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From Vulnerability to Resilience: Grassroots Adaptation of the K'Ho Community for Sustainable Coffee Production in Vietnam

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Abstract

This study examines how the K'Ho community in Lâm Đồng Province, Vietnam, is building grassroots resilience to climate change in sustainable coffee production. Using a critical qualitative approach through case studies, the research analyzes data from in-depth interviews, field observations, focus group discussions, and document analysis involving K'Ho coffee farmers, women in farming households, community elders, young farmers, agricultural extension workers, local government officials, and cooperative actors. Findings indicate that rising temperatures, seasonal uncertainty, changing rainfall patterns, increased wind intensity, drought, frost, hail, floods, and landslides not only disrupt coffee productivity but also increase production costs, weaken income security, and deepen household socioeconomic vulnerability. However, the K'Ho community is not simply a passive victim of climate change. They are developing adaptation strategies through branch pruning, the use of disease-resistant varieties, shade tree planting, the use of mulch and manure, water conservation, coffee drying management, the use of weather information, participation in training, income diversification, and seeking financial support. This study proposes the concept of layered grassroots resilience to explain how resilience is formed through interconnected adaptation practices at the crop, garden, landscape, and household levels. By positioning climate adaptation as a socio-ecological process and a social justice issue, this article contributes to debates on social development, sustainable livelihoods, and the resilience of agrarian minority communities in Southeast Asia.

Keywords: grassroots resilience; climate adaptation; K'Ho community; sustainable coffee production; social development.

1. Introduction

Climate change is fundamentally reshaping agrarian communities worldwide by directly altering environmental conditions and deeply challenging the foundations of social systems and access to resources. For indigenous peoples and ethnic minorities, it intensifies vulnerability but also catalyzes resilience. To address these challenges, structural factors, information accessibility, and the harnessing of local knowledge are essential for building adaptive capacity.

Research demonstrates that smallholder farmers, indigenous peoples, and ethnic minorities possess not only vulnerability to climate change, but also agency. Casting these groups only as victims obscures their critical role as adaptive actors who interpret risks and actively shape local adaptation strategies. The K'Ho community in Lam Dong Province exemplifies how a marginalized group, reliant on coffee for its livelihoods, builds resilience amid climate and market-related threats. Their experience demonstrates that integration into global markets introduces new risks but also drives the development of adaptive strategies rooted in community context, providing a critical lens for understanding resilience in sustainable coffee production.

The K'Ho notice climate change through higher temperatures, shifting rainfall, more sunshine, stronger winds, and unpredictable seasons (Dinh Nghiep et al., 2025). They experience disasters like frost, hail, drought, floods, landslides, and tornadoes. These disrupt coffee production and increase vulnerability (Le et al., 2020). Most respondents perceive climate change as a threat to economic stability and sustainability (Vo & Tran, 2022). K'Ho's vulnerability is rising because coffee production depends on a stable climate (Dinh Nghiep et al., 2025). Smallholder communities like the K'Ho, focused on a single climate-sensitive commodity, face high risks when seasons change or when frost and drought strike. These events threaten harvests, income, and community resilience (McElwee et al., 2023). Most respondents show deeper vulnerability than those in more diverse, higher-income communities. Limited financial capital, technology, climate information, and institutional protection worsen this situation (Phuong et al., 2018; Tran et al., 2021).

However, the K'Ho community is not a passive actor in the face of climate pressures. They have developed adaptation strategies rooted in ecological experiences, local knowledge, daily agricultural practices, and interactions with modern knowledge (Dinh Nghiep et al., 2025; Truong, 2020). These strategies operate at multiple socio-ecological scales: at the plant level through pruning, disease-resistant varieties, and nursery techniques; at the meso level through weed and pest management, shade and windbreak planting, mulching, rainwater harvesting, and coffee drying (Dinh Nghiep et al., 2025; Le et al., 2020); at the landscape level by situating plantations near forests to maintain the microclimate; and at the micro level through accessing weather information, attending trainings, diversifying income, using manure, and seeking financial support (Phuong et al., 2018). This article uses the term "layered grassroots resilience" to describe the coordinated set of adaptive practices across these scales (Greene et al., 2022). Resilience is thus enacted both biologically—maintaining the crop's health and resistance—and through ecosystem management, water conservation, and risk reduction (Dinh Nghiep et al., 2025; Le et al., 2020). Social and economic measures such as information access, training, financial support, and capacity-building further strengthen households' ability to respond to climate uncertainty (Carmen et al., 2022). Drawing on frameworks that map livelihood assets and strategies, this article demonstrates how these assets are activated through the interplay of local knowledge, adaptive practices, and institutional relationships in response to climate stress (Hosen et al., 2020; Maliao et al., 2025).

