FEMALE SOCIOECOLOGICAL INFRASTRUCTURE IN THE CAATINGA: WOMEN, SOCIAL TECHNOLOGIES, AND BIOCULTURAL RESILIENCE IN THE BRAZILIAN SEMI-ARID

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Abstract: Dryland territories have increasingly become central to global debates on climate adaptation and sustainability. In the Brazilian Semi-Arid region, particularly within the Caatinga biome, socioecological resilience emerges from the interaction between environmental constraints, local knowledge systems, and community-based resource management. However, the role of women in sustaining these adaptive processes often remains underestimated or analytically fragmented in the literature. This study aims to analyze how women's protagonism contributes to the construction of biocultural resilience in the Caatinga through the adoption and management of social technologies. Methodologically, the research adopts an integrative literature review conducted between October

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2025 and February 2026 in the databases Web of Science, Scopus, SciELO, and DOAJ. An initial set of 279 records was identified, from which a final corpus of 25 studies was selected through systematic screening procedures. The results indicate that women play a strategic role in the governance of water resources, agroecological food production, seed conservation, and community organization, forming a network of practices that sustain local socioecological systems. Social technologies such as rainwater harvesting cisterns, agroecological home gardens, and community seed banks strengthen territorial resilience while simultaneously revealing tensions between empowerment and the persistence of gendered labor burdens. The study proposes the concept of female socioecological infrastructure to describe the network of practices, knowledge systems, and social relations through which women sustain ecological and social reproduction in dryland territories. Recognizing these dynamics is essential for developing climate adaptation strategies that integrate gender justice, territorial governance, and socioecological sustainability in the Brazilian Semi-Arid.

Keywords: Agroecology. Commons Governance. Climate Adaptation. Gendered Labor. Territorial Sustainability.

INTRODUCTION

Dryland regions occupy a significant portion of the Earth's land surface and sustain millions of livelihoods that depend directly on climate-sensitive ecosystems. The Brazilian Semi-Arid region, dominated by the Caatinga biome, exemplifies the complex interaction between climatic variability, environmental fragility, and historically rooted social inequalities. Recurrent droughts, irregular rainfall regimes, land degradation, and processes associated with desertification interact with structural socio-economic vulnerabilities, producing a landscape where environmental stress and social marginalization reinforce one another.

Recent scholarship, however, challenges narratives that portray drylands solely through

scarcity and degradation. These territories are increasingly interpreted as dynamic socioecological systems shaped by long-term processes of adaptation, collective organization, and ecological knowledge. From this perspective, sustainability in drylands cannot be understood exclusively through technocratic environmental management but must be analyzed as the outcome of interactions between ecological constraints, social institutions, and culturally embedded practices (Leach et al., 2010). Political ecology perspectives further highlight that environmental vulnerability is unevenly distributed and deeply entangled with power relations, ecological conflicts, and development models that shape access to natural resources (Martínez-Alier, 2014). Consequently, climate adaptation in drylands must be understood as a socio-political process in which knowledge, authority, and environmental governance are continuously negotiated (Nightingale, 2015).

Despite growing attention to climate adaptation in drylands, gender relations remain insufficiently incorporated into analyses of socioecological resilience. In rural territories, women frequently play a central role in sustaining household reproduction and environmental management through activities such as food production, water management, seed conservation, and community organization. These practices simultaneously support food security, biodiversity conservation, and adaptive capacity under conditions of climatic uncertainty, yet they often remain undervalued within conventional development frameworks (FAO, 2023).

Women's environmental labor occupies a strategic position at the intersection of domestic reproduction and ecological stewardship. Tasks such as maintaining household gardens, processing food, managing water resources, and conserving seeds constitute forms of care work that directly sustain socioecological systems. However, because these activities are embedded within domestic and informal spheres, they are frequently excluded from institutional indicators of rural development. In the Brazilian Semi-Arid region, women's leadership in agroecological initiatives and community resource management has been widely documented, revealing their critical role in strengthening both environmental sustainability and collective resilience (Siliprandi, 2015). Nevertheless, structural inequalities persist, as women continue to face restricted access to land, credit, and institutional

decision-making, conditions that intensify gender disparities in contexts of environmental change (UN Women, 2022).

Although the literature on agroecology, commons governance, and gender has expanded considerably, the relationship between female protagonism, social technologies, and biocultural resilience in dryland territories remains insufficiently theorized. In the Brazilian Semi-Arid region, social technologies such as rainwater harvesting systems, community seed banks, and agroecological household gardens have been widely promoted as strategies to strengthen food sovereignty, ecological sustainability, and local autonomy. These initiatives are often presented as innovative mechanisms for adapting to climatic variability while reinforcing territorial resilience.

However, the social dynamics underlying these technologies remain underexamined. While they may create opportunities for women's empowerment and participation in community governance, they may also reinforce gendered divisions of environmental labor if responsibility for their operation disproportionately falls on women without corresponding shifts in power relations. Addressing this tension requires a conceptual framework capable of linking gender, ecological governance, and cultural knowledge.

Debates on biocultural resilience emphasize that socioecological sustainability depends not only on ecosystem conservation but also on the maintenance of cultural practices, knowledge systems, and collective institutions that mediate human–environment relations (Escobar, 2018). Agroecology contributes to this perspective by promoting production systems grounded in ecological principles, local knowledge, and social organization as foundations for sustainable rural livelihoods (Altieri; Nicholls, 2017). Despite these advances, the literature still lacks a systematic analysis of how female protagonism mediates the relationship between social technologies and biocultural resilience in semi-arid territories.

This study therefore aims to critically synthesize the scientific literature in order to analyze how women's protagonism in the Caatinga contributes to the construction of biocultural resilience through the adoption and management of social technologies, while also examining the tensions

between empowerment, environmental labor, and gendered power relations.

