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Perceptions and adaptation strategies to climate change in coffee farming: a systematic review

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Abstract

Coffee farming is an activity of major socioeconomic relevance, particularly in countries of the Global South, where it represents a primary source of income for millions of smallholder farmers. Climate change directly affects coffee production and quality, with consequences for producing regions and communities that depend on this activity. This study aimed to identify, through a systematic literature review, methodological approaches used in research on coffee agroecosystems and climate change, to analyze adaptation strategies adopted, and to understand factors influencing coffee farmers' perceptions across different territorial contexts regarding climate change. The methodology followed the PRISMA-RR protocol, which organizes the systematic review process into four stages: (i) literature identification, (ii) screening, (iii) eligibility assessment, and (iv) retrieval of conclusive evidence. Searches were conducted on the Web of Science and Scopus databases. Most studies adopted a mixed-methods approach (70%), combining qualitative and quantitative tools. Among production systems analyzed, hybrid and agroecological systems showed the greatest diversity of adaptation strategies to climate change. Territorial factors, production systems, and socioeconomic conditions directly influenced how farmers perceived and responded to climatic events, as well as adoption of adaptation strategies. Results indicate that adaptation in coffee farming is conditioned by structural and territorial factors, reinforcing the need for interdisciplinary approaches that integrate ecological, productive, and socioeconomic dimensions when addressing climate change.

1 Introduction

Coffee farming is an agricultural activity of major global importance because of its economic and social contributions. An estimated 17.5 million family farmers worldwide depend on coffee production for their livelihoods (Pham et al., 2019).

Brazil, the world's largest producer, accounts for 35.5% of *Coffea arabica* production and 22.25% of *Coffea canephora* production. Vietnam leads global *C. canephora* production with 37.7%, whereas Colombia contributes 13.20% of global *C. arabica* production (BRAZIL, 2025). Coffee farming also supports development in rural communities and producing regions by generating employment and income in countries such as Ethiopia, Mexico, and Rwanda (Jawo et al., 2023; Tesfaye, 2021; Bro, 2020).

Currently, coffee farming faces increasing risks associated with climate change across producing countries (Gomes et al., 2020; Dias, Martins, and Martins, 2024). The most widely cultivated coffee species require distinct climatic conditions for optimum development. *C. arabica*, commonly used for specialty coffee production, performs best under mean annual temperatures of 18–22°C and annual rainfall of 1,200–2,000 mm (DaMatta et al., 2007). *C. canephora* is generally more resilient and productive, although often considered lower in beverage quality, and performs best under mean temperatures of 22–28°C (Magrach and Ghazoul, 2015) and annual rainfall of 1,200–1,800 mm (de Souza et al., 2025).

Under future climate scenarios, projections for Brazil indicate yield losses in *C. arabica* caused by thermal stress and greater susceptibility to infestation by coffee leaf miner (*Leucoptera coffeella* Guérin-Mèneville) and coffee rust (*Hemileia vastatrix* Berkeley and Broome) (Dias; Martins; Martins, 2024). According to these projections, approximately 35% to 75% of Arabica plantations in the country may be negatively affected and could become economically unviable during the twenty-first century. In addition, Venancio et al. (2020) reported that prolonged droughts and elevated temperatures may reduce *C. canephora* productivity by up to 41%.

How farmers perceive and respond to climate change is central to understanding adaptation dynamics within agricultural communities and coffee agroecosystems (Nguyen et al., 2025). Such perceptions do not always align with meteorological records, as they are shaped by farmers' empirical experiences and direct observations of climatic impacts (Jawo et al., 2023; Tesfaye, 2021).

Studies conducted in producing regions such as Mana, southwestern Ethiopia, and Puebla, Mexico, show that perceptions of increasing temperatures and declining rainfall are critical drivers of adaptation strategies (Tesfaye, 2021; Jawo et al., 2023). In Vietnam, recognition of drought periods by 91% of farmers and excessive rainfall by 23% was decisive for adopting adaptation measures (Lan et al., 2023). Reported strategies include agroforestry systems, shade-tree management, crop diversification, and adjustments in agricultural calendars (Shinbrot et al., 2019; Sánchez et al., 2023). In Rwanda, Gather and Wollni (2024) found that farmers' risk perceptions varied mainly according to prior experiences with climatic events. Farmers who perceived stronger

climatic changes were more likely to adopt shading practices and diversify income through cultivation of additional crops (Gather and Wollni, 2024). Conversely, limited perception of climate change may reflect insufficient knowledge of its effects on coffee production, thereby constraining adoption of adaptive strategies (Hasibuan et al., 2023).

Analyzing coffee growers' perceptions of climate change requires consideration of territorial, socio-environmental, and production contexts. Geographic location, agroecosystem type, and socioeconomic structure influence both how climate risks are understood and which production and adaptation strategies are adopted. Therefore, understanding climate adaptation in coffee farming requires recognition that farmers' responsiveness is directly shaped by these variables, which may differ substantially across territories (Jawo et al., 2023; Tesfaye, 2021).

Although climate change adaptation strategies have been widely documented, a gap remains in scientific literature regarding farmers' perceptions, particularly how such perceptions influence adoption of adaptive practices. This gap is especially relevant because available evidence indicates that perception of climate risk is a key determinant of decision-making and implementation of adaptation measures.

Accordingly, this study aimed to identify methodological approaches used in research on coffee agroecosystems and climate change, analyze adaptation strategies adopted, and understand factors influencing coffee growers' perceptions of climate change across different territorial contexts.

2. Materials and Methods

For the systematic literature review, the core collection of the Web of Science platform, originally developed by Thomson Reuters – Institute for Scientific Information (ISI) and currently maintained by Clarivate Analytics, together with the Scopus database by Elsevier, were used. The review was conducted according to guidelines of the PRISMA-RR protocol (Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Rapid Reviews) (Stevens et al., 2018). This protocol is particularly relevant for interdisciplinary and rapidly evolving topics, such as climate change and agricultural adaptation, because it helps ensure that evidence syntheses are robust, comparable, and useful for guiding technical and policy decisions (Stevens et al., 2018; Mouratiodou et al., 2024).

PRISMA-RR organizes the review process into four phases: (I) literature identification, (II) screening, (III) eligibility assessment, and (IV) retrieval of conclusive evidence. In Phase I, the identification stage, the following search strategy was applied: Documents-Topic [("climate change" AND "coffee" AND "percept")]**. Keywords were defined through exploratory searches conducted within the databases. The terms climate change, coffee, and percept were selected because they represent core concepts of this investigation, spanning climatic impacts on coffee farming and subjective perceptions associated with farmers' experiences and management practices. The Boolean operator AND restricted retrieval to articles containing all specified terms simultaneously (Shah et al., 2021), thereby ensuring direct relevance to each theme. The wildcard asterisk (*) was used to capture word variants, whereas quotation marks ensured exact phrase matching for specified terms (Mejia et al., 2021). Publications available in all languages up to March 2025 were considered.