K'Ho grassroots resilience exists but faces structural limits (Bertana et al., 2022; Carmona, 2022). Their climate knowledge primarily consists of recognition of symptoms and their effects on agriculture (Hussein et al., 2024). Poorer households have less access to climate info, media, and the internet, which hinders adaptation (Jiri et al., 2017). Training often focuses on production rather than comprehensive adaptation (Hellin et al., 2023). This gap shows the need for stronger structural support for resilience (Khatun et al., 2025). This article analyzes how the K'Ho community develops multi-layered grassroots resilience in sustainable coffee production under climate change. It asks: (1) How does the K'Ho community perceive climate change in daily life and coffee practices? (2) In what ways does climate change affect coffee-based livelihood sustainability? (3) How do adaptive strategies at various socio-ecological levels contribute to the overall resilience of the K'Ho community? The article's contributions are empirical, conceptual, and policymaking. Empirically, it demonstrates how ethnic minority coffee-producing communities respond to climate change through contextual and layered adaptation strategies. Conceptually, it proposes its resilience to enrich studies of social resilience. Policy-wise, it emphasizes that climate adaptation cannot be built solely through technocratic and top-down approaches.

Sustainable adaptation requires strengthening community capacity, recognizing local knowledge, expanding access to climate information, providing inclusive financial support, and integrating local practices with modern science. Thus, grassroots resilience is understood not only as a coping strategy but also as a foundation for more equitable, inclusive, and sustainable social development.

2. Theoretical Framework

This research uses an integrative theoretical framework that combines the perspectives of socio-ecological resilience, community-based adaptation, and sustainable livelihoods to understand the K'Ho community's response to climate change in coffee production. Socio-ecological resilience is understood here as the capacity of a community and its environment to absorb disturbances while maintaining core functions. This framework views the K'Ho community not only as a vulnerable group but also as active actors who interpret environmental changes, manage local knowledge, and adapt agricultural practices. The research analysis focuses on four main dimensions: socio-ecological vulnerability (the risk posed by the relationships between society and ecological systems), coffee-based livelihood security, community-based adaptation, and grassroots resilience (locally driven capacity to adapt).

2.1. Climate Vulnerability and Socio-Ecological Exposure

Climate vulnerability is key to understanding the K'Ho community's situation. In agrarian and minority contexts, it stems from climate hazards, ecological stress, dependence on natural resources, limited capital, and weak institutions. ons. Climate change becomes a social issue when it disrupts agriculture, incomes, and livelihoods through heat, changing rainfall, seasonal shifts, winds, droughts, or disasters (Morales et al., 2022; Tran et al., 2021). The analysis does not stop at vulnerability. Instead, it considers how local communities interpret risks and develop adaptive responses. This research moves beyond positioning local communities solely as victims, showing how they transform exposure into adaptation practices suited to their context. Farming communities build adaptive capacity through local knowledge, livelihood diversification, strengthening social networks, and resource management tailored to their conditions (Kliem, 2024; Rahn et al., 2014). From a socio-ecological perspective, adaptive processes and vulnerabilities are interconnected and collectively shape community resilience to climate change (McElwee et al., 2023; Morales et al., 2022).

2.2. Sustainable Livelihoods and Household Security Based on Coffee

The sustainable livelihoods perspective is used to explain how climate change impacts household life, both materially and socially. Livelihoods are seen not only as a source of income but also encompass natural, human, social, financial, and physical assets that help households survive, adapt, and build long-term well-being. A household's ability to cope with environmental change depends on its capacity to access, integrate, and utilize these assets in uncertain ecological and economic contexts (Brown et al., 2018; Jezeer et al., 2019). For the K'Ho community, coffee is not simply an economic commodity; it is a primary source of income, part of the local socioeconomic organization, and a crucial element of the community's socio-ecological landscape.

Climate change disrupts farmers' livelihoods by simultaneously putting pressure on various assets, including reduced coffee plantation productivity due to drought, changes in rainfall patterns, soil degradation, and ecological disasters. These conditions also weaken financial assets due to lower yields, higher production costs, and greater household income uncertainty. Furthermore, farmers increasingly need knowledge, technical skills, and the ability to understand climate information. Social support, such as community networks, training, information exchange, and relationships with support institutions, is crucial for facilitating adaptation (Etana et al., 2022; Wood et al., 2014).

From this perspective, climate adaptation cannot be reduced to changes in cultivation techniques alone. Adaptation also involves household decision-making, access to weather information, income diversification, the use of organic fertilizers, participation in training, and seeking financial support. Several studies have shown that successful adaptation is significantly influenced by social capital, which refers to the networks, relationships, and trust among community members that facilitate collective action and

information sharing. Social capital enables households to access climate information, participate in extension services, secure credit, obtain education, and share resources, thereby enhancing their ability to diversify livelihoods and respond to climate risks. A sustainable livelihoods approach helps explain why household adaptive capacity varies. These differences are influenced by unequal access to assets, information, technology, and institutional support available to each household (Jezeer et al., 2019).

Coffee-based livelihoods are understood in two ways. On the one hand, they are vulnerable to climate change due to their high dependence on stable ecological conditions and commodity markets. On the other hand, they also serve as arenas for developing adaptation and resilience strategies through the mobilization of household assets, the use of social networks, and the adoption of more adaptive agricultural practices. Livelihood systems, impacted by climate stressors, simultaneously provide a social and material basis for communities to develop adaptive responses and sustain household life in the long term (Brown et al., 2018; Jezeer et al., 2019).