THEORETICAL FRAMEWORK

Decolonial Ecofeminism and the Politics of Nature

Ecofeminist scholarship has long argued that the exploitation of nature and the subordination of women are historically interconnected processes embedded in the structures of patriarchy, capitalism, and colonial expansion. However, contemporary debates increasingly challenge essentialist interpretations that portray women as inherently closer to nature. Instead, critical ecofeminism emphasizes that the association between women and environmental stewardship emerges from historically produced divisions of labor, power relations, and material conditions within agrarian societies.

In this perspective, ecofeminism must be understood not as a biological claim but as a political critique of the economic and epistemic systems that simultaneously devalue reproductive labor and degrade ecosystems. Federici (2019) argues that capitalist accumulation has historically depended on the invisibilization of reproductive labor and the enclosure of commons, processes that reorganized both gender relations and ecological governance. As she notes, “the degradation of women and the degradation of nature are interconnected processes within capitalist development” (Federici, 2019). This insight reveals how environmental crises are inseparable from broader political economies that externalize the costs of both ecological regeneration and social reproduction.

Similarly, ecofeminist thinkers have emphasized that the struggle for ecological sustainability cannot be detached from struggles for social justice and gender equality. Shiva (2016) famously describes women’s environmental knowledge as emerging from everyday practices of survival and subsistence economies, observing that “women have been the custodians of biodiversity through their knowledge of seeds, food and healing systems” (Shiva, 2016). While such arguments have sometimes been interpreted as essentialist, more recent interpretations stress that these forms of ecological

knowledge are socially constructed through historically gendered responsibilities in agrarian systems rather than biological predispositions.

Decolonial ecofeminism deepens this critique by highlighting how colonial epistemologies have historically marginalized both local ecological knowledge and women's environmental labor. From this perspective, environmental governance cannot be separated from struggles over knowledge, territory, and cultural autonomy. Haraway (2016), for instance, challenges anthropocentric development narratives and calls for new relational ontologies between humans and non-human life, arguing that "it matters what stories make worlds, what worlds make stories" (Haraway, 2016). This provocation underscores the importance of epistemic plurality in rethinking sustainability beyond technocratic frameworks.

Within feminist political ecology, scholars have further emphasized that environmental governance must be analyzed through the lens of power relations embedded in everyday resource management. Rocheleau, Thomas-Slayter and Wangari (2013) argue that gendered environmental knowledge emerges from differentiated experiences of land, labor, and resource access, shaping distinct ecological perspectives and practices. Consequently, ecofeminist analysis must move beyond symbolic associations between women and nature to examine how environmental responsibilities are distributed across gendered social structures.

In dryland territories such as the Caatinga, these insights become particularly relevant. Women's roles in water management, seed conservation, and agroecological practices illustrate how environmental stewardship is deeply embedded in everyday practices of care and survival. Rather than representing a natural affinity with nature, these practices reflect historically constructed responsibilities within rural households and communities. Decolonial ecofeminism therefore offers an analytical framework capable of revealing how environmental governance, gender relations, and territorial autonomy are mutually constituted.

Commons Governance and Collective Management of Natural Resources

The debate on commons governance provides a complementary perspective for understanding how communities organize collective strategies for managing shared ecological resources. Contrary to classical economic theories that predicted the inevitable degradation of shared resources, empirical studies have demonstrated that communities are capable of developing sophisticated institutional arrangements to regulate access, monitor use, and maintain ecological sustainability.

Elinor Ostrom's foundational work demonstrated that the so-called "tragedy of the commons" is not an unavoidable outcome but rather a product of specific institutional failures. Through extensive empirical research, she showed that communities can design durable systems of collective governance capable of preventing resource depletion. As Ostrom (1990) emphasizes, "institutions are the rules of the game in a society", and these rules play a crucial role in shaping patterns of cooperation and resource management. Her work revealed that successful commons governance often depends on locally embedded norms, participatory decision-making, and mechanisms of collective monitoring.

Building on this institutional perspective, later scholarship has highlighted that environmental governance also involves processes of subject formation and political negotiation. Agrawal (2005) introduced the concept of environmentality to describe how environmental governance produces new forms of environmental subjects through participation in resource management practices. According to Agrawal, environmental governance is not merely about regulating resources but about shaping how communities perceive and relate to their environments.

Political ecology approaches have further emphasized that commons governance must be analyzed within broader political and economic contexts. Ecological conflicts over land, water, and biodiversity frequently reflect competing valuation systems and development models. Martínez-Alier (2014) observes that environmental conflicts often arise when local communities defend their territories against extractive activities that threaten their ecological livelihoods. In such contexts, collective management of natural resources becomes not only a strategy for ecological sustainability

but also a form of socio-political resistance.

In semi-arid regions, water management represents one of the most critical arenas of commons governance. Rainwater harvesting systems, community reservoirs, and collective irrigation practices illustrate how communities develop institutional arrangements to cope with climatic uncertainty. These practices often rely on strong social networks, trust-based cooperation, and locally negotiated rules for resource distribution. Consequently, commons governance in dryland territories cannot be understood solely as an institutional mechanism; it also represents a cultural and political process through which communities defend territorial autonomy and ecological continuity.

Biocultural Resilience and Agroecological Territories

The concept of biocultural resilience has emerged as a key analytical framework for understanding the intertwined relationship between ecological diversity and cultural practices. Rather than treating ecosystems and societies as separate domains, this perspective emphasizes their co-evolution within socioecological systems. Cultural knowledge, agricultural practices, and institutional arrangements play a central role in shaping how communities interact with their environments and adapt to environmental change.

In the context of agroecology, farming systems are understood not merely as production techniques but as socioecological systems embedded in cultural traditions and ecological knowledge. Altieri and Nicholls (2017) argue that agroecology represents "the application of ecological concepts and principles to the design and management of sustainable agroecosystems". This approach emphasizes biodiversity, soil conservation, and local knowledge as key elements for building resilient agricultural systems capable of withstanding climatic variability.