In Phase II, the screening stage, inclusion and exclusion criteria were applied (Table 1). Review articles, book chapters, editorial materials, conference papers, and duplicate records were excluded because they did not provide original data and/or presented only partial results related to study objectives. In parallel, titles and abstracts of selected records were examined to confirm whether they effectively addressed the proposed topic and should therefore be included in the review.

Table 1
Inclusion and exclusion criteria applied during the screening phase.

Inclusion criteria	Exclusion criteria
Original research articles only	Review articles, book chapters, editorial materials, conference papers, and duplicate records.
Peer-reviewed publications	Non-peer-reviewed publications
Studies presenting original information on farmers' perceptions of climate change	Studies not presenting original information on farmers' perceptions
Full-text articles available for access	Full-text articles not available for access

Source

The author (2025).

In Phase III, corresponding to the eligibility stage, previously selected articles were organized and subjected to full-text review to confirm their alignment with study objectives. At this stage, the treatment of farmers' perceptions of climate change in coffee agroecosystems was assessed, considering both direct and indirect expressions of such perceptions.

In addition, information reported in each study was examined, with particular attention to how perceptions were described and analyzed. Articles that did not address these aspects were excluded from the final dataset.

In Phase IV, the evidence retrieval stage, selected articles were organized in a spreadsheet using Microsoft Excel containing the following information: (a) reference data, including title, authors, publication year, country of publication, objectives, abstract, and conclusions; (b) territories analyzed, including country and region where the study was conducted; (c) categorization of agroecosystems; (d) methodological approaches, including classification as qualitative, quantitative, or mixed methods, and tools applied (interviews, questionnaires, focus groups, statistical tests, or combinations of these tools); (e) farmers' perceptions, including assessment of coffee growers' perceptions of climate change; and (f) adaptation strategies, including actions and practices adopted in response to climate-related impacts.

All protocol stages were conducted collaboratively by two researchers, thereby increasing methodological rigor and reliability. During the screening phase, disagreements were resolved through final evaluation by a third reviewer.

Data were systematically organized and tabulated to enable detailed analysis of approaches employed in reviewed studies. Initially, 151 records were identified, including 59 from Web of Science and 92 from Elsevier Scopus. These records were assessed according to steps described above. After application of PRISMA-RR criteria (Stevens et al., 2018), the final dataset comprised 53 articles from both databases. A summary of the methodological procedure based on the PRISMA-RR flowchart is presented in Fig. 1.

Source

The author (2025).

Based on evidence retrieval (Phase IV), analysis focused on central elements of research question and study problem. Accordingly, results are discussed according to three main axes: (I) methodological approaches and tools applied in the studies; (II) territories and agroecosystems; and (III) farmers' perceptions of climate change and adaptation strategies.

3. Results

The temporal distribution of publications indicates more consistent growth in this topic from 2017 onward, with clear intensification in recent years and notable peaks after 2020. In 2025, a reduction in the number of studies was observed, possibly associated with the temporal cutoff adopted for data collection rather than reflecting decreased scientific interest in the subject (Fig. 2).

Most of the 53 articles included in the systematic review were published in English (n = 47), followed by publications in Spanish (n = 6) (Appendix 1).

Regarding methodological approaches, studies using mixed methods predominated, representing 38 articles (70%). Exclusively qualitative approaches were identified in 13 studies (23%), whereas exclusively quantitative approaches were found in only 2 articles (3% of the total) (Table 2).

Table 2
Methodological approaches identified in the reviewed articles.

Methodological approach	Perception analysis	References	Number of articles
Mixed	Integrates qualitative and quantitative methodological approaches and research tools	Hernández-Castán and Tapia-Hervert Calderón, (2023); Quiroga et al. (2020); Teodoro et al. (2024); Gather and Wollni, (2024); Ayalew et al. (2024); Há et al. (2024); Rodríguez-Barillas, Poortvliet, Klerkx (2024); Bartl, (2024); Gomm et al. (2024); Rodríguez-Barillas, Poortvliet, Klerkx (2023); Hasibuan et al. (2023); Ayal et al. (2023); Jawo et al. (2023); Sánchez et al. (2023); Tesfaye (2021); Jaramillo-Villanueva et al. (2022); Pons et al. (2021); Tran and Chen (2021); Eise, Lambert and Wiemer (2021); Mbwambo, Maurice and Tarimo (2021); Nguyen and Drakou (2021); Adhikari et al. (2021); Jezeer et al. (2019); Capitani et al. (2018); Asayehegn et al. (2017); Barrucand, Vieira and Canziani (2019); Quiroga, Cristina, Suárez and Solís (2014); Nghiepa et al. (2024); Beristain-Moreno et al. (2024); Lan et al. (2023); Msuya and Mahonge (2022); Byrareddy et al. (2021); Wagner et al. (2022); Le et al., (2020); Shinbrot et al. (2019); Harvey et al. (2018); Chengappa, Devika and Rudragouda (2017); Eakin et al. (2013); Torres-Lezama et al. (2011).	38
Qualitative	Exclusively qualitative approaches and tools	Moreno et al. (2024); Rodríguez-Barillas et al. (2024); Bro, (2020); Altea, (2020); Pham et al. (2020); Borsky and Spata, (2017). Eise, Lambert, Wiemer (2021); Borsky and Spata (2017); Sánchez and Bello (2020); Gerlicz et al. (2018); Vigueira et al. (2018); Vigueira et al., (2019); de los Ríos and Almeida (2010); Palacios et al. (2023).	13
Quantitative	Exclusively quantitative approaches and tools	Lan et al., (2023); Venancio et al., (2024).	2

Source: Own elaboration based on studies from the systematic review (2025).

Among tools employed in mixed-methods studies, the most frequent were interviews (n = 22; 57.9%), structured and semi-structured questionnaires (n = 21; 55.3%), regression models and analysis of variance (n = 21; 55.3%), focus groups (n = 11; 28.9%), and descriptive statistics (n = 12; 31.6%) (Table 3).

In qualitative studies, interviews combined with direct observation of agroecosystems predominated (n = 9; 69.2%), followed by workshops (n = 3; 23.1%) and interactive games with participatory workshops (n = 2; 15.4%) (Table 3).