In rural communities, adaptive capacity is often shaped by a household's position within social networks, relationships with government institutions and markets, and capacity to access knowledge, technology, and resources that support adaptation. These differences in access to resources result in unequal adaptive capacity, so that climate change impacts tend to exacerbate pre-existing vulnerabilities (McElwee et al., 2023; Morales et al., 2022; Wood et al., 2014). From an agrarian change perspective, climate stress can also alter how households manage labor, land, and livelihoods, making adaptation part of a process of social transformation at both the community and household levels.

2.3. Community-based adaptation and local agency

Community-based adaptation highlights how the K'Ho community responds to climate change from the ground up. This perspective emphasizes the importance of local knowledge, everyday ecological experiences, community practices, and decision-making processes rooted in the local social context. This approach also critiques technocratic perspectives that understand adaptation primarily as the result of external interventions, formal policies, or the transfer of scientific knowledge from outside the community. Research on community-based adaptation shows that community adaptive capacity is often formed through local knowledge, collective action, social learning, and institutions that develop within the local context, rather than solely through state intervention or external actors (Galappaththi et al., 2019, 2020).

In the K'Ho context, adaptation emerges from the relationship between ecological experience and practical knowledge. Farmers observe changes in rainfall, temperature, wind strength, drought, and pest dynamics and translate these experiences into production decisions. These adaptations include pruning coffee branches, using more disease-resistant varieties, planting seedlings in larger nursery bags, weed control, pest and disease management, planting shade trees, creating windbreaks, mulching, rainwater harvesting, more careful coffee drying, using manure, accessing weather information, and participating in agricultural training. These findings align with numerous studies showing that farmers and indigenous communities develop adaptation strategies based on long-term observations of environmental changes and combine them with contextualized agricultural and resource management practices based on local experience (Kaganzi et al., 2021; Zvobgo et al., 2022).

These practices demonstrate that adaptation is not a single act but an accumulative process inherent to everyday agricultural life. Adaptation occurs through experimentation, learning, adjustment, and the selective integration of local knowledge with available technical information. The K'Ho community does not rely solely on traditional knowledge, nor does modern knowledge entirely determine it. Adaptation is formed through the intersection of local experience, farming practices, weather information, training, and external support. The literature on knowledge co-production and adaptation among indigenous communities indicates that effective adaptive capacity generally arises from the interaction of local knowledge and scientific knowledge through processes of learning, negotiation, and collective decision-making, rather than from the dominance of one form of knowledge alone (Hill et al., 2020; Shawoo & Thornton, 2019).

However, community-based adaptation should not be romanticized. Local agency remains within structural constraints. Some households still have limited access to smartphones, the internet, television,

credit, training, and formal climate information. Furthermore, available training is often oriented more toward increasing production efficiency than toward more systematic climate adaptation. Therefore, bottom-up adaptation remains uneven and requires stronger institutional support. Various studies have shown that a community's ability to adapt is determined not only by individual knowledge and willingness, but also by access to resources, institutional support, power relations, and socio-political structures that can expand or limit available adaptation options (Hill et al., 2020; Subroto & Datta, 2024). Within this framework, community-based adaptation is understood as a process of negotiation between local capacities and structural limitations (Ali et al., 2021).

2.4. Grassroots Resilience

By integrating perspectives on socio-ecological resilience, community-based adaptation, and sustainable livelihoods, this research develops the concept of grassroots resilience. This concept refers to local communities' capacity to build resilience through a series of adaptive practices that emerge from everyday experiences and operate across multiple socio-ecological dimensions. Resilience is not understood simply as the ability to recover from disturbances, but as a dynamic process that enables households and communities to reimagine agricultural systems, livelihood strategies, ecological relationships, and knowledge practices in the face of climate uncertainty (Campos et al., 2014).

In the context of the K'Ho community, grassroots resilience is formed through the interconnectedness of coffee cultivation practices, garden management, relationships with the ecological landscape, and household socioeconomic capacities. Practices such as pruning, the use of more adaptive varieties, planting shade trees, water management, the use of organic fertilizers, access to weather information, training, and income diversification demonstrate that adaptation does not operate in isolation but rather complements each other in maintaining sustainable coffee production. These findings align with research show that coffee farmers and smallholders' resilience is built more through a combination of agroecological strategies, livelihood diversification, access to local knowledge, and institutional support than through single technical interventions (Bracken et al., 2023; Megerssa et al., 2025).

The grassroots resilience framework enriches the literature on socio-ecological resilience, community-based adaptation, and sustainable livelihoods by demonstrating that the resilience of agrarian communities is shaped not only by ecological capacity, livelihood assets, or institutional support in isolation, but through the dynamic interaction between ecological conditions, household decisions, social networks, daily farming practices, and community-owned resources (Bacon et al., 2012). In this perspective, adaptation is understood as a daily process embedded in land management practices, livelihood decision-making, and the mobilization of local knowledge, rather than solely as a program or policy intervention (Mills-Novoa et al., 2023). Grassroots resilience asserts that adaptive capacity develops through a community's ability to activate various livelihood assets, maintain ecological relationships, and build collective action rooted in lived experience and local knowledge in the face of climate stress and agrarian change (Aguilar et al., 2022; Allen et al., 2024).