Socioecological resilience research similarly highlights that sustainability depends on the capacity of communities to adapt to disturbances while maintaining the integrity of their cultural and ecological systems. Leach, Scoones and Stirling (2010) emphasize that sustainability pathways are not

singular but plural, emerging from diverse socioecological configurations and knowledge systems. They note that development strategies must recognize the multiplicity of ways in which communities negotiate environmental constraints and opportunities.

From a decolonial perspective, the concept of biocultural resilience also challenges universalist models of development that overlook local epistemologies. Escobar (2018) argues that territorial sustainability must be grounded in what he calls the "pluriverse", a world composed of multiple ontologies and ways of inhabiting nature. As he writes, "another world is possible because many worlds fit" (Escobar, 2018). This perspective highlights that resilience is not only an ecological property but also a political project linked to cultural autonomy and territorial self-determination.

In the Brazilian Semi-Arid region, agroecological territories exemplify this biocultural dimension of resilience. Practices such as seed exchange networks, diversified cropping systems, and community water management reflect long-standing strategies through which rural communities adapt to environmental variability while maintaining cultural continuity. These practices illustrate how ecological diversity and cultural knowledge mutually reinforce one another in sustaining territorial resilience.

Gendered Environmental Labor in Rural Territories

Understanding the gendered dimensions of environmental governance requires examining how ecological responsibilities are distributed within rural societies. The concept of gendered environmental labor highlights that environmental management tasks are frequently organized along gendered divisions of labor, reflecting broader structures of social reproduction and power.

In many rural contexts, women play a central role in sustaining household food systems and ecological practices through activities such as seed conservation, small-scale food production, water management, and food processing. Siliprandi (2015) observes that women's participation in agroecology has been fundamental for the consolidation of sustainable farming systems in Brazil,

particularly through initiatives that strengthen biodiversity and local food systems. These practices illustrate how women's environmental labor contributes directly to both ecological sustainability and household resilience.

Global assessments reinforce the structural importance of women's contributions to agrifood systems. The FAO (2023) reports that women constitute a substantial portion of the agricultural workforce worldwide while simultaneously carrying a disproportionate burden of unpaid care work. This dual responsibility places women at the intersection of production and social reproduction, shaping their everyday engagement with environmental resources.

Yet this centrality is often accompanied by structural inequalities in access to land, credit, technical assistance, and decision-making spaces. According to UN Women (2022), gender inequalities in resource access significantly limit women's capacity to influence environmental governance and climate adaptation policies. As a result, women frequently assume expanding environmental responsibilities without corresponding gains in institutional power.

Recent studies on gender and climate adaptation further suggest that environmental initiatives can unintentionally intensify gendered labor burdens if they fail to address underlying power relations. Perz et al. (2020) demonstrate that adaptation programs often rely on women's labor while neglecting the structural conditions that shape gender inequalities in rural contexts. Consequently, environmental sustainability initiatives may risk reproducing the very inequalities they seek to overcome.

These dynamics raise an important analytical question: when women assume central roles in environmental management, does this represent a process of empowerment or a redistribution of environmental labor within persistent gender hierarchies? Addressing this question requires examining how social technologies, agroecological practices, and commons governance intersect with gender relations in shaping socioecological resilience in dryland territories.

Table 1 synthesizes the main analytical axes that structure the theoretical framework of this study. Rather than treating the literature as a collection of isolated contributions, the table organizes the selected works into four interconnected conceptual domains that guide the interpretation of

female protagonism in socioecological resilience processes in the Caatinga. These axes, ecofeminism, commons governance, agroecology, and biocultural resilience, were identified through the integrative review as the most recurrent and analytically productive frameworks for examining the relationships between gender, environmental governance, and territorial sustainability in dryland contexts.

The table therefore functions as an interpretative map of the literature, highlighting the conceptual foundations and empirical domains through which the selected studies approach the nexus between care, climate, and power. By articulating theoretical perspectives with empirical research agendas, this analytical structure allows the literature review to move beyond descriptive synthesis toward a more critical understanding of how gendered environmental labor intersects with collective resource management and agroecological adaptation.

Table 1 – Analytical Categories of the Literature Review

Analytical Axis	Core Concept	Key Authors	Empirical Focus
Ecofeminism	Gender–nature relations; critique of the patriarchal and colonial exploitation of nature and reproductive labor	Shiva (2016); Federici (2019); Rocheleau et al. (2013); Haraway (2016)	Feminist environmental theory; gendered environmental knowledge; critique of extractivist development
Commons Governance	Collective management of shared ecological resources through locally embedded institutions	Ostrom (1990); Agrawal (2005); Martínez-Alier (2014)	Water governance, resource conflicts, and community-based environmental management
Agroecology	Ecologically grounded agricultural systems integrating biodiversity, local knowledge, and social organization	Altieri; Nicholls (2017); Leach et al. (2010)	Sustainable food systems, agroecological practices, and adaptive farming strategies
Biocultural Resilience	Co-evolution between cultural practices, ecological diversity, and territorial autonomy	Escobar (2018); Leach et al. (2010); Altieri; Nicholls (2017)	Territorial sustainability, socioecological adaptation, and knowledge-based resilience

Source: The authors themselves.

The analytical categories presented in Table 1 indicate that contemporary debates on socioecological resilience increasingly recognize that environmental sustainability cannot be dissociated from issues of social justice, knowledge systems, and institutional governance. Ecofeminist

scholarship highlights that women's environmental practices are not the result of an essential connection with nature but rather emerge from historically constructed divisions of labor within agrarian societies (Shiva, 2016; Federici, 2019). Complementarily, studies on commons governance demonstrate that the collective management of natural resources depends on locally embedded institutional arrangements capable of regulating access, ensuring cooperation, and sustaining shared ecological assets, particularly in dryland regions where water scarcity is structurally significant (Ostrom, 1990; Agrawal, 2005).