Among the few studies with an exclusively quantitative focus, use of questionnaires (n = 1; 50.0%), descriptive statistics, and mean comparison tests (n = 2; 100.0%) was identified (Table 3).

Table 3
Predominant methodological tools used in mixed, qualitative, and quantitative approaches among the reviewed articles.

Methodological approach	Tools	Number of articles
Mixed	Interviews	22
	Structured and semi-structured questionnaires	21
	Regression models and analysis of variance	21
	Focus groups	11
	Descriptive statistics	12
Qualitative	Interviews combined with direct observation	9
	Interactive games and participatory workshops	2
Quantitative	Questionnaires	1
	Descriptive statistics and mean comparison tests	2

Source Own elaboration based on studies from the systematic review (2025).

Most studies were conducted in Latin America (40%), Africa (26%), and Asia (21%). Among countries with the highest number of studies, Ethiopia (n = 9), Vietnam (n = 8), Mexico (n = 7), and Costa Rica (n = 4) were most prominent. In addition, three studies each were conducted in Colombia, Guatemala, Tanzania, Honduras, and Nicaragua (Fig. 3).

Based on reading and analysis of the studies, four categories of farming systems were identified: agroecological, conventional, hybrid/transitional, and traditional/subsistence (Table 4).

Agroecological systems are characterized by adoption of sustainable practices such as ecological soil and water management, crop shading, agroforestry systems, crop diversification, and use of biological inputs. In contrast, conventional systems are based on intensive use of chemical inputs and monoculture, with little or no incorporation of sustainable practices such as ecological soil and water management. Hybrid or transitional systems combine agroecological elements with use of local resources, while still maintaining some dependence on conventional practices, such as occasional pesticide application. Finally, traditional or subsistence systems rely on local knowledge and maintain strong integration with surrounding ecosystems, prioritizing agroecological practices mainly directed toward household food security.

Categorization of production systems showed predominance of hybrid or transitional systems (44%), followed by agroecological (22%), conventional (14%), and traditional or subsistence systems (5%). It should also be noted that in 12% of articles analyzed, production systems could not be categorized because of insufficient information (Table 4).

Table 4
Categories of production systems and their frequency of occurrence in the reviewed studies.

Production Systems	Frequency (%)	References
Agroecological	22%	Gather and Wollni (2024); Gom et al. (2024); Ayal et al. (2023); Jawo et al. (2023); Tesfaye (2021); Mbwambo et al. (2021); Altea (2019); Capitani et al. (2018); Barrucand, Vieira and Canziani (2016); Ayalew et al. (2024); Beristain-Moreno et al. (2024); Sánchez and Bello (2020); Shinbrot et al. (2018);
Conventional	14%	Lan et al., (2023); Jaramillo-Villanueva et al., (2022); Nguyen and Drakou (2021); Pham et al., (2020); Le et al. (2020); Viguera et al., (2019); Chengappa, Devika and Rudragouda (2017); Torres-Lezama et al. (2012);
Hybrid/Transitional	44%	Ha et al. (2024); Rodríguez-Barillas, Poortvliet and Klerkx (2024); Bartl (2024); Teodoro et al. (2024); Sánchez et al. (2023); Hernández-Castán and Tapia-Hervert Calderón (2023); Pons et al. (2021); Tran and Chen (2021); Bro (2020); Adhikari et al. (2021); Quiroga et al. (2019); Jezzer et al. (2019); Asayehegn et al. (2017); Tucker, Eakin and Castellanos (2009); Nghiepa et al. (2024); Palacios et al. (2023); Msuya and Mahonge (2022); Byrareddy et al. (2021); Wagner et al. (2021); Gerlicz et al. (2018); Viguera et al. (2018); Harvey et al. (2018); Eakin et al. (2013).
Traditional	5%	Ayalew et al. (2024); Hasibuan et al. (2023); de los Ríos and Almeida (2010).
Non-categorized	12%	Rodríguez-Barillas, Klerkx and Poortvliet (2023); Eise, Lambert and Wiemer (2021); Borsky and Spata (2017); Quiroga, Suárez and Solís (2009); Rodríguez-Barillas, Klerkx and Poortvliet (2024); Lan et al. (2023); Tran and Chen (2021).

Source: Own elaboration based on studies from the systematic review (2025).

Analysis of the regional distribution of production systems showed that hybrid systems predominated in Latin America, traditional/subsistence systems were more common in East Africa, Asia was characterized by intensive conventional systems, and some producing regions of Africa, particularly Ethiopia, showed a substantial presence of agroecological systems (Table 5).

Table 5
Distribution of production systems and their characteristics by region and country.

Region	Predominant production system	Countries	References
Latin America	Hybrid/Transitional	Mexico, Guatemala, Costa Rica, and Honduras	Hernández-Castán and Calderón, (2023); Sánchez et al. (2023); Gerlicz et al. (2018); Viguera et al., (2018); Barillas, Poortvliet, Klerkx, (2024); Palacios et al. (2023); Tucker, Eakin and Castellanos (2009); Jezeer et al. (2019); Bro (2020); Tran and Chen (2021); Pons et al. (2021).
East Africa	Traditional/Subsistence	Ethiopia,	Gomm et al. 2024; Ayalew et al. (2024).
Asia	Conventional/Intensive	Vietnam and Indonesia	Le, Le, Cowal, (2020); Pham et al., (2020); Nguyen and Drakou (2021); Lan et al. (2023).
East Africa	Agroecological	Ethiopia and Tanzania	Gom et al. (2024); Ayal et al. (2023); Tesfaye, (2021); Altea, (2019); Capitani et al., (2018); Jawo et al. (2023); Mbwambo et al., (2021); Capitani et al. (2018).

Source: Own elaboration based on studies from the systematic review (2025).

Analysis of the reviewed articles allowed identification of four territory-related factors that influence farmers' perceptions of and adaptation to climate change in coffee farming. In Vietnam, local climatic conditions and access to credit were reported as key determinants of farmers' perceptions and decision-making. In Mexico, access to markets and technologies increased capacity for adaptive responses. In Colombia, social organization and participation in cooperatives were identified as important facilitators of collective climate adaptation strategies (Table 6).

Table 6
Relationship between territorial factors and their implications for farmers' perceptions of climate change.

