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Original Article

Integrating Sustainable Carbon Farming and Gender Equality: A Critical Interdisciplinary Review

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Abstract

Sustainable carbon farming has become an important tool to fight climate change and improve soil health supporting ecosystem resilience. But there has been little research on the intersection of carbon farming policies and gender equality. The review consolidates interdisciplinary knowledge about the effects of sustainable carbon farming activities with respect to, and as an influence on, gender relations, especially in rural and agrarian communities. Basing on more than twenty academic papers from environmental science, gender studies and agricultural economy, the paper constructs a dual-framework analysis-ecological sustainability and gender inclusion-to examine synergies and tensions within the implementation of gender equitable carbon farming policies. The results indicate a significant deficit in the equity of participation, benefits and roles provided for women, who are nevertheless predominantly involved in managing land. The study ends with policy recommendations for the mainstreaming of gender in carbon farming programs: the importance of participation, capacity development, and just access to climate finance.

Keywords

Carbon Farming; Climate-Smart; Equity; Gender; Women's Role in Agriculture, Environmental Justice

Introduction

The planet-scale imperative of combating climate change has pushed sustainable-agriculture innovations to focus in environmental policy and practice. One of these innovations, carbon farming — a set of agricultural practices designed to enhance soil C sequestration and mitigate GHG emissions (Paustian et al., 2016; Lal, 2020) — has risen as a house-highlights potential path to the achievement of climate-smart agriculture. These practices, such as conservation tillage, cover cropping, agroforestry, biochar application and better grazing, provide not only ecological benefits but the key to unlocking barren lands for transformation towards greater food security and facilitating rural development.

There is also a growing international acknowledgement that such action needs to be socially inclusive and just, drawing on Sustainable Development Goal 5 around gender equality and Goal 13 on climate action (UN Women, 2020; FAO, 2022). But the mainstreaming of gender equality is still largely secondary in carbon farming initiatives. While women are central actors in smallholder agriculture—contributing 60–80% of food production (Quisumbing et al., 2015), they still face systemic hurdles to land ownership, agricultural extension services, access to climate finance and decision-making power (Aguilar et al., 2018).

Notwithstanding this ecological and social potential of carbon farming, gendered dimensions are frequently overlooked in designs and implementation of such interventions. Policies and programmes commonly embrace a gender-blind approach, in which equal opportunities and benefits for all-including women - are presumed; such belief does not correspond to reality. During the process, wealth creation is also skewed such that even with all of these

efforts, women continue to be left out and excluded from participating in these projects, leadership roles as well as income benefits (contributed by carbon markets) making it risked not only to generate but also perpetuate further vulnerability of women (Nelson & Huyer 2016).

This review aims to address this important gap by framing sustainable carbon farming in the context of gender equality through an interdisciplinary approach at the intersection between environmental science, political ecology and feminist theory. Specifically, it aims to:

- Analyze the degree to which existing carbon farming modalities incorporate gender-responsive principles;
- discovering structural and cultural obstacles preventing women to be involved in carbon farming;
- Showcase best practices and case studies that illustrate the potential of gender-inclusive carbon farming; and
- Offer evidence-based guidance on fairer, stronger and different climate entry strategies.

From this perspective, the paper argues for a transition to gender-transformative approaches that involve women not only as participants in carbon farming programs but also as drivers of environmental change and players at the global climate policy table.

Theoretical Framework

The study is informed by an eco-feminist political ecology perspective, a perspective which deconstructs the links between ecological destruction, gender power relations and socio-political formations. As demonstrated by Rocheleau, Thomas-Slayter, and Wangari (1996), eco-feminist political ecology acknowledges that environmental crises are not gender neutral. Instead, they are rooted in historical and structural inequalities that affect women negatively—in particular those living in rural and agricultural areas. These inequalities are perpetuated by colonial legacies, neoliberal land policies and technocratic climate solutions that frequently fail to respect local knowledge and the unpaid labor of women.

