*et al*., 1996; Nightingale, 2020).

Applied to CSA and carbon farming cooperatives, FPE:

- Reveals how women's access to land, water, and knowledge systems is structurally limited by socio-cultural norms and legal systems.
- Highlights that women often carry a disproportionate burden in climate adaptation efforts (e.g., collecting water, managing subsistence crops) while being excluded from the benefits of climate financing and training programs (Acosta *et al*., 2021; Rao*et al*., 2025).

- Emphasizes the importance of recognizing diverse identities and intersectional experiences (age, caste, marital status, etc.) that affect women's participation in cooperatives and CSA programs.

FPE thus challenges mainstream climate interventions that overlook social hierarchies and suggests that truly sustainable CSA must prioritize inclusive participation, equitable benefit-sharing and structural empowerment.

2.2 Collective Action Theory

Collective Action Theory (Olson, 1965) explains how individuals can overcome coordination challenges and collaborate to achieve shared benefits, especially in managing common-pool resources. In the context of rural agriculture, cooperatives embody the principles of collective action by:

- Pooling resources (capital, labor, knowledge) for economies of scale,
- Facilitating knowledge dissemination on climate-resilient practices,
- Creating social accountability mechanisms that promote sustained behavior change,
- Enabling members to access climate financing schemes (e.g., carbon markets, insurance).

Carbon farming, in particular, demands long-term investment and shared stewardship of ecological systems. When organized as cooperatives, farmers can collectively:

- Adopt carbon-sequestering practices (e.g., agroforestry, composting),
- Monitor emissions reductions for certification,
- Share proceeds from carbon credits or ecosystem service payments.

Crucially, cooperatives reduce the transaction costs and knowledge asymmetries that often exclude smallholders-especially women-from engaging in carbon markets (Lee, 2017; Migadde, 2020).

2.3 Synthesis and Relevance to the Study

By integrating FPE and Collective Action Theory, this study adopts a dual lens:

- FPE ensures a gender-conscious analysis, acknowledging the embedded power dynamics within cooperatives and CSA frameworks.
- Collective Action Theory provides a governance rationale, explaining how and why cooperative models can be effective platforms for implementing CSA and carbon farming.

Together, these frameworks underscore that:

- Women's participation is not merely instrumental but transformative.
- Carbon farming cooperatives are not just technical solutions but also social innovations that can reshape gender norms and power relations in rural communities.

This theoretical grounding sets the stage for the conceptual framework that visually maps the linkages between women's empowerment, cooperative functioning, and CSA outcomes.

3.0 Conceptual Framework

To operationalize the theoretical insights drawn from Feminist Political Ecology and Collective Action Theory, this conceptual framework offers a structured visualization of how women's participation in carbon farming cooperative escatalyzes outcomes in climate-smart agriculture (CSA). The framework outlines the causal pathways linking agency, institutional mechanisms, technical practices, and climate-resilient outcomes, while accounting for mediating gender and power dynamics.

3.1 Framework Diagram and Structure

The conceptual framework consists of four interconnected domains:

1. **Input Domain**: Women's Empowerment and Enabling Conditions
2. **Process Domain**: Cooperative Mechanisms and CSA Practice Adoption
3. **Output Domain**: Soil Carbon Gains, Productivity, and Gender Equity
4. **Outcome Domain**: Community Resilience and Climate Mitigation