Territory-Related Factors	Implications for perception and adaptation strategies	Country	References
Climate conditions, water deficit, and access to credit	Influence farmers' perceptions and decision-making	Vietnam	Nguyen and Drakou (2021); Byrareddy et al. (2021). Pham et al. (2020)
Access to markets and technology through cooperatives and associations	Increases adaptative response capacity	Mexico	Jaramillo- Villanueva et al. (2022); Sánchez and Bello (2020). Shinbrot et al. (2019).
Social organization and cooperatives	Facilitate collective adaptation strategies	Colombia	Eise, Lambert, Wiemer (2021); Barrucand, Vieira, Canziani (2016); Borsky and Spata, (2017).
Land tenure structure	Influences how farmers perceive climate risks	Rwanda and Ethiopia	Ayalew et al. (2025); Gather and Wollni, (2024)

Source: Own elaboration based on studies from the systematic review (2025).

Among strategies adopted to adapt coffee agroecosystems to climate change, the most prominent were agroforestry systems and shade management (33.9%), diversification of agricultural crops (32.1%), ecological soil and water management (32.0%), use of resistant varieties (21.4%), access to credit, participation in cooperatives, and fair-trade arrangements (8.9%), and reduced pesticide use combined with greater adoption of biological inputs (8.9%) (Table 7).

Table 7
Main adaptation strategies identified in coffee agroecosystems in response to climate change, expected actions, and frequency of reporting in the reviewed studies.

Adaptation Strategy	Expected Action	Frequency (%)
Agroforestry systems and shade management	Shading, soil conservation, improved water regulation, and a more favorable microclimate.	33.9%
Diversification of agricultural production	Reduced vulnerability through multiple income sources.	32.1%
Ecological soil and water management	Increased biodiversity, greater soil water retention, and water reuse.	32%
Use of resistant varieties	Cultivars tolerant to water deficit, pests, and diseases such as rust and cercosporiosis.	21.4%
Access to credit, cooperatives, and markets	Greater investment capacity in adaptive technologies and market access.	8.9%
Reduction in pesticide use and increased use of biological inputs	Enhanced soil biodiversity and lower input costs.	8.9%

Source Own elaboration based on studies from the systematic review (2025).

Territorial context and production systems seemed to influence farmers' perceptions of climate change, which, when mediated by socioeconomic and institutional factors, are associated with adoption of different adaptation strategies. Figure 4 schematically illustrates this dynamic.

4. Discussion

The predominance of mixed-methods approaches (Table 2) reflects researchers' efforts to address both subjective dimensions of climate perception, such as farmers' narratives, values, and beliefs, and measurable variables related to climate change impacts and adaptive responses (Beristain-Moreno et al., 2024; Mbwambo et al., 2021; Jezeer et al., 2019).

Qualitative methods enable identification of empirical perceptions constructed through direct observation of nature and knowledge acquired through lived experience (Beristain-Moreno et al., 2024; Bro, 2020). Studies adopting this

approach generally emphasize intuitive, historical, and affective dimensions of human perception, thereby providing deeper understanding of relationships between farmers and their environments (Altea, 2019; Viguera et al., 2018). This perspective reinforces the view that individual experiences with nature play a significant role in shaping climate perceptions and in how people interpret environmental change.

In contrast, quantitative approaches are valuable for risk assessment, particularly regarding crop productivity and decision-making. They allow identification of generalizable patterns and establishment of statistical relationships between perception and adoption, or non-adoption, of adaptive practices (Lan et al., 2023). However, when perception is treated as an isolated variable without examining motivations and meanings underlying responses, quantitative approaches may overlook the social and cultural contexts in which such perceptions are formed (Moreno et al., 2024). This limitation may help explain the relatively small number of exclusively quantitative studies identified in this review (Table 2).

The mixed-methods approach effectively integrates subjective and measurable evidence, establishing itself as the predominant methodology among analyzed articles. Jezeer et al. (2019), for example, linked climate perceptions with livelihood assets and selection of sustainable practices in Peru. This finding illustrates how human perceptions can be connected with empirical data to explain climate-related decisions. Likewise, Quiroga et al. (2019) showed that distinct levels of perception directly influenced adoption of diversification strategies in Nicaragua coffee farming. In this case, the mixed-methods approach enabled correlation between farmers' perceptions and their economic and agricultural decisions. By integrating qualitative evidence with quantitative data, mixed methods provide a broader analytical framework for understanding complex issues such as climate adaptation (Shinbrot et al., 2019; Le et al., 2020).

Among methodological tools employed (Table 3), interviews, structured and semi-structured questionnaires, regression models, and analysis of variance were most prominent, appearing in more than half of studies that adopted mixed methods.

Understanding coffee growers' perceptions of climate change requires consideration of territorial, socio-environmental, and production contexts in which they are embedded. Although research methods strongly influence how perception is interpreted, factors such as geographic location, agroecosystem type, and socioeconomic structure shape not only production strategies but also how climate risks are perceived and addressed (Jawo et al., 2023; Tesfaye, 2021).

Most studies were conducted in countries of the Global South (Fig. 3), widely recognized as major coffee producers. Vietnam, the world's second-largest coffee producer and responsible for 37.7% of global *C. canephora* production (Brazil, 2025), and Ethiopia, the largest producer in Africa and responsible for approximately 5% of global *C. arabica* production (USDA, 2023), were particularly prominent in number of publications.

Although Brazil is the leading global coffee producer, accounting for 35.5% of global *C. arabica* production and 22.25% of *C. canephora* production (Brazil, 2025), it was the focus of only one study assessing coffee growers' perceptions of climate change (Venancio et al., 2020). This finding reveals a substantial research gap on the topic when compared with other producing countries.

Among cropping systems, the hybrid/transitional system, which combines conventional and agroecological practices, was predominant among retrieved studies (Table 4) and was mainly concentrated in Latin America, particularly Mexico, Guatemala, and Colombia (Table 5).

Adoption of hybrid systems suggests a transition toward more sustainable agricultural models driven by climate change impacts, in which farmers implement adaptation strategies often stimulated by lived experience, participation in farmer associations (Shinbrot et al., 2019), and exchange of information (Eise, Lambert, and Wiemere, 2021). Farmers operating under hybrid systems frequently adopt strategies for both adaptation and income generation. Notable practices include shade management, in which companion tree species are introduced to provide canopy cover for coffee plants (Jezeer et al., 2019), introduction of cultivars more resistant to prolonged drought (Harvey et al., 2018), and diversification of crop species to generate income and enhance

food supply (Sánchez et al., 2023; Hernández-Castán and Calderón, 2023). These practices indicate progress toward production systems that are more climate-adapted and better integrated into territorial contexts.