Agroecology and the concept of biocultural resilience further expand this analytical framework by emphasizing the interdependence between ecological diversity, cultural knowledge, and territorial governance. Agroecological systems integrate biodiversity, local knowledge, and cooperative practices as key elements for building resilient food systems under conditions of climatic variability (Altieri; Nicholls, 2017).

From this perspective, resilience emerges from the co-evolution of ecological processes and cultural practices within socioecological territories (Escobar, 2018). Together, these perspectives suggest that female protagonism in dryland territories must be understood not merely as participation in environmental initiatives but as a central component of socioecological governance processes that sustain territorial resilience in the Caatinga.

METHODOLOGY

Research Design: Integrative Literature Review

This study adopts an integrative literature review as its methodological strategy in order to synthesize, critically interpret, and theoretically integrate the scientific production on female protagonism, social technologies, and biocultural resilience in dryland territories. The integrative review method was selected because it allows the systematic combination of empirical and theoretical studies, enabling the construction of a comprehensive analytical framework capable of addressing

complex socioecological phenomena that involve multiple disciplinary perspectives.

Unlike traditional narrative reviews, integrative reviews aim to generate conceptual synthesis through transparent and systematic procedures of literature identification, selection, and analysis. According to Whittemore and Knafl (2005), integrative reviews permit the inclusion of diverse methodological approaches, allowing researchers to integrate qualitative, theoretical, and empirical evidence in order to develop broader theoretical interpretations. This methodological flexibility is particularly appropriate for research topics situated at the intersection of environmental governance, gender studies, and socioecological resilience.

In the context of interdisciplinary environmental research, integrative reviews are especially valuable because they allow the identification of conceptual convergences, theoretical tensions, and emerging research gaps within heterogeneous bodies of literature. As highlighted by Souza, Silva and Carvalho (2010), the integrative review provides a structured process for synthesizing scientific knowledge, contributing to the advancement of theoretical frameworks and supporting the development of evidence-based interpretations. In addition, Torraco (2016) emphasizes that integrative literature reviews play a fundamental role in theory-building by connecting fragmented research findings and identifying conceptual patterns that may not be evident in isolated studies.

The methodological design of this study therefore follows the classical stages of integrative review research: definition of the research problem, systematic literature search, application of inclusion and exclusion criteria, critical screening of the retrieved studies, and analytical synthesis of the selected corpus. The objective of this methodological procedure is not merely to summarize the literature but to critically interpret how female protagonism interacts with social technologies and commons governance in shaping biocultural resilience in the Caatinga biome.

Search Strategy and Databases

The bibliographic search was conducted between October 2025 and February 2026 using four

major academic databases widely recognized for their coverage of interdisciplinary environmental and social science research: Web of Science (Core Collection), Scopus (Elsevier), SciELO, and the Directory of Open Access Journals (DOAJ). The combination of these databases was chosen in order to ensure both international academic coverage and regional representation of studies focusing on Latin American socioecological contexts.

The search strategy was structured through combinations of controlled descriptors and Boolean operators designed to capture the multidimensional nature of the research topic. Search terms were formulated in English, Portuguese, and Spanish to maximize the retrieval of relevant studies addressing gender, environmental governance, and social technologies in dryland regions.

The search expressions combined four thematic axes derived from the theoretical framework of the study:

- Gender and social actors: “women” OR “female protagonism” OR “women farmers” OR mulheres OR campesinas
- Territorial context: “Caatinga” OR “Brazilian semiarid” OR “semi-arid region” OR drylands
- Theoretical lenses: “ecofeminism” OR “decolonial feminism” OR “biocultural resilience” OR decoloniality
- Environmental practices and governance: “social technologies” OR “rainwater harvesting” OR “seed banks” OR agroecology OR commoning OR “water management”

These descriptors were systematically combined using Boolean operators AND and OR, allowing the identification of studies addressing the intersections between gender relations, environmental governance, agroecology, and community-based resource management.

The initial search retrieved a total of 279 scientific records, including journal articles, book chapters, and selected academic publications relevant to the scope of the study.

Inclusion and Exclusion Criteria

Following the identification stage, inclusion and exclusion criteria were applied to ensure the analytical coherence and scientific relevance of the studies considered in the review. These criteria were defined a priori based on the research objectives and theoretical framework guiding the study.

Inclusion criteria: a) Peer-reviewed scientific articles or relevant academic publications; b) Studies addressing gender relations in environmental governance or natural resource management; c) Research examining social technologies, agroecology, or community-based environmental practices; d) Studies focusing on dryland territories, particularly the Brazilian Semi-Arid region or comparable socioecological contexts; e) Publications addressing commons governance, socioecological resilience, or agroecological systems; f) Studies published approximately within the last 10–15 years, ensuring analytical relevance to contemporary debates; and g) Publications available in English, Portuguese, or Spanish.

Exclusion criteria: a) Publications unrelated to gender or environmental Governance; b) Studies focusing exclusively on technical agricultural innovations without socioecological analysis; c) Articles lacking methodological transparency or academic peer review; d) Duplicated records retrieved across multiple databases; and e) Publications with insufficient conceptual relevance to the research objectives.

The application of these criteria ensured that the selected corpus would maintain both thematic coherence and methodological rigor while adequately representing the interdisciplinary nature of the research topic.

Screening and Selection Process

The screening and selection of the retrieved studies followed procedures inspired by the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework, which

provides guidelines for transparent reporting of literature review processes. Although the present study adopts an integrative rather than a strictly systematic review design, the PRISMA flow structure was incorporated in order to improve methodological transparency and reproducibility.

The screening process occurred in three sequential stages. First, duplicated records retrieved from multiple databases were identified and removed. Second, titles and abstracts of the remaining publications were examined in order to assess their thematic alignment with the objectives of the study. In the third stage, the full texts of the eligible publications were analyzed to verify their conceptual relevance and methodological consistency with the analytical framework of the review.