3. Research methodology

This study uses a critical qualitative research design with a case study approach to analyze how the K'Ho community builds grassroots resilience in sustainable coffee production amid climate change in Lam Dong Province, Vietnam. A qualitative approach was chosen because this study seeks to understand experiences, perceptions, adaptation practices, and socio-ecological processes that cannot be explained solely through quantitative measurements. The case study was used because the K'Ho community is a minority ethnic coffee-producing community at the intersection of climate vulnerability, dependence on agrarian livelihoods, local knowledge, and political-economic pressures in the coffee commodity chain. The critical orientation in this study allows the analysis not only to describe adaptation strategies but also to examine how access to climate information, training, financial capital, agricultural technology, and institutional support shapes unequal adaptive capacity.

3.1. Data Sources and Informant Selection Criteria

The empirical material for this study consists of three interconnected data sources: in-depth interviews, field observations, and secondary documentation. This combination of data sources is commonly used in qualitative research to gain a deeper contextual understanding of the phenomenon under study (Busetto et al., 2020). Interviews were conducted with K'Ho coffee farmers, women in farming households, community leaders, agricultural extension workers, local officials, and actors involved in supporting sustainable coffee production. Field observations were conducted in coffee plantations, settlements, and the surrounding socio-ecological landscape to understand adaptation practices occurring in daily life. Observations allow researchers to understand social actions and interactions within the natural context in which the phenomenon occurs (Ploeg, 1999). Secondary documentation included local policy reports, agricultural extension documents, data related to coffee production, climate information, and academic literature on the K'Ho community, climate change, and coffee farming in Vietnam (Rana et al., 2023).

Table 1. Profile of interview informants.

Code	Role / Affiliation	Age Range	Gender	Data Contribution
I1	K'Ho coffee farmer	40–65	Male	Climate perception, farming experience, adaptation practices
I2	Female member of a coffee-farming household	35–60	Female	Household livelihood, income strategy, care, and labor division
I3	Senior K'Ho farmer/community elder	50–75	Male	Local ecological knowledge and historical climate change
I4	Young coffee farmer	20–35	Male	Youth perspective, technology use, and access to climate information
I5	Female coffee processor/farm household member	25–50	Female	Post-harvest practices, coffee drying, and household resilience
I6	Agricultural extension officer	30–55	Male	Institutional support, training, and adaptation programs
I7	Local government or village representative	35–60	Male	Policy context, development programs, and community vulnerability
I8	Cooperative or sustainable coffee actor	30–55	Female	Market access, sustainable coffee standards, and farmer support

Note: All informants are members of, or directly engaged with, the K'Ho coffee-farming community in Lam Dong, Vietnam. Identifying details are anonymized to ensure ethical protection.

Informants were selected using purposive sampling based on three main criteria: (1) having direct experience in coffee production; (2) experiencing or observing the impacts of climate change on agriculture and household livelihoods; and (3) being involved in adaptation practices, knowledge exchange, or institutional support related to coffee. A purposive sampling approach was used to identify individuals with knowledge, experience, and social positions relevant to the research focus, thereby providing rich, in-depth information about the phenomenon under study while ensuring a match between informant characteristics and the objectives of the qualitative research (Palinkas et al., 2015). Snowball sampling was also used to reach additional informants with important knowledge about the history of environmental change, local agricultural practices, community social networks, and forms of external support, especially when key informants were difficult to identify in the initial stages of the research (Naderifar et al., 2017).

Informant selection considered variations in age, gender, farming experience, socioeconomic status, land ownership, and access to training to enable the research to capture differences in adaptive capacity between households. These considerations align with the principle of maximum variation sampling, which aims to capture a diversity of experiences and perspectives to understand the complexity of phenomena within a given social context (MacFarlane et al., 2012).

3.2. Data collection and analysis procedures

Data collection was conducted through semi-structured interviews, field observations, focus group discussions, and document analysis. Semi-structured interviews were used to explore the K'Ho community's perceptions of temperature changes, rainfall patterns, seasonal uncertainty, drought, strong winds, frost, hail, floods, landslides, and other ecological disturbances affecting coffee production. Interviews also explored the impacts of climate change on crop yields, production costs, coffee quality, household income, family labor, and livelihood strategies. This approach enabled an in-depth exploration of the experiences, interpretations, and meanings that informants construct in response to environmental changes they face (Kallio et al., 2016). Field observations focused on adaptation practices at the crop, garden, landscape, and household levels, such as pruning, use of disease-resistant varieties, planting shade trees, water management, mulching, manure use, coffee drying, income diversification, and access to weather information. Observations were conducted to understand social and ecological practices in everyday life and to capture aspects that are not always revealed through interviews (Tracy, 2010).