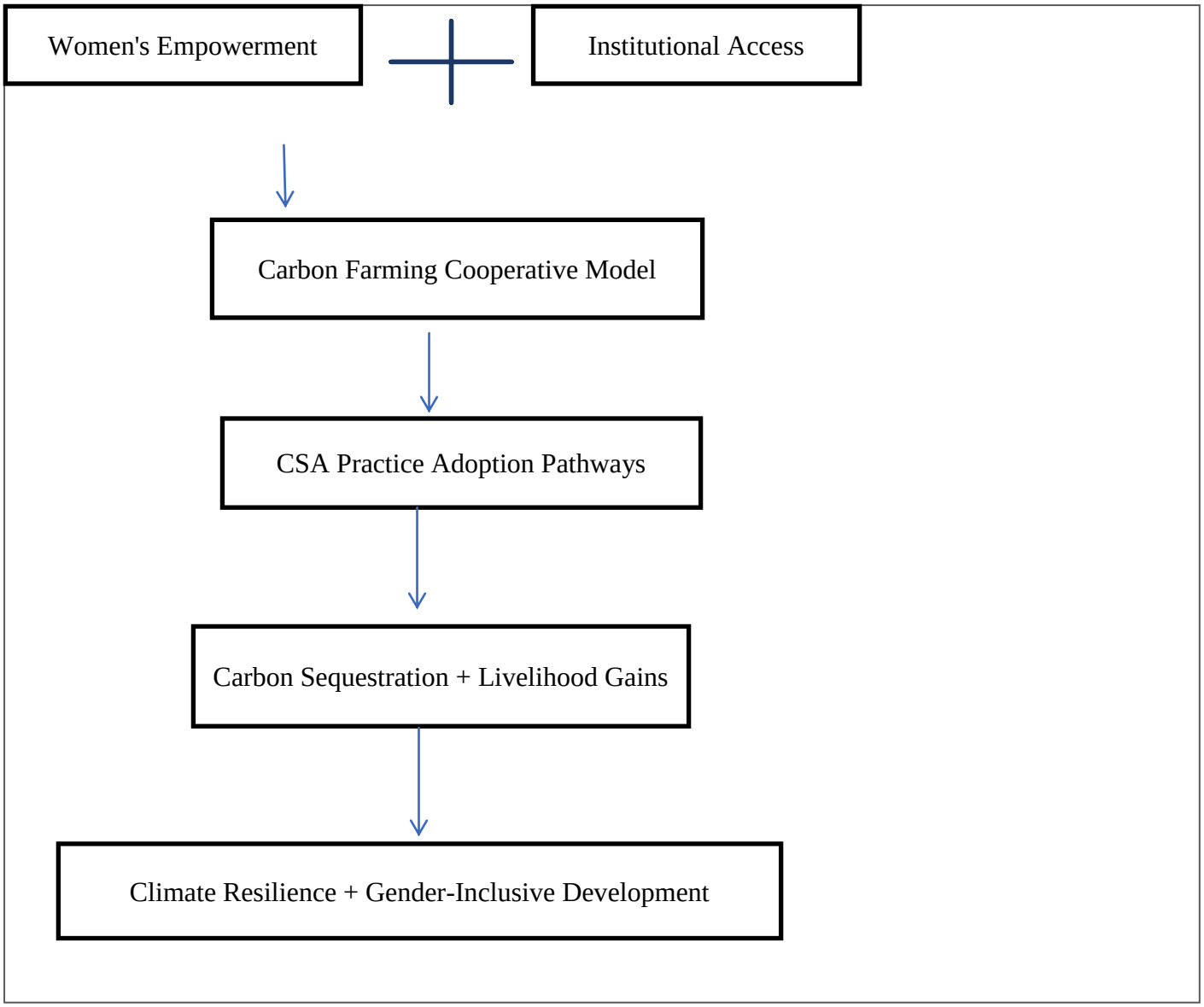

Figure 1: Conceptual framework

3.2 Key Components Explained

A. Inputs: Women's Empowerment and Enabling Conditions

These are the socio-political prerequisites for women's active and sustained engagement in carbon farming cooperatives:

- Land ownership and tenure security
- Access to financial services (e.g., microcredit, climate funds)
- Extension services and training tailored to women's contexts
- Social capital and collective identity, often rooted in women's groups or self-help networks

These inputs align with the agency dimension in feminist political ecology, recognizing that without addressing systemic barriers, participation remains superficial.

B. Processes: Cooperative Mechanisms and CSA Practice Adoption

Cooperatives act as enablers of transformation by:

- Facilitating knowledge exchange (peer learning, demo plots, mobile-based advisories)
- Distributing CSA technologies and inputs (e.g., drought-tolerant seeds, compost kits)
- Aggregating carbon data and providing access to carbon markets

- Encouraging participatory governance that includes women in decision-making roles

This phase highlights the collective action mechanisms that drive sustained behavioral and technological adoption.

C. Outputs: Technical and Social Benefits

Successful implementation results in:

- Improved soil organic carbon through techniques like agroforestry, mulching, reduced tillage
- Increased yields and income diversification through CSA-aligned value chains
- Enhanced gender equity in rural resource governance, as women transition from passive laborers to active agents and decision-makers

D. Outcomes: Climate Resilience and Developmental Impact

Long-term outcomes from sustained cooperative CSA engagement include:

- Increased adaptive capacity of women and communities to climate shocks
- Reduced greenhouse gas emissions, particularly CO_2 from soils
- Institutional sustainability, where cooperatives become platforms for inclusive rural development

These outcomes also contribute to achieving multiple Sustainable Development Goals (SDGs), including:

- **SDG 1** (No Poverty)
- **SDG 5** (Gender Equality)
- **SDG 13** (Climate Action)
- **SDG 15** (Life on Land)

3.3 Relevance and Application

This conceptual model provides a scaffold for both research and policy design, enabling:

- Researchers to empirically test linkages between gender, CSA adoption, and cooperative structure.
- Practitioners to diagnose bottlenecks in cooperative functioning or women's participation.
- Policymakers to tailor interventions that enhance equity while maximizing environmental benefits.