Through this multi-stage process, the initially identified 279 records were progressively filtered until the final corpus of studies was defined. The selected publications were subsequently subjected to qualitative analytical synthesis, focusing on how the literature conceptualizes the relationship between female protagonism, social technologies, commons governance, and biocultural resilience in dryland socioecological systems.

Table 2 presents the PRISMA-based flow of the literature selection process adopted in this integrative review. The table summarizes the sequential stages through which the initially identified publications were progressively screened and refined until the final analytical corpus was defined. The procedure followed internationally recognized transparency standards for literature reviews, enabling clear documentation of how the initial body of retrieved studies was reduced to the set of publications included in the analytical synthesis.

The identification stage resulted in 279 records retrieved from the four selected databases: Web of Science, Scopus, SciELO, and DOAJ. After the removal of duplicated entries and an initial screening based on titles and abstracts, the number of potentially relevant studies was reduced to 214. These records were then subjected to a more detailed evaluation to determine their conceptual alignment with the research objectives and analytical framework guiding the review.

Table 2 – PRISMA Flowchart of the Literature Selection Process

Stage	Number of studies	Description of the process
Identification	279	Records identified through database search in Web of Science, Scopus, SciELO, and DOAJ between October 2025 and February 2026
Screening	214	Records remaining after removal of duplicates and preliminary exclusion based on title and abstract relevance
Eligibility	96	Full-text articles assessed for conceptual alignment with gender, social technologies, commons governance, and socioecological resilience
Final Sample	25	Studies selected for the integrative review corpus after applying inclusion and exclusion criteria

Source: The authors themselves.

The eligibility stage involved the full-text examination of 96 publications whose abstracts indicated potential relevance to the themes of gender, environmental governance, agroecology, and social technologies in dryland contexts. During this stage, studies that did not directly address the intersection between gender and socioecological management, or that lacked conceptual alignment with the theoretical framework adopted in this research, were excluded from the final sample.

The final corpus of 25 studies represents the set of publications that most directly addressed the analytical dimensions central to this review: ecofeminism, commons governance, agroecological practices, and biocultural resilience. Rather than maximizing the number of included studies, the selection process prioritized conceptual coherence and analytical relevance, ensuring that the final corpus provided a theoretically robust foundation for examining how female protagonism interacts with social technologies and collective environmental governance in the Caatinga biome.

RESULTS

Women as Socioecological Managers in the Caatinga

The literature analyzed consistently highlights that women occupy a central position in

the everyday governance of socioecological systems in the Brazilian Semi-Arid region. Far from being restricted to domestic spheres, women frequently act as key actors in water management, food production, and agroecological innovation, shaping local strategies for adaptation to climatic variability. In territories characterized by recurrent droughts and structural water scarcity, these practices become fundamental mechanisms for sustaining household reproduction and community resilience.

Empirical studies demonstrate that women are often responsible for managing domestic water systems, maintaining household cisterns, and organizing community practices of water distribution. Oliveira and Silva (2022) emphasize that women's involvement in water-related social technologies frequently extends beyond household management to include participation in collective decision-making spaces and community training initiatives. Their study shows that women's participation in social technology projects contributes to strengthening environmental awareness and local governance capacities, particularly in contexts where water access represents a critical socioecological challenge.

Evidence from agroecological initiatives further reinforces the role of women as environmental managers in the Caatinga. Agroecological household gardens, diversified cropping systems, and seed preservation networks represent important strategies for strengthening food security and ecological sustainability in rural communities. Ferreira et al. (2022), examining agroecological initiatives led by rural women in Bahia, highlight that participatory tools such as agroecological notebooks have strengthened women's autonomy in monitoring production and biodiversity. As the authors observe, "the agroecological notebook became an instrument for women to recognize the economic and ecological value of their work" (Ferreira et al., 2022).

The expansion of agroecological practices in the Semi-Arid region has also contributed to redefining local food systems. Moreira et al. (2025), analyzing agroecological experiences in Ceará, report that diversified agroecological production systems significantly increase household food availability while reducing dependency on external agricultural inputs. According to their findings, agroecological social technologies foster both environmental sustainability and socio-economic

resilience by strengthening local food sovereignty and reducing vulnerability to climate shocks. In this context, women's participation becomes particularly significant because their roles in seed preservation, food processing, and biodiversity management connect ecological sustainability with everyday practices of care and social reproduction.

Quantitative evidence reinforces this pattern. Studies on agroecological initiatives in semi-arid communities indicate that women are frequently responsible for a substantial proportion of agroecological household production, particularly in diversified food gardens and small-scale animal husbandry systems (Moreira et al., 2025). These activities directly contribute to local food security and dietary diversity, especially in contexts where market access remains unstable and climatic variability affects agricultural yields. Consequently, women's environmental labor operates simultaneously as a strategy of ecological adaptation and as a mechanism for sustaining rural livelihoods.

Taken together, these findings challenge conventional representations of environmental governance that focus primarily on formal institutions or technological infrastructures. Instead, the evidence suggests that women's everyday practices constitute a crucial but often invisible dimension of socioecological resilience in dryland territories.

Social Technologies and the Feminization of Environmental Work

The literature also reveals that the expansion of social technologies in the Brazilian Semi-Arid region has profoundly transformed the organization of environmental labor in rural communities. Initiatives such as rainwater harvesting cisterns, agroecological household gardens, and community seed banks have become central strategies within policies aimed at promoting coexistence with the semi-arid climate. These technologies are frequently celebrated as successful examples of socially embedded innovation capable of combining ecological sustainability with community participation.

However, a closer examination of the literature reveals that these initiatives also produce complex gender dynamics. While social technologies can create new opportunities for women's

participation and leadership, they may simultaneously reinforce gendered divisions of environmental labor. Torres et al. (2019), analyzing agroecological projects linked to cistern programs, observe that women often assume responsibility for managing water storage, maintaining agroecological gardens, and organizing food production activities within households. As the authors note, these initiatives "reveal the central role of women in the management of social technologies associated with agroecology" (Torres et al., 2019).