The agroecological system was the second most frequently studied category (Table 4) and was concentrated in East Africa, especially Ethiopia and Tanzania (Table 5). Agroecological practices are widely adopted by rural communities that structure their agroecosystems through traditional knowledge and well-established socioecological relationships (Altea, 2019; Mbwambo et al., 2021; Capitani et al., 2018). In some regions of Ethiopia, coffee cultivation is integrated into natural forests or along fragments and edges of native vegetation (Gomm et al., 2024), forming multifunctional landscapes that may simultaneously support environmental conservation and agricultural production. In this context, agroecological production extends beyond technical and productive functions, assuming a vital role in management of common resources and sociocultural continuity of local communities (Ayal et al., 2023).

The conventional or intensive production system was among the least cited in reviewed articles, ranking above only traditional systems (Table 4), and occurred mainly in Southeast Asia, particularly Vietnam and Indonesia (Table 5).

Vietnam and Indonesia together account for more than 24% of global coffee production (FAO, 2023). This output is largely based on conventional systems characterized by monoculture, high input dependence, and strong orientation toward export markets (Le et al., 2020; Nguyen and Drakou, 2021; Pham et al., 2020).

These findings indicate that studies addressing farmers' perceptions of climate change are more strongly associated with hybrid/transitional and agroecological systems, which are generally linked to family farming and small- to medium-scale producers. For this production profile, conventional systems are often regarded as costly and unsustainable from both environmental and economic perspectives (Lan et al., 2023; Torres-Lezama, 2012). The limited number of studies on conventional systems, such as Nguyen and Drakou (2021) and Le et al. (2020), examined broader grower profiles and regions, while treating climate perception and adaptation strategies as secondary issues.

Although less frequently cited, traditional systems identified in reviewed studies were concentrated mainly in Ethiopia (Table 4). Under climate change pressures, these systems remain important for food sovereignty, biodiversity conservation (Ayalew et al., 2024), and maintenance of local ways of life (Hasibuan et al., 2023).

Climate perception is not homogeneous, but rather emerges from interaction among local experience, structural conditions, and existing support networks (Jaramillo-Villanueva et al., 2022). Perception and adaptation are contextual processes shaped by factors such as access to technology, social organization, land tenure structure, and local climatic conditions. Therefore, methodological approaches that ignore territorial diversity tend to oversimplify a complex phenomenon and may compromise understanding of resilience dynamics in coffee farming under climate change (Sánchez et al., 2023; Jezeer et al., 2019).

Studies conducted in Vietnam (Table 6) indicate that water deficit, deforestation, and rising temperatures influence producers' perceptions and encourage adaptive practices (Pham et al., 2020). However, adoption of these strategies is constrained by barriers such as limited access to credit and resistance among smallholders to adopt shaded or diversified systems because of concerns over reduced cultivated areas and lower economic returns (Pham et al., 2020; Nguyen and Drakou, 2021; Byrareddy et al., 2021).

Access to markets and technologies (Table 6) also proved to be a determining factor in expanding adaptive capacity in coffee farming, as reported by Jaramillo-Villanueva et al. (2022), Sánchez and Bello (2020), and Shinbrot et al. (2019). Concern over low coffee prices and high input costs often meant that, although climate change was recognized as a central issue, it was not always perceived as the most immediate challenge.

Social and productive organization (Table 6), particularly through cooperatives, favors development of collective adaptation strategies such as information networks, workshops, technical training, and participation in fair-trade schemes (Eise, Lambert, and Wiemer, 2021; Borsky and Spata, 2017; Barrucand, Vieira, and Canziani, 2016). In Ethiopia, Jawo et al. (2023) reported that producers linked to cooperatives had greater access to climate information, sustainability certification programs, and community initiatives focused on environmental conservation, thereby strengthening collective response capacity to climate change.

Land tenure structure, often characterized by smallholdings, also appears to influence how farmers perceive climate risks, as observed in studies conducted in countries such as Rwanda and Ethiopia (Ayalew et al., 2025; Gather and Wollni, 2024). On smallholdings, perception tends to be more empirical, grounded in direct environmental observation and traditional knowledge developed collectively.

Farmers' perceptions of climate change are a key element for understanding adaptation processes in agricultural systems. Rather than being merely technical phenomenon, perception is socially constructed and mediated by practical experience, territorial conditions, and ability to access information, collective networks, and public policies (Eise et al., 2021; Mbwambo et al., 2021).

The reviewed studies indicate that coffee growers' climate perceptions generally arise from direct experience with extreme events and visible environmental changes, such as altered rainfall and temperature patterns, increased incidence of pests and diseases, reduced productivity, and impacts on household income (Jezeer et al., 2019; Quiroga et al., 2020; Ayal et al., 2023).

This empirical form of perception is especially pronounced in regions with limited access to climate monitoring technologies, which may directly affect agricultural management conditions of these communities, as reported in studies conducted in Ethiopia and Uganda (Jawo et al., 2023; Bartl, 2023).

However, farmers do not perceive or interpret climate change uniformly. The intensity and nature of perception are conditioned by factors such as years in farming, education level, access to technical information, and participation in collective organizations (Adhikari et al., 2019). Farmers with higher educational attainment and stronger integration into cooperatives tend to recognize signs of climate change more readily and adopt better-structured adaptation strategies, such as crop diversification, agroforestry systems, and soil conservation practices (Jawo et al., 2023; Jezeer et al., 2019).

Despite clear recognition of climate risks, studies indicate that perception does not automatically translate into adaptive action (Quiroga et al., 2020; Sánchez et al., 2023). Economic, cultural, and institutional barriers often limit farmers' ability to implement effective responses, highlighting need for public policies that strengthen connections between perception and action (Asayehegn et al., 2017).

The analysis also suggests that farmers who interpret climate change systemically, understanding it as part of a broader process of environmental transformation, tend to adopt more diversified and long-term strategies (Adhikari et al., 2019; Mbwambo et al., 2021). In contrast, more fragmented perceptions focused only on isolated extreme events tend to generate short-term responses that are insufficient to build resilience (Wagner et al., 2021).

The adaptation strategies (Table 7) adopted by farmers across different territorial contexts reflect both local perceptions of risk and resources available in each region.

Agroforestry systems (AFS) and shade management were the most recurrent adaptation strategies identified in reviewed studies. Incorporation of tree species into production systems is described as a practice adopted to regulate microclimate, reduce crop exposure to high temperatures and intense solar radiation, and promote conservation of air and soil moisture (Beristain-Moreno et al., 2024; Palacios et al., 2023; Venancio et al., 2020). In this context, shading is presented as an important strategy for coping with climatic variability (Jezeer et al., 2019; Bro, 2020).