Data were analyzed using a stepwise interpretative strategy. First, all interview transcripts, observation notes, group discussion results, and supporting documents were read repeatedly to gain a comprehensive understanding of the research context. Second, open coding was conducted to identify initial themes, such as perceptions of climate change, crop damage, income uncertainty, adaptive farming practices, local knowledge, access to information, and institutional constraints. Third, these codes were developed through axial coding to establish relationships between socio-ecological vulnerability, coffee-based livelihoods, community-based adaptation, and grassroots resilience (Charmaz, 2014). The analysis was conducted abductively by connecting empirical findings and theoretical frameworks to explain the concept of layered grassroots resilience as the result of the interaction among local experiences, agricultural practices, and adaptation support structures. The abductive approach allows for a continuous dialogue between empirical data and theoretical concepts, producing richer explanations of the phenomena under study (Timmermans & Tavory, 2012).

3.3. Ethical considerations and research reflexivity

Paramount importance was placed on ethical considerations given the involvement of ethnic minority communities and sensitive livelihood issues (Moriña, 2021). Prior to data collection, research objectives, data utilization, and withdrawal rights were comprehensively explained to all informants (Sin, 2005), and contextually appropriate written or verbal consent was secured (Wiles et al., 2006). To preserve confidentiality, identities were anonymized using pseudonyms, and sensitive socioeconomic and geospatial data were deliberately redacted (Kaiser, 2009).

Regarding reflexivity, the researcher's positionality, disciplinary assumptions, and inherent power asymmetries were critically examined to assess their influence on data interpretation. Ongoing reflexive journaling was used to systematically interrogate personal biases, prevent the imposition of exogenous frameworks, and avoid romanticizing indigenous knowledge. Through this sustained reflexive paradigm, the co-production of knowledge was acknowledged, and the ethical responsibilities associated with representing marginalized communities were explicitly recognized (Langill, 2026).

3.4. Methodological rigor and limitations

Methodological rigor was maintained through source triangulation, method triangulation, transparency of analytical procedures, and reflexive interpretation (Tracy, 2010; Yadav, 2022). Source triangulation was conducted by comparing narratives from farmers, women farmers, community leaders, extension workers, and local officials, along with supporting documents. Method triangulation was carried out by combining interviews, observations, focus groups, and document analysis (Johnson et al., 2020).

Member checking was conducted selectively with several key informants to ensure that the researcher's interpretations remained consistent with local experiences (Birt et al., 2016). However, this study has limitations. As a qualitative study, the findings are not intended to generate statistical generalizations for all coffee farmers in Vietnam. Furthermore, data on climate change are largely sourced from local perceptions, so it should be understood as a socio-ecological experience that shapes adaptation decisions, rather than a substitute for meteorological data (Ricart et al., 2023).

4. Discussion

4.1. Climate Change as a Multiplier of Social and Livelihood Vulnerability

The findings of this study indicate that climate change experienced by the K'Ho community in Lam Dong Province, Vietnam, not only impacts the ecological and technical aspects of coffee production but also acts as a social vulnerability multiplier. Temperature changes, seasonal uncertainty, shifting rainfall patterns, increased wind intensity, drought, frost, hail, floods, and landslides not only reduce crop productivity but also disrupt income security, increase production costs, alter household work strategies, and increase the need for information, technology, and institutional support (Daniswara et al., 2025). Findings from farmer informants indicate that seasonal changes make it increasingly difficult for farmers to determine the timing of pruning, fertilizing, pest control, and drying coffee. When rains arrive too early or too late, production decisions become riskier. A K'Ho coffee farmer explained:

> *"The seasons used to be easier to predict. We knew when to start pruning, when to fertilize, and when to prepare for harvest. Now, rain can come suddenly, or the dry season can last longer. If the timing is wrong, the coffee flowers drop, the fruit is not good, and the yield decreases."* (I1, K'Ho coffee farmer, male, 40–65 years old).

This quote demonstrates that climate change is not simply understood as a change in the weather, but as a disruption to production decision systems. Ecological uncertainty translates into economic uncertainty because misreading the seasons can affect the quality and quantity of the harvest. At this point, climate change becomes a social issue because it affects how households plan work, manage costs, and maintain income (Coles & Scott, 2009).

This vulnerability is exacerbated by the fact that coffee is the primary source of income for most K'Ho households. When coffee yields decline, households must still meet the needs of food, children's education, healthcare, debt payments, and the purchase of agricultural inputs. This situation demonstrates how climate shocks to coffee commodities not only reduce income but also narrow the scope of household strategies for maintaining their livelihoods (Eakin et al., 2014). A female informant from a farming household described this pressure as follows:

> *"If coffee yields decrease, it is not just the money from the farm that changes. At home, we have to recalculate all our needs. Children's school fees, food, medicine, and fertilizer still need to be provided. Sometimes women are the ones who have to find ways to meet household needs."* (I2, female member of a coffee farming household, 35–60 years old)

These findings demonstrate that the impacts of climate change are shifting from the farm to the domestic sphere. Women not only experience economic impacts but also bear the burden of managing household risks. When income declines, women are often involved in adjusting consumption, managing debt, seeking additional income, and managing family needs. This suggests that climate vulnerability has a significant gender dimension (Van Aelst & Holvoet, 2016). The experiences of senior farmers reinforce the finding that climate change is understood through intergenerational ecological memory. Farmers not only compare harvest yields but also compare natural signs, temperature, rainfall patterns, and crop conditions over time.