This dynamic illustrates an important analytical tension. On the one hand, social technologies can function as instruments of empowerment by increasing women's access to productive resources such as water, seeds, and agroecological knowledge. On the other hand, they may also redistribute environmental responsibilities without necessarily transforming underlying gender hierarchies. The expansion of agroecological initiatives often relies heavily on women's labor, particularly in activities related to biodiversity conservation, food processing, and seed exchange networks.

Research on rural collective organization further highlights the gendered dimension of these processes. Brandão et al. (2022) show that women frequently occupy leadership roles in community associations involved in agroecological production and resource management. Their findings suggest that women's participation strengthens collective governance structures and enhances the sustainability of local initiatives. However, the authors also warn that increased participation in community organizations may result in an accumulation of responsibilities, as women continue to maintain domestic care work alongside their environmental and organizational activities.

This dual dynamic, empowerment combined with increased labor burdens. raises critical questions about the social sustainability of environmental initiatives. If adaptation strategies rely disproportionately on women's unpaid labor, they risk reproducing gender inequalities even while promoting ecological sustainability. Consequently, understanding the gendered impacts of social technologies requires moving beyond celebratory narratives to critically examine how environmental governance redistributes responsibilities within rural societies.

Collective Resource Management and Local Autonomy

The evidence reviewed also indicates that collective resource management constitutes a central dimension of socioecological resilience in dryland territories. Community-based governance of water resources, seed systems, and agroecological production networks frequently operates according to principles consistent with the theory of commons governance.

Ostrom's (1990) foundational research demonstrated that communities can develop robust institutional arrangements for managing shared resources when governance systems are based on locally defined rules, monitoring mechanisms, and participatory decision-making processes. As Ostrom famously noted, "institutions are the rules of the game in a society" (Ostrom, 1990). These institutional arrangements enable communities to regulate resource access and prevent the overexploitation of shared ecological assets.

Subsequent research has expanded this perspective by examining how environmental governance also shapes social identities and environmental subjectivities. Agrawal (2005) introduced the concept of environmentality to describe how participation in resource management practices can produce new forms of environmental consciousness and collective responsibility. In the context of the Brazilian Semi-Arid region, participation in water governance initiatives, seed exchange networks, and agroecological associations contributes to the formation of environmental subjectivities grounded in collective stewardship.

Empirical studies in the Caatinga suggest that these forms of collective governance play a crucial role in sustaining territorial autonomy. Community-managed water systems and agroecological networks reduce dependence on external markets and centralized infrastructures, strengthening local capacities to cope with climatic uncertainty. Moreover, collective management practices frequently reinforce social solidarity and trust-based cooperation among community members, elements widely recognized as fundamental components of socioecological resilience.

Importantly, women often play a decisive role in these collective governance processes. Their

participation in community associations, seed banks, and water management committees contributes not only to the functioning of these institutions but also to the diffusion of ecological knowledge and cooperative practices within rural territories. As a result, female protagonism becomes deeply intertwined with the functioning of commons governance systems in the Semi-Arid region.

Table 3 synthesizes the main empirical and theoretical contributions identified in the literature reviewed in this study. The table organizes key studies according to their analytical focus, the environmental practices or social technologies examined, the gender dimensions addressed, and the principal findings related to female protagonism in socioecological resilience processes. By systematizing the selected literature in this way, the table provides a concise overview of how different studies approach the relationship between environmental governance, social technologies, and gender relations in the Brazilian Semi-Arid region and comparable socioecological contexts.

The table highlights that the literature spans multiple analytical levels, ranging from empirical case studies on agroecological initiatives and social technologies to theoretical frameworks addressing commons governance and territorial sustainability. This diversity reflects the interdisciplinary character of research on socioecological resilience and reinforces the importance of integrating environmental governance, gender analysis, and agroecological knowledge in order to understand adaptation processes in dryland territories.

Table 3 – Synthesis of Evidence from the Selected Studies

Author	Study focus	Social technology / Practice	Gender dimension	Main findings
Oliveira & Silva (2022)	Contextualized education and environmental practices in the Semi-Arid	Water management training and social technologies	Women's leadership in community environmental education	Women act as key facilitators in the diffusion of environmental knowledge and community governance of water resources
Ferreira et al. (2022)	Agroecological initiatives led by rural women	Agroecological notebooks and diversified home gardens	Recognition of women's productive and ecological labor	Women's documentation of agroecological production strengthens autonomy and visibility of their environmental work
Moreira et al. (2025)	Agroecology and coexistence strategies in the Semi-Arid	Agroecological production systems and rainwater harvesting	Women as central actors in local food systems	Diversified agroecological practices increase food security and reduce vulnerability to climate variability
Torres et al. (2019)	Social technologies and agroecology	Fertilized cistern systems and agroecological gardens	Feminization of environmental labor	Women become primary managers of water and agroecological production associated with social technologies
Brandão et al. (2022)	Rural associative governance and collective organization	Community associations and agroecological networks	Women's leadership in collective governance	Female participation strengthens institutional sustainability but may increase cumulative labor burdens
Ostrom (1990)	Commons governance theory	Collective management of shared resources	Gender not central but relevant in local governance	Community-based institutions can effectively regulate common resources and sustain cooperation
Agrawal (2005)	Environmental governance and subject formation	Community resource management practices	Participation shapes environmental subjectivities	Environmental governance produces new environmental identities and collective responsibility
Altieri; Nicholls (2017)	Agroecological sustainability	Biodiverse agroecosystems	Gendered knowledge in agroecological practices	Agroecology integrates ecological principles and local knowledge to build resilient food systems
Escobar (2018)	Territorial sustainability and decolonial ecology	Territorial autonomy and pluriversal development	Recognition of local epistemologies	Biocultural resilience emerges from the interaction between ecological systems and cultural knowledge

Source: The authors themselves.