In this way, eco-feminist political ecology contests the prevailing technocentric and market-based discourses on carbon farming that are instead based on inclusivity, rights and justice as sustainability. In doing so, environmental degradation and gender oppression are understood as co-produced by patriarchal and capitalist systems that commodify nature alongside women's labor. Carbon farming, if gender-blind, is in danger of reproducing these exploitative dynamics through male-elite driven governance, the unequal distribution of land tenure and limited access to climate finance.

Besides eco-feminism, the thesis also places a focus on intersectionality theory (Crenshaw, 1989) in order to enrich its analysis of varying experiences. Intersectionality demonstrates that there is no single "woman's" experience in agricultural systems, only a complex web of intersecting identities (such as class, ethnicity, age, caste and marital status) which shape or frame women's experiences. For example, a forest margin dwelling indigenous widow may face much higher transaction costs to access carbon farming schemes than an attached peri-urban cooperative woman.

Taken together, the two approaches offer a strong theoretical foundation for examining:

- Who gets to define sustainability?
- Who has the power and profits in carbon credits?
- How does power and privilege influence who participates in and benefits from climate-smart agriculture?

They give a way to critically analyse climate mitigation discourse and practice while eschewing tokenistic gender inclusion in favour of transformative, emancipatory forms of climate justice.

Conceptual Framework

The conceptual lens through which we read is the bridging of ecological aspirations for carbon farming and social determinations for gender equity. It is based on two related axes which capture the essential aspects of sustainable and equitable carbon farming:

A. Axis A – Sustainability Dimension

This dimension assesses the environmental effectiveness of carbon farming measures, and is based on three components:

- Carbon Sequestration Potential - The ability of a specific method (e.g., agroforestry, biochar, conservation tillage) in agriculture to store more organic carbon in soil and emit less greenhouse gases.
- Soil health enhancements – comprised of physical (structure, porosity), chemical (PH, nutrient holding) and biological (microbial diversity, organic material) measures.

- Climate Resilience - The capacity of the agroecosystem and community to resist and accommodate unexpected natural phenomena due to climate (i.e. drought, erratic rainfall, temperature extremes).

B. Axis B – Dimension of Gender Equality

The social inclusiveness and justice aspects of carbon farming activities (This axis refers to:

- Land Tenure and Access: Assesses whether women have secure and recognized rights to land (access, ownership as well as inheritance and usufructuary rights) in both statutory law and under customary law.
- Roles in Decision-Making: Whether women are represented and carry influence in the local public bodies, smallholder organisations, and carbon project planning institutions.
- (4) Access to Technology and Climate Finance: Assess if women have equal access to carbon monitoring technologies, extension services, mobile -based applications, and the same rights as men when it comes to benefits from carbon-credit revenues or subsidies.

C. Framework Application: Integrated Evaluation Matrix

The intersection of these axes provides a conceptual matrix which can be utilized to assess particular carbon farming interventions or projects along four quadrants:

Quadrant	Sustainability Performance	Gender Equality Performance	Implication
A	High	High	Ideal Model (Scalable)
B	High	Low	Technocratic, Inequitable
C	Low	High	Socially Inclusive, Ecologically Weak
D	Low	Low	Unsustainable and Exclusive

The matrix helps diagnose strengths and weaknesses in the design and implementation of projects that should provide ecologically viable and socially just climate mitigation.