In subsequent sections, the framework guides the methodological approach and helps interpret the empirical evidence reviewed across case studies.

4.0 Research Methodology

This research review adopted a systematic qualitative meta-synthesis approach to consolidate and interpret findings from diverse empirical studies, reports, and scholarly analyses published between 2020 and 2025. The methodology was designed to ensure rigorous identification, selection, evaluation, and synthesis of peer-reviewed literature addressing the intersections of gender, carbon farming, cooperative models, and climate-smart agriculture (CSA).

4.1 Research Design

The methodology followed a multi-stage process:

Stage	Description
1. Problem Identification	Define the central research question: *How do women-led or women-inclusive carbon farming cooperatives contribute to climate-smart agriculture?*
2. Literature Search	Systematic search using academic databases and AI-enhanced scholarly tools (e.g., Google Scholar, Scopus, ScienceDirect, Sider AI).
3. Screening and Selection	Inclusion/exclusion criteria applied to filter relevant studies.
4. Thematic Coding	Extract key variables and themes across studies for synthesis.
5. Meta-Synthesis	Integrate and interpret findings through qualitative synthesis and comparative analysis.

4.2 Search Strategy

To identify relevant literature, the following search keywords and Boolean operators were used:

"women AND carbon farming AND cooperatives" OR "gender AND climate-smart agriculture" OR "women AND CSA AND governance" OR "climate cooperatives AND carbon sequestration AND gender equity"

Databases Searched:

- Google Scholar
- MDPI Journals
- Scopus
- Science Direct
- Wiley Online Library

- CGIAR/CG Space
- PLOS Climate
- Frontiers in Climate

Time Range: January 2020 – May 2025
Languages: English
Article Types: Peer-reviewed journal articles, conference papers, institutional working papers, and systematic reviews.

4.3 Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Studies focused on women in agriculture with climate-smart practices	Articles lacking gender analysis or cooperative dimension
Studies examining cooperatives involved in carbon farming or CSA	Purely theoretical works with no empirical data
Empirical studies from Sub-Saharan Africa, South Asia, and Latin America	Studies not peer-reviewed or lacking methodological transparency
Publications from 2020–2025	Grey literature or anecdotal evidence unless institutionally endorsed

A total of 172 articles were initially retrieved. After screening titles, abstracts, and full texts, 18 high-relevance studies were selected for synthesis.

4.4 Data Extraction and Analysis

Key information was extracted using a data matrix capturing:

- Authors and publication year
- Geographic context
- Study objectives and design
- CSA practices and cooperative features
- Women's participation and empowerment metrics
- Measured outcomes: e.g., yield, soil carbon, income, resilience

Each article was analyzed through thematic coding using NVivo-based inductive techniques, guided by the conceptual framework. Emerging themes included:

- Access to cooperative governance
- CSA technology adoption patterns
- Carbon sequestration indicators
- Social and economic empowerment outcomes

4.5 Quality Assurance

To ensure validity and reliability, the following steps were taken:

- Cross-verification of sources using citation checks and peer-review status.
- Triangulation of findings from multiple regions and disciplines.
- Transparency in selection through documentation of search process and decisions.

Additionally, studies from diverse agro-ecological zones and cultural contexts were purposefully included to enhance generalizability while allowing for contextual insights.

4.6 Limitations

- Geographical skewness: Most empirical studies were concentrated in Sub-Saharan Africa and South Asia; limited data from Latin America and MENA.
- Underreporting of gender-disaggregated data: Several studies lacked rigorous gender impact indicators.
- Carbon measurement inconsistency: Not all studies used standardized methods for quantifying carbon sequestration outcomes.

Despite these limitations, the synthesis provides robust, comparative evidence of the multifaceted role of women in carbon farming cooperatives and their contribution to CSA.

5.0 Results and Discussion

5.1 Enablers of CSA through Cooperatives

Cooperatives function as critical enablers for the adoption and scaling of CSA practices. By organizing farmers-especially marginalized women-into structured collectives, cooperatives:

- **Reduce barriers to technology adoption** by pooling resources for purchasing CSA inputs like drought-tolerant seeds, compost, or irrigation systems.
- **Facilitate knowledge sharing** through group-based training, peer-led demonstrations, and participatory learning platforms (Aryal*et al.*, 2020; Simelton*et al.*, 2021).
- **Enable collective market access** for produce and environmental services (e.g., carbon credits), enhancing the economic viability of CSA.