In the reviewed studies, this practice was treated not only as an agronomic technique but also as an integrated ecological response to climatic pressures. Research conducted in Ethiopia by Ayal et al. (2023) and Jawo et al. (2023) indicates that farmers widely adopt shading to mitigate rising temperatures and irregular rainfall, highlighting strong dependence of coffee systems on natural resources and local ecological processes.

Diversification of production, including cultivation of crops other than coffee, aims to promote more stable and economically sustainable farming systems. In Rwanda, Gather and Wollni (2024) reported adoption of income diversification strategies through planting of additional crops and shade trees, motivated by previous experiences with extreme weather events. Incorporation of distinct species into production systems helps reduce vulnerability to climatic shocks, expand income sources, and promote ecological balance and sustainable soil management (Ha et al., 2024).

Ecological soil and water management also emerged as an important adaptive strategy. Practices such as maintaining permanent ground cover, applying organic fertilizers, intercropping, terracing, and rainwater harvesting were described as measures intended to increase soil water retention, reduce losses caused by surface runoff, and improve water availability under irregular rainfall conditions (Rodríguez-Barillas et al., 2024; Hernández-Castán and Calderón, 2023; Adhikari et al., 2021).

Water storage and reuse, in turn, appeared as initiatives aimed at increasing water autonomy within production systems (Mbwambo et al., 2021; Adhikari et al., 2021). Collectively, these actions indicate a strategy directed toward strengthening ecological foundations of agroecosystems, based on recognition that soil and water conservation are central elements in adaptation to climate change.

Adoption of resistant varieties has proven to be a relevant measure in countries such as Mexico and Tanzania. As reported by Jaramillo-Villanueva et al. (2022) and Mbwambo et al. (2021), producers have invested in cultivars that are more tolerant to water deficit and fungal diseases such as coffee rust (*Hemileia vastatrix* Berkeley and Broome). Adoption of these varieties represents an effort to maintain productivity under climate instability, particularly in response to rising temperatures and irregular rainfall (Beristain-Moreno et al., 2024).

Access to credit and collective organizations, such as cooperatives, also emerged as strategic factors in climate adaptation. As noted by Borsky and Spata (2017), cooperatives and associations increase capacity to invest in adaptive technologies while facilitating access to differentiated markets and certification programs. Institutional coordination, combined with mechanisms such as fair trade, strengthens social capital and broadens opportunities to respond to climate-related challenges (Rodríguez-Barillas et al., 2024).

Reduced pesticide use associated with adoption of biological inputs was also highlighted in reviewed studies as an adjustment strategy in coffee agroecosystems. This transition is described as an initiative aimed at reducing dependence on external inputs and mitigating environmental impacts (Jezeer et al., 2019; Mbwambo et al., 2021), while promoting soil biodiversity and strengthening ecological processes linked to biological balance. In addition, partial replacement of chemical inputs with biological alternatives is frequently cited as a measure intended to reduce production costs, especially under rising prices of fertilizers and pesticides (Tucker et al., 2009; Jawo et al., 2023).

Understanding responses to climate change depends largely on relationships among territory, farmers' perceptions, and adaptation strategies. This connection shows that local responses to climate change are not determined solely by environmental conditions, but are also strongly shaped by sociocultural, economic, and institutional factors that influence farmers' capacity to act (Fig. 4).

Coffee growers' perceptions are largely built from empirical experiences, such as observing irregular rainfall patterns and temperature fluctuations (Tesfaye, 2022; Jawo et al., 2023). However, recognition of climate change does not necessarily lead to adoption of adaptive measures.

Implementation of adaptive responses is conditioned by structural factors such as availability of financial resources, access to credit, technical assistance, and market integration (Jezeer et al., 2019; Mbwambo et al., 2021; Nguyen et al., 2021). These elements function as mediators between perception of environmental change and farmers' practical capacity to respond. Therefore, even when environmental changes are clearly recognized, implementation of adaptation strategies may remain limited by institutional, economic, and organizational constraints.

5. Conclusions

Most research on climate perception in coffee farming adopts mixed-methods approaches that integrate qualitative and quantitative techniques to capture subjective variables, such as farmers' narratives and experiences, together with measurable variables, such as productivity and incidence of pests and diseases. This methodological choice reflects an effort to understand not only what farmers observe and perceive, but also how they construct interpretations and strategies in response to challenges posed by climate change.

Territorial conditions associated with production systems are determining factors in the capacity of coffee farmers to adopt adaptive strategies under climate-related pressures.

Farmers' perceptions, built through direct observation of environmental change, are mediated by socioeconomic, structural, and territorial factors such as access to credit, technical assistance, and participation in collective organizations, including associations and cooperatives. These elements are essential for transforming perceptions into concrete adaptation strategies and for strengthening both productivity and community resilience.

The reviewed studies demonstrate progress in integrating subjective dimensions, including lived experiences, observations, and local knowledge, with technical analyses based on climatic and agronomic data. However, further investigations are still needed to better connect farmers' perceptions, management practices, adaptation strategies, and effects of these actions on resilience of their agroecosystems.

Declarations

Disclosure Statement

The authors declare no potential conflicts of interest.

Ethical Approval

This article does not contain any studies involving human participants or animals.

Author Contribution

Author Contributions[Author CA], [Author AF], [Author AG], and [Author LM] contributed equally to the conception and planning of the study, as well as to the development of the systematic review protocol. Authors [Author CA] and [Author AG] independently performed the literature search, screening, and data extraction to ensure methodological rigor and reliability.[Author LM] acted as a third reviewer during the screening phase, resolving disagreements when consensus could not be reached.All authors contributed to data interpretation, manuscript writing, and critical content review. All authors read and approved the final version of the manuscript.

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Data Availability Statement

The data supporting the conclusions of this study are available within the article and its supplementary materials.