D. Axis A - Sustainability Dimension

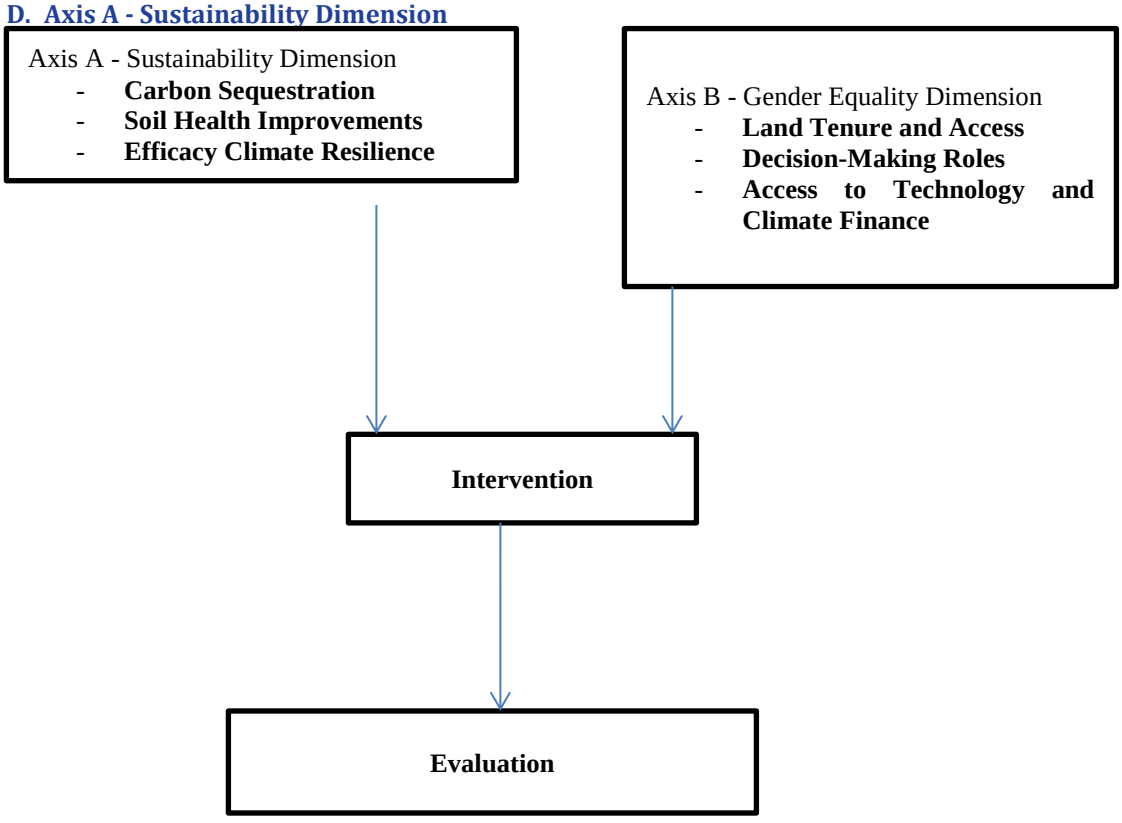

Figure 1: Conceptual framework

Research Methodology

This paper adopts a strong Systematic Literature Review (SLR) and consolidating the empirical evidence base at the nexus of Gender Equality, and Carbon Farming. The methodological approach adheres to academic standards of systematic review (e.g., PRISMA 2020) and combines qualitative thematic analysis in uncovering central trends, gaps, and policy considerations.

A. Research Design

The research approach is based on a qualitative meta-synthesis of the empirical literature. A systematic literature review (SLR) was selected for transparency in the methodology, reduction of bias and to facilitate comparison between different studies. The overall process consisted of three primary phases:

- Identification: Literature search using predefined search terms.
- Selection: Screening of title, abstract and inclusion.
- Methods of analysis: Thematic coding and cross-case comparison to identify patterns and insights.

Joined thematic coding and content analysis were applied to draw together case study findings, with specific attention dedicated to the location of cases, gender relations from cases, environmental outcomes presented in articles on a case-by-case basis and patterns of institutional arrangements as reported in literature.

B. Data Collection

There were 25 peer-reviewed articles, books and grey literature reports in the data corpus, which were retrieved across a range of databases:

- Library Sources: Scopus, Web of Science, JSTOR and Google Scholar.
- Official Reports: FAO, CIFOR, CGIAR, UNFCCC and World Bank reports containing empirical case elements.
- The search was performed with the use of Boolean operators (e.g., “carbon farming” AND “gender,” “climate-smart agriculture” OR “REDD+” AND “women”) to narrow down and increase relevance.