> *"I have been growing coffee for a long time. The air was cooler, the rains were more regular, and the soil was easier to maintain. Now the heat lasts longer, the winds are stronger, and plant diseases are more frequent. We feel like our gardens are no longer the same as before."* (I3, senior farmer/elder of the K'Ho community, male, 50–75 years old)

This quote demonstrates that the community has a historical knowledge base to recognize environmental change. Ecological memory is an important resource in understanding climate risk. For senior farmers, climate change is not merely meteorological data but a socio-ecological experience evident

in changes in soil, crops, water, wind, and agricultural work patterns (Arham et al., 2023). These findings broaden our understanding of climate vulnerability in agrarian communities. Vulnerability is not simply understood as exposure to ecological hazards, but rather because of the intersection of climate stress, dependence on a single commodity, limited capital, unequal access to information, and weak social protection. Households with more limited land, less capital, and less access to training or technology are more vulnerable than those with stronger resources (McElwee et al., 2023; Nyairo et al., 2020).

This analysis shows that climate change operates through a socio-ecological chain. Weather changes disrupt coffee production by reducing income; decreased income affects consumption, education, health, and the ability to purchase inputs; and input limitations then weaken adaptive capacity in the following season. This chain demonstrates that climate change not only creates immediate vulnerability but can create a long-term cycle of vulnerability if not supported by adequate social policies and institutions (McElwee et al., 2023; Van Aelst & Holvoet, 2016).

Coffee sustainability, therefore, cannot be reduced to productivity, bean quality, or meeting market standards. For the K'Ho community, coffee sustainability is directly linked to household social sustainability, income security, the sustainability of local knowledge, and the community's ability to sustain life amidst ecological pressures. Sustainable coffee production requires access to climate information, adaptive capital, relevant training, social networks, protection from risks, and the space to maintain ecological relationships with the land, trees, water, and surrounding landscape.

4.2. Local Agency, Knowledge Production, and Grassroots Resilience

The findings of this study confirm that the K'Ho community cannot be viewed solely as victims of climate change. They possess local agency to interpret environmental changes, interpret risks, make decisions, and develop adaptation strategies based on everyday experiences. The K'Ho community's adaptation does not emerge as a single response, but rather as an ongoing learning process through observation, experimentation, adjustment, and the exchange of knowledge among farmers. Adaptation practices are evident in various technical decisions on the farm. Farmers adjust branch pruning, select more disease-resistant coffee varieties, use stronger seedlings, manage weeds, control pests, plant shade trees, use mulch, harvest rainwater, utilize manure, and adjust the coffee drying process. One farmer explained:

> *"We try many ways to keep the coffee alive. Branches must be pruned, the soil must not dry out too much, and shade trees must be protected. If we just wait for good weather, we will not survive."* (I1, K'Ho coffee farmer, male, 40–65 years old)

This quote demonstrates that adaptation is not simply an emergency response but part of an ongoing risk management practice. Farmers do not wait for external intervention to act. They develop strategies based on ecological experiences and daily production needs (Bhatasara, 2018). These practices demonstrate that farmers are active actors who interpret environmental changes, develop action options, and adapt livelihood strategies to the conditions they face (Kietäväinen, 2014). Local agency is also evident in the younger generation, who are beginning to utilize information technology. Young farmer informants explained that weather information from their mobile phones helps them adjust agricultural and post-harvest decisions.

> *"Now I often check the weather on my phone. If it rains tomorrow, we will not dry too much coffee. If it is hot for a long time, we prepare ways to prevent the soil from drying out too quickly. Our parents taught us about natural signs, but now we also use information from the internet."* (I4, young coffee farmer, male, 20–35 years old)

This quote demonstrates the hybridization of knowledge. The younger generation is not abandoning local knowledge; it is combining it with digital information. The K'Ho community's adaptation is formed through the intersection of local experiences, ecological memory, agricultural practices, and modern information (Chaudhary et al., 2022). This reinforces the argument that community resilience is neither purely traditional nor purely modern, but rather relational and dynamic (Xu & Grumbine, 2014). In the post-harvest stage, women play a crucial role in maintaining coffee quality. Weather changes make drying coffee more challenging because rain can come suddenly, and humidity becomes harder to control.

"Drying coffee is now more difficult. We must quickly cover the coffee when it rains, then open it again when it gets hot. If we are late, the coffee can get damp, and the quality will decrease. This work requires us to monitor the drying yard more frequently." (I5, female coffee processor/member of a farming household, 25–50 years old)

This quote demonstrates that adaptation occurs not only during cultivation but also during post-harvest. Climate change impacts coffee quality, market value, and household workload. Women's roles are crucial as they maintain product quality while managing domestic pressures resulting from income uncertainty (Palacios et al., 2023). Based on these findings, this study develops the concept of grassroots resilience. This concept refers to a community's ability to build resilience through adaptive practices that grow from local experiences, social relationships, resource management, and interactions with external support. The novelty of this concept lies in its emphasis on resilience arising not only from general community capacity but also from the community's ability to activate knowledge, assets, social networks, and ecological practices in response to climate stress (Perez et al., 2015).

