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How Do Institutions Shape the Resilience of the Ethiopian Coffee Sector Amidst the Pressures of Climate Change?

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ABSTRACT

Climate change currently impacts coffee production, which necessitates institutional interventions to enhance the resilience of the coffee sector. The study aims to explore the institutional responses to climate change and the factors influencing their decisions in the Ethiopian coffee sector. 44 semi-structured interviews and 30 focus group discussions were used to address the study question. We identify three types of institutions involved in climate interventions: public, private, and civil institutions. These institutions have contributed by providing information, technology transfer, financial support, and leadership development. Despite their significant contributions, they are influenced by financial constraints, human resource shortages, lack of modern equipment, and farmers' resistance to change. We suggest that policymakers and agricultural practitioners assess the efficacy of climate interventions, identify areas for improvement, and translate these findings into practice to enhance the resilience of the coffee sector. This study advances scientific knowledge by providing insights into sustainable coffee value chains, focusing on how institutions contribute to climate resilience in the coffee industry.

1 | Introduction

As coffee production is embedded in the natural environment, sustainable coffee production depends on effective environmental governance. Environmental governance encompasses the regulatory systems, mechanisms, and institutions that shape environmental activities and outcomes (Lemos and Agrawal 2006). It involves strategies designed to conserve natural resources to address climate change, resource depletion, biodiversity loss, and desertification (Agrawal et al. 2022). A lack of environmental governance, in turn, can cause environmental degradation, which accelerates climate change by altering temperature and rainfall patterns. Governments, private businesses, nongovernmental organizations, and community-based organizations can play a significant role in making environmental governance more effective (Agrawal et al. 2022; Li and Puppim De Oliveira 2021). Institutions can enhance environmental governance by creating frameworks for policymakers, stakeholders, and academics to ensure climate resilience policies. As climate interventions never occur in an institutional vacuum, a number of institutions are involved (Amaru and Chhetri 2013). This implies that environmental governance has become the collective responsibility of all stakeholders. However, there are challenges that inhibit environmental governance success, such as a lack of resources, inadequate institutions, and political will, particularly in African countries (Tsitohery and Zafimahova 2022). Failure in environmental governance systems also puts the government at risk of escalating policy costs (Patterson and Beunen 2019). As a result, climate change, biodiversity loss,

resource depletion, food insecurity, and poverty are currently getting worse. Therefore, environmental governance needs to prioritize institutional reforms to achieve the goal of sustainable development (Dzebo and Adams 2023).

Most developing countries heavily rely on agriculture as their primary income source (Abbasi and Zhang 2024; Chen and Li 2024; Touch et al. 2024). However, greenhouse gas emissions (GHG) and temperature changes are currently affecting agricultural production (Baig et al. 2023; Ramzan 2023). This impact has caused a decline in production output, food insecurity, and the perpetuation of the poverty cycle (Tanti et al. 2022). Sustainable agricultural practices are thus necessary to overcome the effects of climate change (Pickson and He 2021). Nevertheless, many nations have their own policies and strategies to tackle climate change impacts in agricultural practices to promote sustainability (Abbasi and Zhang 2024). For instance, climate-smart agriculture has gained traction as a potential solution to reduce GHG emissions, but it is still in its infancy stage in many developing nations (Tanti et al. 2022).