C. Keywords Used

- "Carbon farming"
- "Climate-smart agriculture"
- "Gender equality"
- "Women in agriculture"
- "Sustainable land management"
- "REDD+ and gender"
- "Agroforestry and women"

Reference snowballing was used wherever applicable to identify papers with high citations or relevance which were missed in the original database searches.

D. Inclusion Criteria

The following studies met the inclusion criteria of this review:

Criterion	Description
Study Type	Empirical studies, case studies, program evaluations, and meta-analyses
Topical Focus	Must address carbon farming, REDD+, agroecology, or climate-smart agriculture with a gender or social inclusion lens
Publication Type	Peer-reviewed journal articles, institutional working papers, and policy reports
Language	English only
Time Frame	Studies published between **2014–2024** to capture both pre- and post-Paris Agreement developments
Geographic Scope	Global South focus (Africa, Asia, Latin America), though relevant global or comparative studies were also included

E. Exclusion Criteria

- Papers that are entirely theoretical and lack empirical support
- Technical studies no more on gender, land rights or social structures
- Publications not reported in the English language because of the inability to translate
- Such papers are those limited to mitigation technologies with the exclusion of sociopolitical analysis

F. Data Analysis

We performed thematic coding with NVivo 12 software which made possible to analyse in-depth the qualitative information from the studies that were selected. Key themes identified included:

- Women's Land Tenure and Property Rights
- Participation in decision-making structures
- Access to markets and finance for carbon
- Gender-responsive agroecological innovations
- Institutional and policy constraints

Cross-case synthesis allowed for the classification of successful gender-integrated models, structural barriers and contextual variables (e.g., customary tenure regimes, donor intervention, co-benefit incentives) that are important to consider.

Reliability was strengthened by triangulation with other datasets and policy frameworks (e.g.UNFCCC gender action plans, FAO statistics on landownership).

Results and Discussion

A. Limited Female Participation

Despite performing 60–80% of labour in smallholder agriculture throughout Sub Saharan Africa and regions of Asia, women remain relatively invisible in formal carbon farming projects (FAO,2018). They are constrained culturally and institutionally from enrolling in training programs, using extension services, or joining land-user cooperatives which distribute the benefits of carbon market credits.

A fundamental structural bottleneck is lack of secure land tenure. Customary systems tend to disadvantage women because they are patriarchal inheritance laws and land registration practices that identify male heads of households as owners. Where ownership is not recognized, women cannot engage in carbon offset schemes which require demonstration of land stewardship (Meinzen-Dick et al., 2019).

Moreover, technical gatekeeping such as the application of digital tools for carbon measurement or remote sensing is putting extra disadvantages to women who may not dispose over skills on digital literacy and mobile technologies(Jost et al., 2016). This exclusion is further experienced in indigenous and ethnic minority groups where intersectional discrimination related to gender and ethnicity is common (Colfer, et al., 2015).

Illustration: Women in local forest management committees In Ethiopia's Humbo community afforestation project, women were not fully represented on the local forest management committee despite being involved as collectors of biomass and stewards of agroforestry practices (Shames et al., 2022).

B. Gendered Implications on Carbon Sequestration Benefits

While it is usually women who are hit hardest by ecological breakdown- for example as wood for cooking or animal fodder becomes scarce, or as soil fertility declines- they tend to be the last in line to tap any potential carbon farm windfall in the form of a payment for carbon credits, direct investment or subsidy. These financial flows frequently run through male- dominated community institutions, and power dynamics operate to shape the sharing of benefits (Kulkarni et al., 2022).

Even when women contribute equally to tasks such as composting, tree planting, or conservation tillage, acknowledgment and payment are seldom shared fairly. A study in Uganda also showed that while women planted 70% of the different trees for a reforestation programme, fewer than 30% of them were getting payments from the carbon credits it produced (Agarwal, 2020).