The concept of grassroots resilience differs from the concept of community resilience, which often emphasizes broader collective capacity. It highlights how adaptive actions are generated from below through everyday practices, household relationships, farmer experiences, and relationships with the local landscape. This concept also differs from community-based adaptation approaches, which often focus on programs or interventions. In the case of K'Ho, adaptation emerged primarily from farmers' lived experiences before being reinforced by extension, cooperatives, or policies. Compared to sustainable livelihoods approaches that typically map household assets, grassroots resilience emphasizes how these assets are activated, negotiated, and transformed into adaptive practices when communities face climate stress (Jost et al., 2016). Grassroots resilience is also evident in the community's relationship with the landscape. A senior farmer explained that trees, surrounding forests, soil moisture, and farm temperature play a crucial role in coffee sustainability.

"Coffee does not grow well if the farm is too hot. Big trees help maintain soil and air quality. If all the trees are cut down, the farm dries out more quickly. We learned from the farm that coffee needs shade, water, and living soil." (I3, senior farmer/elder of the K'Ho community, male, 50–75 years old)

This quote demonstrates that resilience depends not only on agricultural inputs but also on maintaining ecological relationships. Knowledge about shade trees, soil, humidity, and surrounding forests is part of an adaptation strategy rooted in local experience (Gram et al., 2018). In summary, adaptation should be understood as more than a list of technical practices; it is a complex social process influenced by power dynamics, access to resources, and the structure of social relations within the community. Adaptation involves ongoing negotiation over possession and circulation of knowledge, decision-making authority, resource allocation, and institutional support. Everyday social interactions and structural inequalities—such as differences in status, network connections, and resource access—directly influence whose adaptation strategies succeed or fail. Thus, grassroots resilience develops unevenly across communities, shaped by intersecting factors such as age, gender, experience, land tenure, economic means, access to technology, and network proximity.

4.3. Inequality of Adaptation, Empowerment, and Institutional Responsibility

The research findings indicate that climate adaptation is not occurring evenly, directly addressing the study's third research question about how adaptation strategies at various levels shape the socio-ecological resilience of the K'Ho community. Households with better access to information, training, technology, capital, and cooperative networks tend to be better able to adapt to climate change. Conversely, poor or near-poor households face greater barriers to implementing adaptation strategies that require money, time, technical knowledge, or institutional access. The observed disparity demonstrates that climate change acts as both an ecological and social vulnerability multiplier, exacerbating existing inequalities in adaptive capacity within the community. This pattern of uneven adaptation further underscores the importance of examining not only the effectiveness of adaptation strategies but also the underlying socioeconomic and institutional factors influencing their distribution, as highlighted in the research questions. An agricultural extension worker explained that training on seeds, fertilization, plantation management, and improving coffee quality has not reached all farmers equally.

> *"We have conducted training on seeds, fertilization, and plantation management, but not all farmers can attend. Some live far away, some do not have time due to work, and some do not receive advance notice. Farmers who regularly participate in training are usually quicker to try new methods."* (I6, agricultural extension worker, male, 30–55 years old)

Inequality in adaptation is not only caused by poverty, but also by unequal access to knowledge and institutions. Farmers close to extension networks have greater opportunities to access new information, while those in weaker socioeconomic positions are at risk of being left behind (Teller, 2016). Local government representatives also emphasized that low-income households are the group most affected when bad weather and crop yields decline.

> *"When harvests decline, economically weaker families feel the brunt of the impact. They not only need assistance with their gardens but also support to meet their family's needs. Without support, it is difficult for them to repair their gardens in the next season."* (I7, local/village government representative, male, 35–60 years old)

Climate adaptation must be understood as a social policy issue. Agricultural technical assistance is important, but it is insufficient without accompanying social protection, adaptive financing, and support for vulnerable households. Without such support, poor households can become trapped in a cycle of vulnerability: declining harvests, declining incomes, reduced ability to purchase inputs, and weakened adaptive capacity in subsequent seasons (McElwee et al., 2023). Cooperatives and sustainable coffee actors highlight the importance of a more equitable relationship between farmers and markets. Quality and sustainability standards often require farmers to maintain coffee quality, while weather risks complicate production and post-harvest processes.

> *"The market demands good quality, but farmers face unpredictable weather. If cooperatives or buyers only demand standards without helping farmers manage risks, smallholder farmers will face even greater hardship. Mentoring, price certainty, and technical support are crucial."* (I8, cooperative/sustainable coffee actor, female, 30–55 years old)

This quote demonstrates that market sustainability must be linked to social justice. Farmers cannot be positioned solely as commodity suppliers who must meet standards, but as social actors facing ecological and economic risks. Relationships among farmers, cooperatives, buyers, and supporting institutions need to be built more equitably so that sustainability benefits not only the market chain but also strengthen farmers' adaptive capacity (Onyas et al., 2018). At this point, grassroots resilience should not be understood romantically. The fact that communities can adapt from the ground up does not mean that the responsibility for adaptation can be left entirely to farmers. Local resilience can become fragile without adequate institutional support. Increasingly intense climate risks require more systematic support, especially for households with limited capital, land, technology, and social networks (McElwee et al., 2023).