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Figures

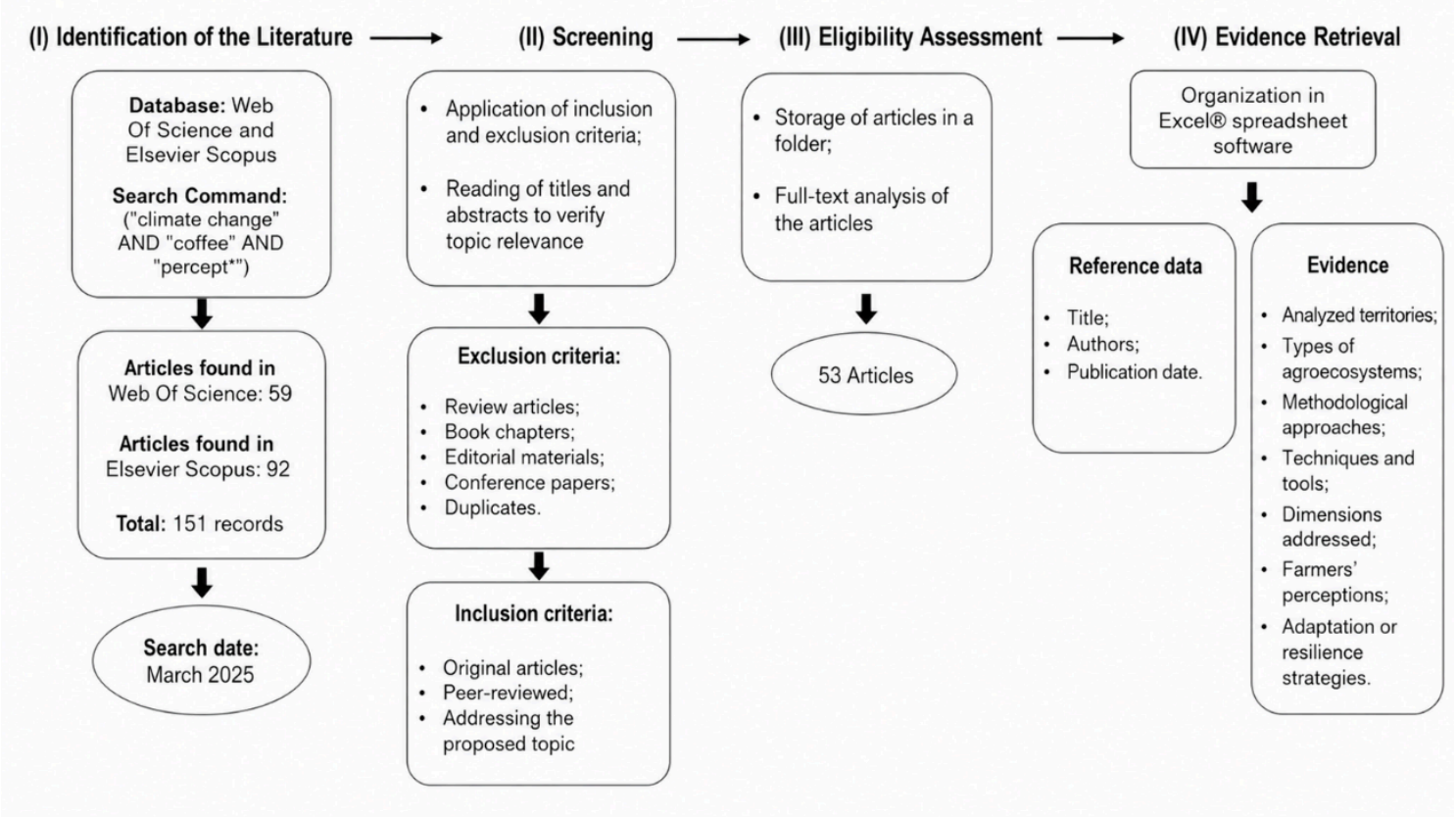


Figure 1

Methodological summary of the PRISMA-RR flowchart, comprising four main phases:(I) Identification, (II) Screening, (III) Eligibility, and(IV) Evidence Retrieval.

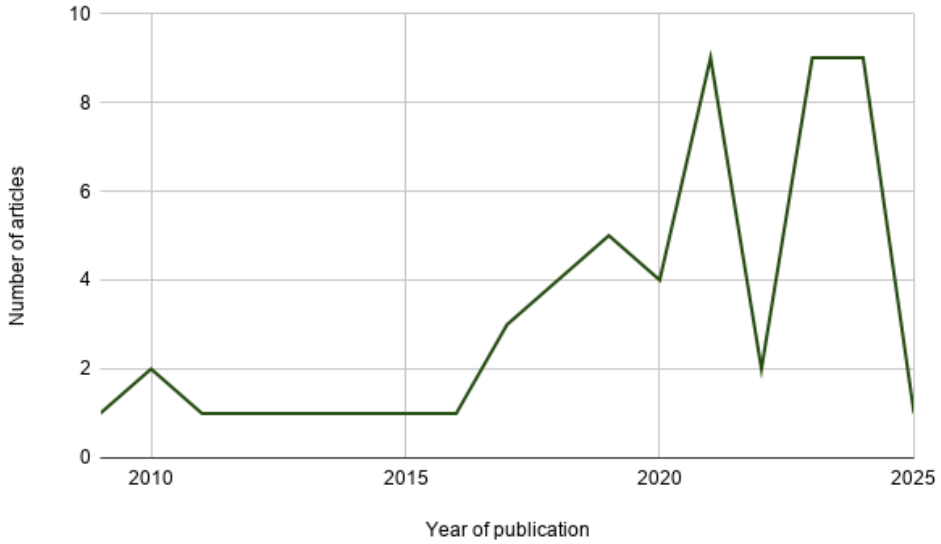
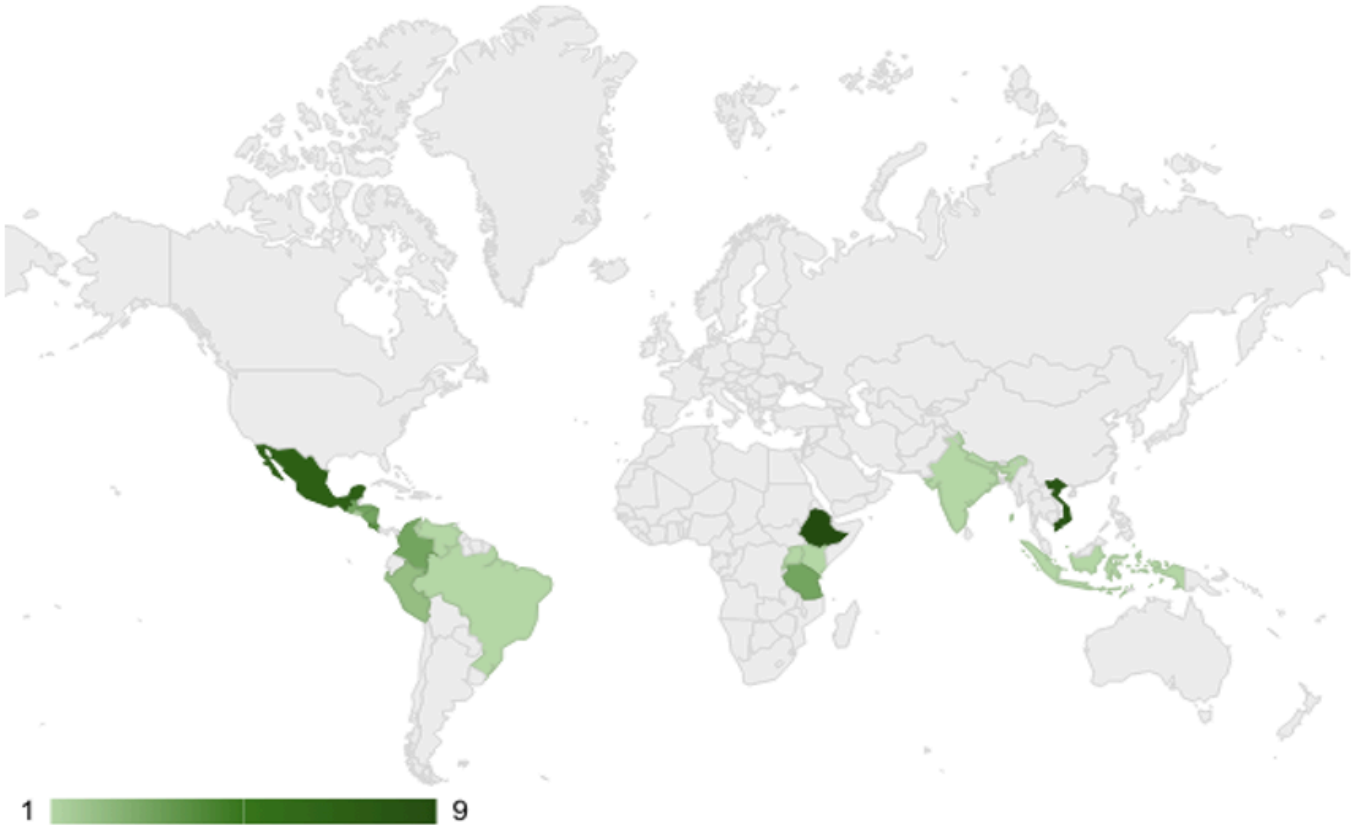