Moreover, the rewards from carbon farming are not all financial. Also the differences in endowments on social capital, access to extension support and training are not evenly distributed. It is normal for women to feel uncomfortable with mixed training or having to make long journeys to project sites,P Shades of grey: the role of gender in community-based adaptation programmes.

Conclusion: The gendered distribution of non-financial resources (e.g., access to seedlings, extension workers) undermines the carbon farming sustainability by excluding half the farming population.

C. Institutional Gaps

Carbon farming standards meanwhile—both at large-scale scales such as REDD+ and Clean Development Mechanism (CDM) but also at project-level—have been characterised by a gender-neutral approach, with an

assumption that all those participating will benefit in the same way. But this empty-handedness often turns into a willful blind against gender background, about the way in which structural inequality conditions access, participation and control.

For instance, REDD+ initiatives were found to lack gender safeguards leading to elite capture by male leaders and exclusion of women from benefit sharing (Phiri et al., 2021; Larson et al., 2018). In addition, the majority of the MRV systems lack gender disaggregated data, which impedes assessing a gender impact and ensuring that gender commitments are met.

Institutional architectures frequently also fail to include affirmative action, such as quotas for women on carbon project governance boards, or ring-fenced funding for women's cooperatives participating in the carbon markets.

Observation: Without gender mainstreaming, carbon farming could perpetuate the same inequalities it aims to address, especially under patriarchal agrarian economies.

D. Success Stories: Gender-Integrated Models

Yet there have been some success stories — case studies in which carbon farming has deliberately prioritised women, with beneficial results for both the environment and local populations.

a) Kenya: The Kenya Agricultural Carbon Project (KACP)

This initiative, which was led by Vi Agroforestry with support from the World Bank, provided more than 60,000 farmers—40% of whom were women—with training in sustainable land management and how to measure carbon. Women participated in participatory mapping and soil-testing, and women "emerged as leading farmers" in terms of the spread of techniques like agroforestry and mulching (Bryan et al., 2018).

b) Nepal: Community Forest Users Groups (CFUGs)

Conclusion In Nepal CFUGs have been a global model for integrated forestry and gender justice. In many of the CFUGs participating in carbon credit schemes, women make up more than 50 percent of their executive committees. As co-stewards, these women have demonstrated carbon accounting and how funds should stem down to households headed by females and girls' education (Gurung et al., 2020).

c) India: Women-Farmer Producer Organizations (FPOs)

In Maharashtra and Madhya Pradesh, woman-headed FPOs have taken on biochar and composting with the support of local NGOs and engaged in voluntary carbon markets. These groups re-allocated own-acquired carbon credits to contribute funds for maternal health centers and water points, demonstrating how gender-sensitive CSAs can generate their multifunctional co-benefits for development (Bhattarai et al., 2021).

d) Key Factors for Success

- Integration of women in project planning and MRV systems
- Title to Royalty recognition and issuance of community land use certificates
- Gender sensitive climate-smart technology focused trainings

Conclusion

Sustainable carbon sequestration is seen as a remarkable opportunity to address climate change and restore degraded agricultural land – especially in the Global South. Soil organic carbon management for example, through agroforestry, conservation tillage and using nutrient-rich organic compost is one way in which carbon farming can be effective in climate adaptation as well as rural livelihoods. But the social and economic effects of such interventions are not evenly distributed.

Furthermore, gender inequality continues to be an obstacle that hampers the overall success of such carbon sequestration initiatives with regard to inclusivity. Without the priority of incorporating gender-responsiveness, carbon initiatives risk reinforcing or worsening existing forms of power inequality, particularly in customary land tenure where there is less legal recognition and control to implement changes by women.

Women are not merely passive recipients, but potential agents of environmental care such as soil fertility management, agro-biodiversity and local knowledge systems. By excluding them from the planning, decision-making and revenues of carbon projects we not only violate principles of social justice, but also their technical effectiveness. There is evidence that these gender-sensitive strategies lead to increased participation rates, enhanced uptake of sustainable interventions and more equal sharing of benefits.