The synthesis presented in Table 3 reveals several converging patterns across the selected studies. First, the empirical evidence consistently indicates that women play a central role in managing key components of rural socioecological systems, particularly in activities related to water governance, agroecological food production, and biodiversity conservation. Studies focusing on social technologies and agroecological practices demonstrate that women frequently act as facilitators of environmental knowledge, community organization, and food security strategies in the Caatinga.

At the same time, the literature also points to important tensions within these processes. While women's participation in social technologies and community governance structures often contributes to strengthening collective resilience, it may also intensify gendered labor burdens when environmental responsibilities accumulate alongside domestic and care work. Consequently, the evidence synthesized in Table 3 suggests that female protagonism in dryland socioecological systems should be interpreted not simply as participation in environmental initiatives but as a complex socio-political process in which empowerment, labor redistribution, and institutional transformation interact in shaping pathways of territorial resilience.

DISCUSSION

The Care–Climate–Power Nexus

The findings of this review suggest that the relationship between gender, environmental governance, and socioecological resilience in dryland territories can be analytically understood through what may be described as a care–climate–power nexus. In the Brazilian Semi-Arid region, everyday practices associated with water management, food production, seed conservation, and household reproduction reveal that adaptation to climatic variability is not only a technical process but also a deeply social and political one. The literature consistently indicates that women's environmental labor constitutes a central yet frequently invisible dimension of local adaptation strategies.

This dynamic resonates with feminist analyses of reproductive labor and ecological governance. Federici (2019) argues that the historical separation between productive and reproductive labor within capitalist economies has systematically obscured the ecological foundations of social reproduction. As she observes, "the degradation of women and the degradation of nature are interconnected processes" (Federici, 2019). In rural dryland contexts, this connection becomes particularly evident: the labor that sustains household reproduction, water management, food preparation, seed preservation, simultaneously functions as ecological stewardship.

At the same time, the literature demonstrates that climate adaptation initiatives frequently operate within unequal power structures that shape how environmental responsibilities are distributed. Nightingale (2015) emphasizes that adaptation processes must be understood as political arenas where authority, knowledge, and access to resources are continuously negotiated. According to the author, climate governance is inherently linked to struggles over recognition and participation, meaning that adaptation strategies may simultaneously reproduce and challenge existing social hierarchies.

The evidence reviewed in this study illustrates precisely this ambivalence. Social technologies and agroecological initiatives have expanded women's participation in community governance, strengthening their visibility in local environmental management. However, these same initiatives may also intensify gendered labor burdens if institutional arrangements fail to address underlying inequalities in resource access and decision-making. In other words, while women's environmental labor contributes significantly to climate adaptation, the political recognition of this labor remains uneven.

Donna Haraway's reflections on relational ecologies provide an important conceptual lens for interpreting this dynamic. Haraway (2016) famously argues that "it matters what stories make worlds, what worlds make stories". This statement underscores the importance of narrative and epistemology in shaping environmental governance. When adaptation is framed solely through technical infrastructure, the everyday practices of care that sustain socioecological systems remain invisible. Reframing adaptation through the care–climate–power nexus therefore allows for a more

comprehensive understanding of how climate resilience is produced within everyday social relations.

Quantitative evidence reinforces the structural importance of these dynamics. Global assessments indicate that women represent approximately 43% of the agricultural labor force worldwide and are heavily involved in food production and resource management in rural regions (FAO, 2023). At the same time, women perform a disproportionate share of unpaid care work, often dedicating significantly more time to domestic and reproductive activities than men (UN Women, 2022). In dryland territories where environmental management is closely tied to household survival strategies, these gendered labor patterns become central components of climate adaptation processes.

Consequently, the care–climate–power nexus highlights that climate resilience cannot be understood solely as an ecological or technological outcome. Rather, it emerges from socially embedded practices of care, cooperation, and environmental stewardship that are deeply intertwined with gender relations and territorial governance.

Biocultural Resilience as a Feminized Infrastructure

The results of this review also suggest that socioecological resilience in dryland territories is sustained through what may be conceptualized as a female socioecological infrastructure. This concept refers to the network of practices, knowledge systems, and social relations through which women contribute to the maintenance of ecological diversity, food systems, and collective resource management.

Agroecological research provides important evidence supporting this interpretation. Altieri and Nicholls (2017) argue that agroecological systems are built upon the integration of ecological principles with traditional knowledge and local social organization. As they note, agroecology involves "the application of ecological concepts and principles to the design and management of sustainable agroecosystems" (Altieri; Nicholls, 2017). In the Brazilian Semi-Arid region, women frequently play key roles in sustaining these systems through seed conservation, diversified food production, and

agroecological experimentation.

From the perspective of biocultural resilience, these practices illustrate the co-evolution of ecological diversity and cultural knowledge within territorial systems. Escobar (2018) conceptualizes this dynamic through the notion of the pluriverse, emphasizing that sustainable futures depend on the coexistence of multiple epistemologies and ways of inhabiting the Earth. As Escobar argues, "another world is possible because many worlds fit" (Escobar, 2018). In agroecological territories of the Caatinga, women's environmental practices embody precisely this pluriversal logic, integrating ecological knowledge, cultural traditions, and collective governance.

Empirical studies included in the review demonstrate that women's participation in agroecological networks significantly contributes to local food security and biodiversity conservation. For example, agroecological household gardens often maintain a high diversity of plant species used for food, medicinal purposes, and small-scale market exchange (Moreira et al., 2025). These systems reduce dependence on external inputs and strengthen local adaptive capacities under conditions of climatic variability.

However, recognizing women's role in sustaining socioecological resilience also requires acknowledging the structural inequalities that shape their environmental labor. While women's contributions are central to the functioning of agroecological systems, they often remain undervalued within institutional frameworks of agricultural development. As Siliprandi (2015) observes, women's work in agroecology frequently operates within informal economies and domestic spaces, making it difficult to capture through conventional economic indicators.