Figure 2

Temporal distribution of publications included in the review.

Source: Authors' elaboration based on studies included in the systematic review (2025).



País	TP	País	TP	País	TP
Ethiopia	9	Costa Rica	4	Tanzania	3
Vietnam	8	Colombia	3	Honduras	3
Mexico	7	Guatemala	3	Nicaragua	3

TP: Total number of publications per country, with three (03) or more articles.

Figure 3

Distribution of analyzed studies by region and country.

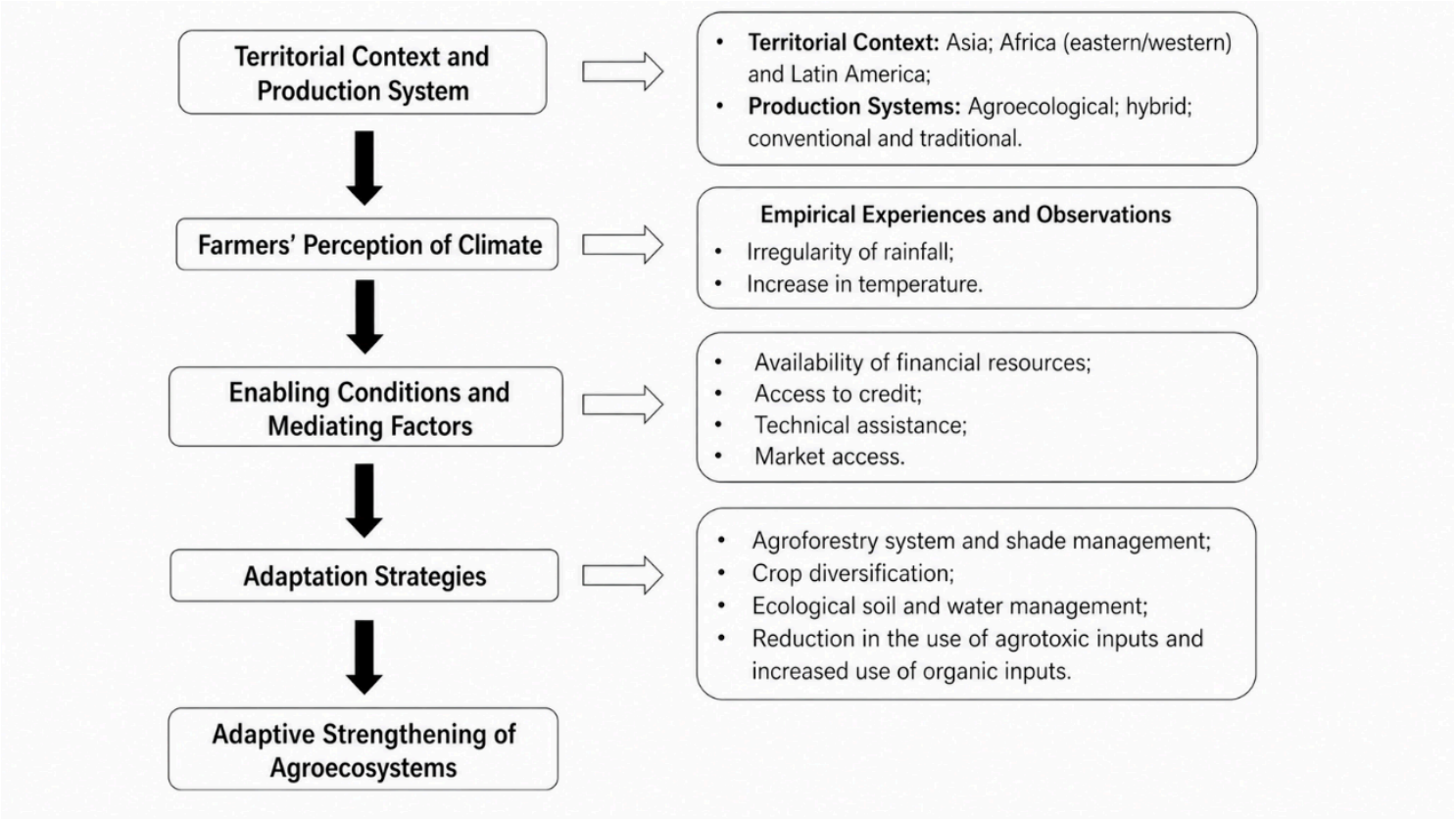


Figure 4

Dynamics of farmers' perceptions of climate change and adaptation strategies in coffee farming.

Source: Author's elaboration.

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