For carbon farming to succeed holistically as a climate and social-engineering solution, the following priorities must be formalized:

- Ensure women's land and natural resources rights by reforming laws and implementing participatory models of land governance.
- Enhancing gendered capacity to use digital tools, soil science and carbon accounting to account for knowledge technology deficit.
- Fair share of climate finance, including the carbon market and safeguards to guarantee benefits for women-led co-operatives and households.
- Institutional requirements for sex-disaggregated data, evidence monitoring and accountability mechanisms to monitor achievement of goals and address inequalities.

At the end of the day, climate transformation is also not possible without gender justice. A feminist approach in carbon farming isn't only a normative one, but also a strategic one—based on the evidence that gender-inclusive approaches drive more resilient ecosystems, empowered communities and sustained climate gains.

With the climate crisis escalating, infusing equity into mitigation strategies like carbon farming is no longer simply good to have-it's a must.

Policy Implications and Recommendations

To bridge the gender gap in carbon farming and for climate-smart agriculture to strengthen both ecological and social resilience, specific and transformative policy interventions are necessary. Final recommendations are outlined in Additional file 2 and are based on empirical evidence, case studies as well as best practice.

A. Policy Mainstreaming

- Mainstream gender equality as a principle in all carbon-farming–related policy instruments, including NDCs, REDD+ frameworks, and climate-smart agriculture strategies.
- All climate action should be required to include a Gender Action Plan (GAP) as part of its architecture, not as an option, but as a performance indicator linked to funding release (UNFCCC, 2019).
- For example, the FCPF Carbon Fund has adopted gender integration guidance that can be adapted at the national and sub-national levels.
- Policy needs to ensure that women are legally represented in all land management decision making and carbon finance.

B. Gender-Sensitive Land Reforms

- Insecure land tenure is one of the most frequent obstacles to women's involvement in carbon farming.
- Reforms should also consider the right of women to own and inherit property under statutory and customary law.
- Evidence from Rwanda and Ethiopia suggest that joint titling policies, which entitle land holding registration in the names of both spouses, does increase women's agricultural investment and access to incentives (Ali et al., 2014).
- Governments could form community-based adjudication committees for land disputes with gender parity that also documented tenure.

C. Capacity Building

- Programmes of training should be adapted to perceived differences in knowledge needs and constraints between men and women in agriculture.
- Extension services have to create women-friendly curricula in local languages and combine traditional knowledge with modern science.
- Training should include soil carbon sampling, biochar application and agroecological design using technologies for monitoring carbon.
- For example, programs such as Women in Agroecology Leadership for Conservation (WALC) based in the Central America offer evidence of how mentorship, peer learning approaches can help to diversify and empower rural women farmers.

D. Equitable Financing

- Climate finance needs to be redesigned so that women have access to credit, insurance and carbon markets.

- Create dedicated financing mechanisms, such as gender-responsive climate funds or grants for women's cooperatives involved in carbon farming.
- Develop low-barrier application processes for smallholder women farmers to access carbon credit programs–– in plain language, with less collateral and mobile-based submissions.
- Public-private partnerships should provide climate resilient farming with matching grants, micro-insurance or revolving loans adapted to gender specific constraints.

E. Monitoring and Accountability

- Transparency in data practices is essential for monitoring and addressing gender imbalances.
- Demand for gender-disaggregated data in reporting on land ownership, benefit sharing, training attendance, carbon credit revenues.
- Create impact evaluation systems that measure how projects change power dynamics with households and communities, not just carbon commutes.
- Utilize participatory monitoring methods, such as gender audits and community score cards, to empower local women to assess programme impacts and hold implementing agencies accountable.

This suite of policy recommendations is not a series of isolated fixes but a set of interlocking levers for transformation. By linking gender equity with the goals of carbon farming, policy makers can ensure that climate action does not just work, but is also just and inclusive.

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