Coffee is a vital commercial commodity in the agricultural sector that millions of people worldwide rely on for their livelihoods (DaMatta et al. 2019; DaMatta and Ramalho 2006). Millions of smallholder farmers in developing countries also rely on coffee as their primary income source (Jacobi et al. 2024; Van Kollenburg and Van Weert 2024). However, the sector is currently facing sustainability challenges (Barreto Peixoto et al. 2023; Canwat 2023; Wright et al. 2024; Yang et al. 2024). Climate change poses critical challenges to coffee-producing countries (Bunn et al. 2015; Hylander et al. 2024; Mamuye et al. 2024) by shifting production areas, decreasing quality, reducing output, and disrupting the value chain (Hylander et al. 2024; Karim et al. 2023; Moat et al. 2019). To address this challenge, sustainable coffee farming practices are being practiced to reduce the effects of climate change (Adane 2024; DaMatta et al. 2019; Pham et al. 2019). The growing demand for sustainable coffee farming practices also holds the potential to increase coffee production and product value (Van Kollenburg and Van Weert 2024). Pertaining to that, farmers require institutional support to improve their adaptability and coffee production. Literature suggests farmers need resources, robust institutions, and education to protect their livelihoods from climate change (Ifejika Speranza et al. 2014). Adaptation efforts are, however, hindered by weak institutional structures, low levels of education, lack of access to information, and inadequate resources (Barokatuminalloh and Setiarso 2022; Tanti et al. 2022). Therefore, institutional interventions are essential to reduce the effects of climate change on the coffee sector and enhance its resilience.

Climate change adaptation necessitates efforts that increase societal resilience (Busch et al. 2022; Wu 2021), while also taking into account the dynamics of human actors and institutional roles (Susskind and Kim 2022). Institutions provide credit services, subsidies, and agricultural extension services (Dougill et al. 2017; Mazhar et al. 2021). Although institutions play a crucial role in climate interventions, they face challenges such as local community exclusion, weak communication, limited technical capacity, and finances (Ampaire et al. 2017); lack of external support (Zea-Reyes et al. 2021). These challenges result in inconsistencies, inadequate monitoring and evaluation systems, and failures to achieve changes (Matewos 2019). Few studies have looked into the functions of institutions in local climate adaptations (Agrawal 2008; Mekonnen et al. 2021). However, limited information exists on the dynamic roles of institutions in addressing climate change impacts on Ethiopian Arabica coffee and the factors influencing their responses. Therefore, this research aims to explore the institutional responses to climate change and the factors influencing their decisions.

This paper thus seeks to unravel a critical inquiry: How do institutions shape the resilience of the Ethiopian coffee sector amidst the pressures of climate change? What factors influence institutional decisions? This study significantly contributes to scientific knowledge through various ways. First, it highlights that coffee is embedded in environmental elements where institutions can play their roles in managing these resources for their sustainability. Second, this study fills a gap in the empirical literature by adding the roles of institutions in sustainable coffee production methods in the coffee industry, which may benefit other coffee-producing countries. Third, the study provides valuable information for policymakers and agricultural practitioners on coffee climate resilience initiatives to improve sustainable practices to ensure sustainable coffee production. We have also adapted Agrawal (2008)'s framework to analyze the institutional response to climate change in the coffee sector. The framework supports policymakers and agricultural practitioners in making informed decisions about climate change, adaptation methods, institutional constraints, and opportunities for improvement in the Ethiopian coffee industry.

2 | Literature Review

2.1 | Institutions and Climate

Institutions are central actors in the governance system. According to FAO (2005), institutions encompass both membership organizations and invisible "rules of the game." They include formal membership organizations, informal groups, and political institutions, markets, private companies, etc. Institutions and organizations shape the rules that govern social and economic exchange, regulating access to resources, and determining control over decisions and change processes (FAO 2022). Williamson (1985) discusses institutions in the context of economic governance and transaction cost economics, emphasizing their role in reducing uncertainty in exchanges.

We follow Agrawal (2008) in placing special emphasis on three categories of institutions that are relevant in the context of climate adaptation: public institutions (i.e., government agencies), private institutions (i.e., businesses and service organizations), and civil institutions (i.e., unions and membership organizations). In contrast, we do not study socio-cultural institutions such as marriage or religion, or broad structures such as the market or tax system, leaving such emphasis to future research.

Institutions play a crucial role in achieving sustainable development goals by enhancing climate resilience, fostering adaptive capacity, and shaping policies. Climate change causes gradual changes in temperatures, rainfall patterns, and catastrophic weather events, which can devastate ecosystems (Pickson

et al. 2024; Ramzan 2023; Shah et al. 2023). This exposes rural communities to environmental risks, resource damage, economic losses, increased stress on social institutions, and geopolitical instability (Chen et al. 2023; Holling 2001). This indicates human actions, triggered by environmental stressors, can significantly influence ecological resilience (Malhi et al. 2020). The action, however, requires a collaborative effort from public, private, and civil institutions at various scales (Tompkins and Adger 2004). These institutions can shape climate adaptation measures by creating, reinforcing, and reproducing institutions (Hufty 2011); however, there is a fragmentation of institutions in climate politics, particularly in the Global South (Marquardt et al. 2023).