For example, **carbon farming cooperatives in Uganda** implemented under the Van Hall Larenstein program trained women farmers in biochar production and soil carbon monitoring, leading to increased adoption of sustainable land practices (Migadde, 2020). In India, local cooperatives helped institutionalize agroecological practices among women's groups, improving yields and reducing emissions (Barooah *et al*., 2023).

5.2 Women's Participation and Empowerment Outcomes

Empirical studies consistently highlight that when women are actively involved in cooperatives, they experience multiple dimensions of empowerment:

a) Decision-Making Power

Participation in cooperatives enhances women's voice in household and farming decisions. A study in the Indo-Gangetic Plains revealed that women members of farmer groups were 47% more likely to influence CSA adoption decisions (Aryal *et al*., 2020).

b) Access to Resources

Through cooperatives, women gained access to:

- Extension services
- Agricultural insurance schemes
- Climate finance instruments like Results-Based Payments (Rao et al., 2025; Olumba&Olumba, 2025)

c) Social Capital and Leadership

Cooperative models supported the rise of women leaders in local governance. In the Manyakabi Area Cooperative in Uganda, women held 38% of board positions by 2022 (Huyer, 2021).

These gains are not merely developmental but foundational for gender justice in climate response. Feminist political ecology underscores this shift as a disruption of traditional gendered power structures in rural communities (Acosta *et al*., 2021).

5.3 Carbon Sequestration and Environmental Outcomes

Adoption of CSA practices via cooperatives has shown measurable ecological benefits, particularly in soil carbon retention and emission reduction. Key techniques include:

CSA Technique	Reported Outcome	Study Reference
Agroforestry	+22% in SOC* over 3 years	Nipa (2024)
Biochar addition	-18% in net CO_2 emissions	Migadde (2020)
Cover cropping	Reduced erosion and nitrogen loss	Mizik (2021)
Reduced tillage	SOC increase by 0.4% annually	Lee (2017)

*SOC = Soil Organic Carbon

In a study by Cacchiarelli *et al*. (2024), across 17 African cooperatives, women-led initiatives were more likely to engage in regenerative practices due to strong peer enforcement and participatory accountability.

Moreover, cooperatives were more successful than individual farmers in accessing carbon credit schemes, as the collective structure reduced transaction costs and improved monitoring capacities.

5.4 Challenges and Structural Barriers

Despite the clear benefits, several barriers continue to limit the full potential of women-led carbon farming cooperatives:

a) Gendered Land Tenure Insecurity

In many regions, women still lack legal ownership of land, making them ineligible for CSA subsidies, long-term climate financing, or carbon offset registration. This restricts their agency despite active participation.

b) Gender Bias in Extension Services

According to Boudalia *et al*. (2024), only 5% of agricultural extension services in Africa target women, often delivered at times or in locations unsuitable for their domestic workload.

c) Limited Financial Literacy and Market Integration

Women in cooperatives are less likely to receive training in financial management or carbon market dynamics. This hinders their ability to benefit from Results-Based Financing (RBF) or climate-smart value chains (Olumba&Olumba, 2025).

d) Cultural Norms and Power Asymmetries

In patriarchal contexts, men may dominate cooperative leadership, relegating women to auxiliary roles. Without deliberate quotas or legal safeguards, these hierarchies persist.

5.5 Cross-Cutting Insights

- **Context matters**: Cooperative impact varies significantly by region, depending on land laws, climate policies, and cultural norms (Kahsay&Endalew, 2025).

- **Women's cooperatives outperform mixed-gender groups** when focused on CSA-due to stronger internal trust, flexibility, and community mobilization.
- **Sustainability requires policy support**: Without enabling state frameworks or public-private partnerships, cooperatives often lack resources for continuity.

5.6 Comparative Summary Table

Region	Cooperative Model	CSA Practices Adopted	Main Benefits	Barriers
Uganda	Women-led agroforestry groups	Biochar, composting	Soil restoration, income boost	Land insecurity
India	Mixed-gender self-help groups	Conservation tillage, micro-irrigation	Resilience to drought	Extension bias
Nigeria	Farming associations	Drought-resistant crops, mulching	Market access, food security	Credit constraints
Latin America	Climate-Smart Villages	Farmer field schools, crop rotation	Women's leadership growth	Language/education gaps

Women-inclusive and women-led cooperatives in carbon farming present an **effective grassroots mechanism** for implementing CSA. The model improves environmental performance, empowers marginalized farmers, and offers a participatory pathway toward sustainable development. However, realizing their full potential depends on addressing **deep-seated gender inequalities** and **institutional blind spots** that limit women's agency.