Conceptualizing socioecological resilience as a feminized infrastructure therefore offers an analytical shift. Instead of viewing resilience solely through the lens of technological innovation or institutional governance, this perspective highlights the everyday practices of care, cooperation, and ecological knowledge that sustain territorial systems.

Decolonial Ecofeminism in Dryland Territories

The theoretical and empirical insights discussed above point toward the relevance of decolonial ecofeminism as a framework for interpreting socioecological resilience in dryland territories. By connecting gender analysis, environmental governance, and critiques of development, decolonial ecofeminism reveals how environmental conflicts and sustainability debates are embedded within broader histories of colonialism and economic extraction.

Political ecology research has long documented how extractive development models disproportionately affect rural and traditional communities. Martínez-Alier (2014) describes these conflicts as expressions of the environmentalism of the poor, in which marginalized populations mobilize to defend their ecological livelihoods against external pressures. As he argues, many environmental conflicts arise from "the defense of livelihood against the expansion of extractive activities" (Martínez-Alier, 2014).

In dryland territories such as the Caatinga, these conflicts often intersect with gendered environmental labor. Women's involvement in agroecology, water governance, and community organization places them at the forefront of struggles to defend territorial autonomy and ecological sustainability. These struggles frequently challenge dominant development narratives that prioritize large-scale agricultural modernization or extractive industries over locally embedded socioecological systems.

Recent scholarship on dryland political ecologies further highlights how colonial epistemologies continue to shape environmental governance in arid regions. Meché (2022) argues that drylands are often represented as spaces of scarcity and marginality within global development discourses, obscuring the complex socioecological knowledge systems that sustain life in these environments. This framing contributes to policies that overlook local adaptive strategies while privileging external technological interventions.

Decolonial ecofeminism therefore provides a powerful analytical framework for

reinterpreting resilience in dryland territories. By foregrounding women's environmental knowledge and everyday practices of care, it challenges dominant narratives that portray sustainability as primarily a technological or institutional challenge. Instead, it emphasizes that resilience emerges from historically situated practices of cooperation, knowledge exchange, and territorial governance.

In this sense, the socioecological dynamics observed in the Caatinga illustrate how gender, ecology, and politics are deeply intertwined. Women's environmental labor does not simply sustain household livelihoods; it also contributes to broader processes of ecological stewardship and territorial autonomy. Recognizing these dynamics is essential for developing more equitable and culturally grounded approaches to climate adaptation and environmental governance in dryland regions.

Taken together, the analyses developed in this section indicate that socioecological resilience in dryland territories cannot be adequately understood through purely technical or infrastructural approaches to climate adaptation. Rather, resilience emerges from the complex interaction between gendered labor, collective governance institutions, agroecological knowledge, and struggles over territorial autonomy. The evidence synthesized in this review suggests that women's environmental practices constitute a critical yet often invisible foundation of socioecological stability in the Caatinga.

At the same time, these practices reveal important tensions between empowerment and the persistence of gendered labor inequalities within environmental governance systems. Interpreting these dynamics through the lenses of the care–climate–power nexus, feminized socioecological infrastructure, and decolonial ecofeminism allows for a more nuanced understanding of how adaptation processes are embedded in broader political, cultural, and epistemic disputes over the governance of nature and territory.

CONCLUSION

This integrative review demonstrates that female protagonism constitutes a central yet frequently overlooked dimension of socioecological resilience in the Caatinga. The evidence

analyzed reveals that women play decisive roles in water management, agroecological production, seed conservation, and community organization, forming a dense network of everyday practices that sustain rural livelihoods under conditions of climatic variability. Social technologies such as rainwater harvesting systems, agroecological household gardens, and community seed banks have expanded the material and organizational capacities of rural communities to coexist with the Semi-Arid climate. Within these initiatives, women frequently emerge as key actors who connect environmental stewardship with food security, cultural knowledge, and social reproduction.

At the same time, the findings highlight important tensions within these processes. While social technologies can strengthen women's agency and leadership within local governance structures, they may also intensify gendered labor burdens if institutional arrangements fail to address structural inequalities in access to resources and decision-making. Consequently, female protagonism in dryland territories should not be interpreted simply as participation in environmental initiatives but rather as a fundamental component of the socioecological systems that sustain territorial resilience.

This study contributes to the literature by advancing the concept of biocultural resilience through the recognition of women's environmental labor as a foundational element of socioecological adaptation. By conceptualizing women's practices as a form of female socioecological infrastructure, the article shifts the analytical focus from technological solutions toward the everyday practices of care, cooperation, and ecological knowledge that sustain territorial systems.

Furthermore, the study articulates insights from decolonial ecofeminism and commons governance theory, demonstrating that socioecological resilience emerges from the intersection of gendered labor, collective resource management, and culturally embedded ecological knowledge. This theoretical integration provides a more comprehensive framework for understanding how resilience in dryland territories is produced through relational processes that link ecological systems, social institutions, and everyday practices of care.

The findings of this review have important implications for environmental governance and climate adaptation policies in dryland regions. Public policies aimed at strengthening resilience in the

Semi-Arid should move beyond purely technical interventions and explicitly recognize the central role of women in sustaining socioecological systems. Climate adaptation strategies that fail to address gender inequalities risk reproducing structural vulnerabilities even while promoting environmental sustainability.

Future policy frameworks should therefore incorporate gender-sensitive approaches that expand women's access to land, credit, technical assistance, and decision-making spaces within environmental governance institutions. At the same time, further research is needed to deepen the understanding of how social technologies, commons governance, and agroecological knowledge interact with gender relations in shaping territorial resilience.

Ultimately, recognizing the socioecological intelligence embedded in women's everyday practices invites a broader reimagining of sustainability itself. In the landscapes of the Caatinga, resilience is not only built through infrastructure and policy but also through networks of care, knowledge, and collective stewardship that quietly sustain life in one of the world's most challenging environments.

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