Institutions can influence climate change by structuring the impacts and vulnerability, mediating and shaping the outcomes of the adaptations, and delivering and governing the resources (Agrawal 2008). To examine the roles that institutions play in climate interventions, Agrawal emphasizes the institutional nature and goals, their involvement in particular adaptation measures, and their relationships with rural households. Nevertheless, the effectiveness of local responses to climate change depends on the roles of rural institutions, the applicability of adaptations, and the extent to which implemented measures improve the livelihoods of rural communities (Agrawal 2008; Mahmood et al. 2021). Furthermore, institutional performance is influenced by demographic, socio-cultural, economic, environmental, and political factors, which can lead to deviations from the desired output. The identification of these factors helps in locating institutions that have successfully implemented climate intervention measures. Agrawal (2008) highlights the role of institutions in climate change adaptation through information transferring, technological provision, financial support, and leadership development, as stated in the following paragraphs.

2.2 | Institutional Response Strategies to Climate Change

Institutions share climate information to inform, educate, and empower agricultural producers to adapt to climate change, enhancing their yields and livelihoods. This involves creating, distributing, and localizing scientific knowledge to enhance sustainable development (Ofoegbu and New 2021; Velmourougane and Bhat 2017). Nonetheless, despite the availability of climate-related data, ensuring its accessibility and utilization remains a significant challenge, particularly in most developing countries (Angula and Kaundjua 2016; Naab et al. 2019; Singh et al. 2018). Prior studies highlighted that the effective transfer of agricultural information significantly improved the adoption of sustainable agricultural practices by smallholder farmers, thereby enhancing agricultural productivity (Parks 2022; Tesfaye et al. 2020). However, institutions encounter challenges in effectively disseminating information due to socio-cultural, economic, and institutional-related factors (Mollo et al. 2024; Naab et al. 2019; Ofoegbu and New 2021). Yet, the empirical literature lacks detailed information on the specific roles of institutions in disseminating climate information in the Ethiopian coffee sector. This study, therefore, addresses the gap in the literature on how public, private, and civil institutions respond to climate change through information transfer, emphasizing the resilience of the coffee sector.

Technology has a significant impact on economic growth, particularly within the agricultural sector (Kuhl 2020; Wijeratne and De Silva 2024). Despite the beneficial role of technology in enhancing climate resilience among farmers, scholars have yet to achieve a comprehensive understanding of the correlation between technology and climate resilience (Kuhl 2020). Many developing countries have begun to adopt environmentally friendly technologies to increase climate resilience. For instance, Tanzanian farmers have adopted improved crop varieties, agroforestry, and energy-efficient stoves to improve their agricultural practices (Nyasimi et al. 2017). The literature also shows that Vietnam (Kahsay et al. 2023) and Colombia (Hidalgo et al. 2024) have made significant changes to improve their agricultural productivity. However, weak coordination, inadequate resources, poor institutional collaborations, and poor infrastructure impede technology transfer (Kuhl 2020; Wijayanti et al. 2019). While institutions have contributed to climate resilience, there has been little information on specific institutional functions in minimizing climate change through technology dissemination in the Ethiopian coffee sector.

Lack of financial support hinders climate change adaptation in developing nations, causing slow economic growth and the need for additional funds for initiatives (Bianco 2020; Karyani et al. 2024; Timilsina 2021). Developing countries require climate finance urgently, but donors and investors often hesitate, prioritizing projects with clearer returns over adaptation efforts (Bianco 2020). International and national institutions provide financial aid to enhance climate resilience; however, the specific institutional roles involved in climate adaptation activity within these streams are not clearly delineated. This indicates there is inadequate information on the financial support of public, private, and civil institutions with their respective climate intervention activities. This study intends to close this gap by delving into the details of institutional response mechanisms that provide financing to increase climate resilience.