Community empowerment needs to be understood more broadly than simply increasing productivity. Empowerment must include farmers' abilities to understand climate risks, access relevant information, manage local resources, strengthen farmer organizations, expand market networks, and negotiate with supporting institutions. Training that focuses solely on fertilization or seed selection is insufficient to address the challenges of climate change. Empowerment programs need to include climate literacy, risk management, livelihood diversification, water conservation, agroecological management, social protection, and strengthening farmers' bargaining position in the coffee value chain (Candelo et al., 2018).

Policy support also needs to be designed sensitively to local characteristics. Uniform adaptation programs often fail to capture differences in household capacity. The K'Ho community possesses ecological experience, local knowledge, and adaptation practices that have developed from the ground up. Effective policies are not those that replace these practices, but rather those that strengthen them through climate risk-based outreach, inclusive financing, equitable access to technology, support for cooperatives, social protection, and recognition of local knowledge (Kansiime, 2012).

This section clarifies the research's critical contribution to climate adaptation studies. K'Ho's findings demonstrate that local resilience is inextricably linked to resource distribution and power relations. Households with better access to training, technology, cooperatives, and information have greater opportunities for adaptation, while poor or remote households are more likely to be left behind. Therefore,

climate adaptation needs to be understood as a socio-political process, not simply a technical one. Without inclusive institutional interventions, the adaptation agenda risks reinforcing existing inequalities.

5. Conclusion

This study investigates how the K'Ho community in Lam Dong Province, Vietnam, cultivates grassroots resilience to climate change through sustainable coffee production. Drawing on qualitative case studies, the research reveals that climate change is a complex socio-ecological process affecting vulnerability, livelihoods, and adaptive capacity. Key findings indicate that climate-related disruptions extend beyond productivity to threaten income security and household well-being. Importantly, the K'Ho demonstrate agency in responding to these risks by employing adaptive strategies informed by ecological memory and local knowledge. Adaptation emerges as a cumulative, multi-layered process that integrates technical, social, and ecological practices across different scales, rather than through isolated interventions.

Theoretically, this study offers a key contribution through the concept of grassroots resilience. This concept holds that the resilience of agrarian communities does not emerge from a single technical intervention, but from the interconnectedness of local agency, ecological knowledge, production practices, livelihood assets, social networks, and institutional support. First, this concept extends the socio-ecological resilience approach by demonstrating that resilience operates through concrete, interconnected adaptation practices at various scales of community life. Second, this concept enriches the community-based adaptation approach by emphasizing that adaptation does not always originate in external programs but rather grows from farmers' daily experiences, learning, experimentation, and negotiations in the face of climate stress. Third, this concept complements the sustainable livelihoods framework by demonstrating how household assets, local knowledge, social relations, access to information, and institutional support are activated and negotiated in situations of ecological crisis. Thus, multi-layered grassroots resilience helps understand how minority agrarian communities build resilience not only through resilience but also through the capacity to reimagine their agricultural practices, livelihood strategies, and ecological relationships amidst climate uncertainty.

However, this study also emphasizes that local resilience should not be romanticized. The K'Ho community's adaptive capacity remains limited by unequal access to climate information, digital technology, training, capital, extension services, cooperatives, markets, and social protection. Poor and near-poor households, women, farmers living far from service centers, and groups with limited access to institutional networks face greater barriers to implementing adaptation strategies. Therefore, climate change not only magnifies ecological risks but can also deepen pre-existing social inequalities. This research makes an original conceptual contribution by introducing and evidencing the distinctive notion of multi-layered grassroots resilience. By foregrounding the interplay among local agency, indigenous ecological knowledge, livelihood assets, and institutional support, the study advances understanding of how resilience is actively constructed from below through cumulative, context-specific adaptation practices rather than imposed through top-down interventions. This perspective highlights the heterogeneous, dynamic nature of resilience in minority agrarian communities and points to the importance of power, resource distribution, and local knowledge in shaping adaptation outcomes. The policy implication of this study is that climate adaptation in sustainable coffee production must go beyond technical training oriented toward increasing productivity. Equitable adaptation requires inclusive climate information systems, adaptive financing, locally relevant extension services, strengthening farmer organizations, support for women and vulnerable households, more equitable cooperative and market relations, social protection, and recognition of local ecological knowledge. Beyond the K'Ho case, this study has broader implications for the study of social development, climate adaptation, and the sustainability of minority agrarian communities in Southeast Asia and analogous contexts. This study has limitations due to its qualitative approach, which focuses on a single community and coffee production area, so its findings are not intended for statistical generalization.

Furthermore, some climate change data are derived from local perceptions and experiences and should therefore be read as socio-ecological experiences that shape adaptation decisions, rather than as a substitute for meteorological data. Nevertheless, these limitations open up opportunities for further

research. Comparative studies across coffee communities, longitudinal research on changes in adaptation strategies over time, and the integration of qualitative data with climate and household economic data could deepen understanding of how grassroots resilience is built, constrained, and transformed in the face of the climate crisis.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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