6.0 Conclusion

The integration of women into carbon farming cooperatives offers a compelling model for advancing climate-smart agriculture (CSA). This review has demonstrated that such cooperatives serve as powerful platforms for enhancing both environmental resilience and social equity. By organizing farmers around shared ecological goals-particularly those related to carbon sequestration-cooperatives facilitate the adoption of sustainable practices such as agroforestry, reduced tillage, and organic soil management.

Crucially, the inclusion of women in these cooperatives is not merely a symbolic gesture. It is transformative: women's participation enhances decision-making diversity, ensures equitable distribution of benefits, and leverages local ecological knowledge often excluded from mainstream agricultural interventions. Case studies from Uganda, India, Nigeria, and Latin America illustrate that women-led or women-inclusive cooperatives consistently outperform their counterparts in climate resilience metrics and community-level impact.

However, the success of these models is not guaranteed. Persistent barriers-including gendered access to land and finance, limited technical training, sociocultural restrictions, and policy gaps-undermine the scalability and sustainability of cooperative-driven CSA. Without targeted interventions that dismantle these barriers, the full potential of women as climate change leaders remains unrealized.

In essence, carbon farming cooperatives represent more than a technical solution-they are a social innovation that bridges climate mitigation, rural development, and gender equality. Their replication and scaling should be a priority for governments, NGOs, and multilateral agencies committed to inclusive and sustainable agricultural transitions.

7.0 Policy Implications and Recommendations

To maximize the impact of women-led carbon farming cooperatives on climate-smart agriculture, the following policy actions and strategic interventions are recommended:

7.1 Legal and Institutional Reform

- **Secure Land Tenure for Women**
  Governments must prioritize gender-equitable land reforms that recognize and

formalize women's land rights-enabling them to register cooperative membership, access climate funds, and claim carbon credits.

- **Enact Cooperative Gender Mandates**
  National cooperative legislation should include mandatory gender quotas in leadership and membership, as practiced successfully in Rwanda and Kenya.

7.2 Climate Finance and Market Access

- **Support Women's Entry into Carbon Markets**
  Introduce simplified and inclusive carbon credit registration frameworks tailored for smallholder cooperatives. Provide grants for monitoring equipment, data systems, and training.
- **Establish Gender-Smart Climate Funds**
  Create targeted funding windows for women's cooperatives under Green Climate Fund (GCF), Adaptation Fund, and national climate finance schemes. Provide results-based financing (RBF) for verified carbon farming outcomes.

7.3 Capacity Building and Extension Reform

- **Scale Gender-Responsive CSA Training**
  Extension services must be overhauled to:
  - Schedule trainings at times accessible to women
  - Include women facilitators and trainers
  - Use local dialects and participatory tools
- **Promote Peer Learning Networks**
  Invest in women-to-women farmer field schools, cooperative exchanges, and mentorship programs that build trust and confidence in CSA adoption.

7.4 Data, Monitoring, and Evaluation

- **Develop Gender-Disaggregated Climate Indicators**
  Governments and donors should require all CSA projects and cooperatives to track:
  - Women's participation and leadership rates
  - Gendered outcomes in yield, income, and climate resilience
- **Encourage Participatory M&E Systems**
  Allow women cooperative members to co-design and implement monitoring tools. This enhances data accuracy and ownership.

7.5 Integrated Rural Development Approach

- **Link Cooperatives to Broader Services**
  CSA cooperatives should be embedded in local development ecosystems by connecting members to:
  - Health care
  - Education
  - Social protection schemes
  - Infrastructure projects (e.g., water harvesting, rural roads)
- **Foster Public–Private–Community Partnerships (PPCPs)**
  Encourage collaborations between governments, agribusiness, civil society, and cooperatives to co-finance CSA projects and ensure long-term sustainability.

To meet global climate targets and achieve the Sustainable Development Goals (SDGs), climate action must be inclusive, equitable, and participatory. Women in carbon farming cooperatives offer a grounded, proven, and scalable model for just transitions in agriculture.

It is time to move beyond pilot projects and embed these models in mainstream agricultural policy and planning-transforming not just how we grow food, but who holds power in shaping our ecological future.

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