Leadership plays a pivotal role in ensuring sustainable development (Eustachio et al. 2024; Garcia-Blandon et al. 2024; Ngwu et al. 2024). Leadership can empower the community to reduce climate risks. Community empowerment is necessary to develop the human resource capacity to efficiently use resources for resilience (Wijayanti et al. 2019). This implies that equipping individuals with skills, knowledge, and competencies is critical for driving initiatives, influencing policies, and promoting sustainable farming practices that improve climate adaptation. Kruse (2013) defines leadership as the act of social influence that maximizes the efforts of others to achieve a specific goal. External actors can provide strong leadership or attempt to reconfigure local institutions to support climate adaptation (Agrawal 2008). The actors can also reduce the costs of collective action for adaptation practices. Meijerink and Stiller (2013) also suggest that leadership needs to address four key challenges in the climate adaptation process: influencing policy implementations, enhancing connectivity, enhancing societal adaptability, and increasing the capacity of government networks. Therefore, leadership requires institutional roles to empower communities for climate adaptation actions in the coffee sector. Table 1

TABLE 1 | Summary of the research gaps comparing the current work.

Research area	Literature (Findings)	Research gaps	Relevant literature
Coffee production and marketing	Market reform, extension services, and certification schemes have boosted coffee productivity and prices in Ethiopia. However, challenges remain, including climate change, extreme weather, pest outbreaks, land degradation, outdated technologies, weak linkages, and traceability issues	The institutional intervention focused on market policy regarding traceability and vertical integration but overlooked the role of institutions in reducing climate risks in Ethiopia's coffee value chain. Additionally, this literature also lacks a conceptual framework to guide policymakers in enhancing the sector's climate resilience	(Minten et al. 2019) (Tikuneh et al. 2023) (Tadesse et al. 2020)
Sustainable agricultural practices	Smallholder coffee producers implement sustainable practices such as soil and water conservation, agroforestry, mulching, irrigation, and composting. Studies identified factors affecting farmers' adoption decisions, including demographics, socioeconomic status, and access to extension services	The climate adaptation practices concentrate on coffee farms, overlooking broader elements like private investors, exporters, processors, and roasters. This includes strategies for climate adaptation or mitigation related to coffee processing, storage, transportation, and current challenges. Furthermore, the research lacks a conceptual framework to guide policymakers in crafting strategies that strengthen climate adaptation practices	(Chemeda et al. 2023) (Eshetu et al. 2021) (Diro et al. 2022) (Olana Jawo et al. 2023)
Climate change and agroecological shifts	Changes in temperature and rainfall are impacting coffee production in East Africa, making current growing areas unsuitable without significant intervention. The effects differ by altitude; while Ethiopian coffee cultivation may increase until 2090, specialty areas are expected to decline due to climate change and soil characteristics	The study primarily predicted future climate impacts on coffee production and suggested potential mitigation strategies, but overlooking ongoing climate adaptation and mitigation activities and investigating institutional support for climate risk mitigation. The study also lacks a policy framework for future climate intervention initiatives involving various institutions to enhance the resilience of the coffee sector	(Davis et al. 2012) (Moat et al. 2017) (Chemura et al. 2021)
Certification and sustainability	Certification schemes prioritized pricing and social and environmental sustainability. The overhead and certification costs, uneven distribution, and auditing loopholes were also another challenge. Although certification is intended to improve forest conservation, severe deforestation and degradation of certified coffee forests are still prevalent	While the study focused on income earned through certification schemes, there was little information on their effects on climate adaptation practices. The certification primarily targets premium pricing, increasing income, and improving farmers' welfare while neglecting support for sustainable coffee production practices that enhance climate adaptation. It also overlooks institutional dynamics in climate interventions	(Mitiku et al. 2017) (Minten et al. 2018) (Arai et al. 2023) (Winter et al. 2020)

further shows the summary of the research gaps compared with the current work.

3 | Research Methods

Interviews and focus group discussions (FGDs) are the most common strategies used to collect qualitative data (Breen 2006; Gill and Baillie 2018). In this study, we used a semi-structured interview and FGDs to answer the research question. The following sections provides an overview of the study area, selection of participants, and collection and analysis of the research data.

3.1 | Study Area

The study was conducted in Illubabor zone, Jimma zone, and Addis Ababa, in Ethiopia. The agro-ecological settings and meteorological conditions of the Jimma and Illubabor zones are similar, but environmental degradation has intensified due to climate change. Limmu Seka, Gera, and Gomma districts were selected from Jimma, while Yayu and Ale districts were chosen from Illubabor based on their coffee production potential. These districts consist of highland, midland, and lowland areas, with varying impacts of climate change on coffee production. They primarily rely on rainfall for coffee cultivation. Six Kebeles were randomly selected from each district for focus group discussions with smallholder coffee producers. Addis Ababa was purposefully chosen for interviews with various coffee institutions due to its proximity. Figure 1 shows the map of the study areas.

3.2 | Participant Sampling

This research is based on qualitative methods. Ethiopia has five political administrative structures: federal, regional state, zone, district, and kebeles (Tolera and Senbeta 2023). Before starting the research, a pilot survey was conducted to identify the institutions involved in the coffee sector in each of these administrative structures. The institutions involved in climate change interventions were meticulously identified. Accordingly, the research was conducted using two distinct sampling methods. First, we used the snowball sampling method to determine the total number of institutions engaged in climate interventions. This is a widely used method in qualitative research, primarily used for accessing informants during the sampling process (Sorgho et al. 2023; Tolera and Senbeta 2023). We used a method where the initial institutions were intentionally selected and requested to recommend other institutions that fulfilled the study's requirements. The study involved participants from various public, private, and civil institutions who actively participated in climate change interventions. Second, we used a purposive sampling method to identify key informants who have in-depth knowledge and experience regarding the linkage between coffee and climate change. 44 informants were selected for the purpose of this study. The interviews were conducted with representatives from government (8), agencies (7), private businesses (7), service organizations (15), cooperatives (5), and membership organizations (2) (see Table 2 below).

We furthermore conducted focus group discussions with coffee farmers to understand farmers' perceptions of institutional support. We held focus group discussions in 30 kebeles, each with 9 to 12 participants, in line with best practices (Bloor et al. 2001). The participants selected were heads of households who have in-depth information and experience about coffee production. A total of 367 coffee producers participated in group discussions. Unfortunately, a few candidates were unable to attend the discussion sessions due to health problems and personal cases. In such circumstances, we replaced these candidates with other farmers.

3.3 | Data Collection

Our semi-structured interviews primarily focused on the institutional level to investigate the institutional responses to climate change and the factors influencing their decisions. Our interview guide contained a range of open-ended questions, ranging from simple to more difficult, which can increase the respondent's confidence and elicit more information (Gill et al. 2008). Institutions were asked mainly about their strategies for addressing climate change, including information transfer, technology provision, financial support, and leadership development. In addition, institutions were also asked about the challenges they faced during the implementation of climate adaptation activities. Before starting the data collection, a pilot study was also conducted to test the clarity, understanding, and ability to answer the research question. Interviews were conducted in Afan Oromo, Amharic, or English. The choice of language was based on the informant's preferences. Overall, all the interviews lasted between 35 and 90 min (Table 2). Participants were informed about their anonymity, which encouraged thoughtful debates, enhanced credibility, and improved communication. The interviews were conducted in an environment free of noise in which the participants felt comfortable. This improves the quality of sound recordings. 36 interviews were audio-recorded, while 8 were recorded via notetaking, as several interviewees were apprehensive to participate in sound recording interviews for their own safety or organizational ethos. Their interview reports were meticulously paraphrased without altering the original meaning. However, five institutional representatives were deemed unwilling to participate in the interview. If there was any confusion during the report writing, we conducted additional phone interviews for further clarification.

FGDs were conducted with smallholder coffee farmers at the village level in each of the selected kebeles. Discussion with focused groups can provide a more comprehensive understanding of group dynamics than individual interviews (Nyumba et al. 2018; Wong 2008). The discussion was aimed at better understanding farmers' perceptions of the efficacy of institutional climate initiatives. These initiatives indicated whether farmers were receiving support from institutions such as climate information and knowledge, technology dissemination, financial support, and leadership development. Moreover, the group discussions help to catch up any responses overlooked by key informants during the interview. Group discussions were conducted using open-ended questions about the research topic. The questions also included probing questions to encourage further discussions, especially for problems requiring detailed

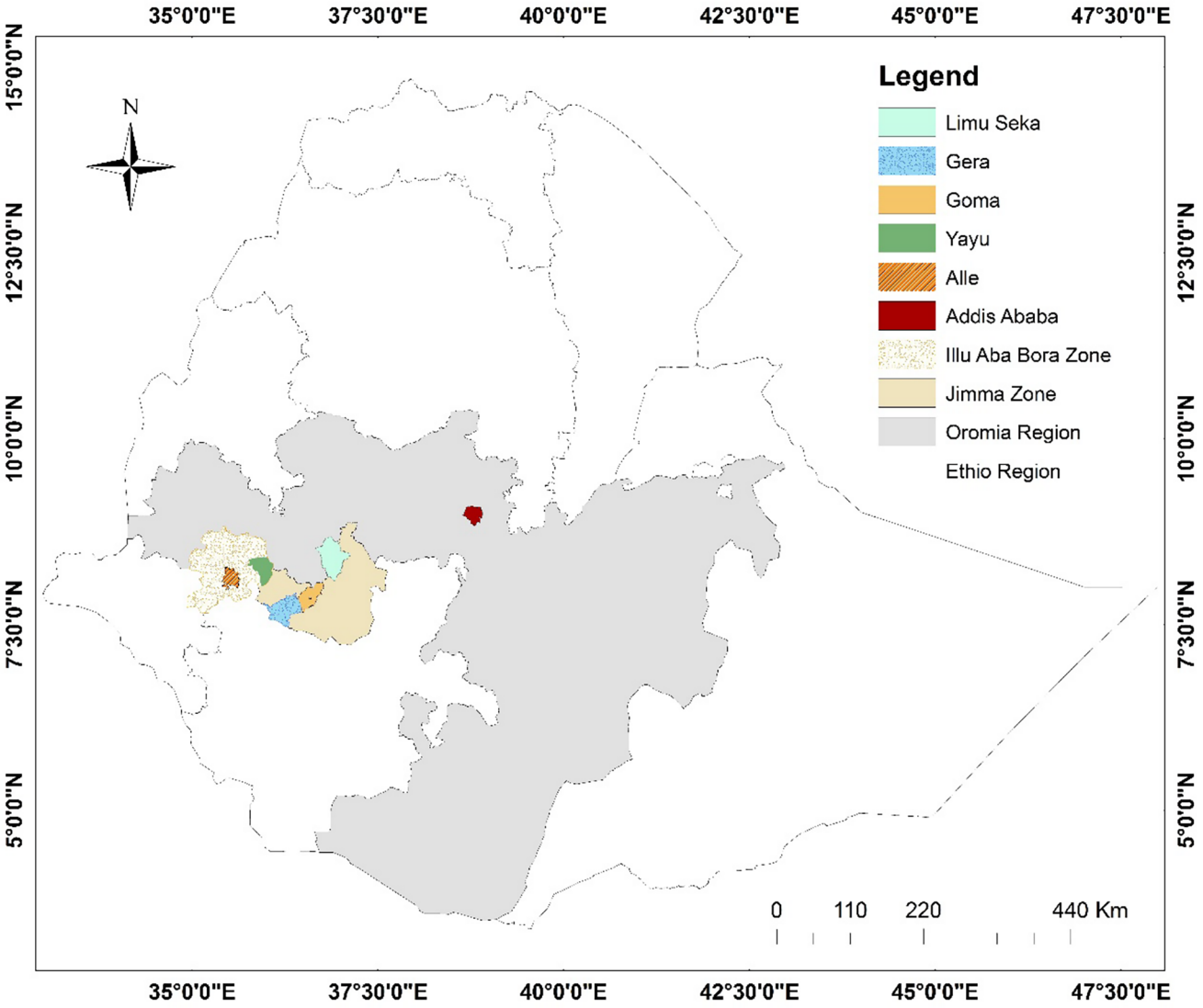

FIGURE 1 | Location of the study area.

understanding. Before beginning group discussions, we chose a comfortable environment with no noise pollution in which group members could openly communicate with one another. The discussions were also facilitated by a moderator, note-taker, and tape-recorder (Morgan 1998). The discussion was held in Afan Oromo or Amharic. The choice of the language was based on respondents' preferences. Each discussion lasted between 90 and 120 min.

Before beginning data analysis, the interview and FGD transcripts were first translated from the native languages of Afaan Oromo and Amharic to English.

3.4 | Methods of Data Analysis

Research scholars such as Ostrom (2011), Delmas and Toffel (2004), and Agrawal (2008) have developed institutional frameworks with varying purposes, structures, legal systems, governance systems, and applications. For example, Ostrom's framework emphasizes community rules for resource management, with institutions playing a decision-making role that promotes community-driven self-governance. Delmas and Toffel's framework emphasized the involvement of stakeholders and corporations in environmental management. In contrast, Agrawal's framework analyzes the functions that institutions play in enhancing climate adaptation practices. This framework is unique in that it is more of a policy-oriented approach that integrates institutional diversity, environmental conservation, climate adaptation, and agricultural production activities, making it suitable for applied research. Thus, this framework, tailored to the coffee sector, supports the development of effective climate adaptations by analyzing institutional functions. Therefore, Agrawal's framework was chosen for this study as it provides a distinct approach to analyzing the diverse institutional roles in responding to climate change in the Ethiopian coffee sector. Moreover, this framework is more flexible and practical compared to the above frameworks.

The data was analyzed deductively, and then inductively. First, we deductively analyzed the institutional responses to climate change using Agrawal's framework. Agrawal classified the types of institutions engaged in climate adaptation into three categories: public (local governments and agencies), private (service organizations and private businesses), and civil (membership organizations and

TABLE 2 | Name of institutions, abbreviations, location, institutional type, code, duration of interview, and date of interview.

Name of institution	Abbreviation	Location	Institutional type	Institutional category	Code	Interview duration	Date of Interview
Bureau of Agriculture	BA	Ale	Public	Government	GO1	47 min	1/25/2023
Bureau of Agriculture	BA	Yayu	Public	Government	GO2	63 min	1/29/2023
Bureau of Agriculture	BA	Gera	Public	Government	GO3	64 min	2/10/2023
Bureau of Agriculture	BA	Gomma	Public	Government	GO4	35 min	2/24/2023
Bureau of Agriculture	BA	Gomma	Public	Government	GO5	41 min	2/21/2023
Ministry of Agriculture	MoA	Addis Abeba	Public	Government	GO6	43 min	6/02/2022
Trade And Market Development	TMD	Limu Seka	Public	Government	GO7	47 min	1/21/2023
Trade And Market Development	TMD	Gomma	Public	Government	GO8	55 min	1/21/2023
Environmental Protection Authority	EPA	Ale	Public	Agency	AG1	39 min	1/26/2023
Ethiopian Coffee and Tea Authority	ECTA	Addis Abeba	Public	Agency	AG2	40 min	4/13/2023
Environmental Protection Authority	EPA	Yayu	Public	Agency	AG3	70 min	2/01/2023
Environmental Protection Authority	EPA	Alle	Public	Agency	AG4	57 min	2/01/2023
Environmental Protection Authority	EPA	Gera	Public	Agency	AG5	68 min	2/11/2023
Jimma Agricultural Research Center	JARC	Mettu	Public	Agency	AG6	45 min	27/5/2022
Environmental Protection Authority	EPA	Gomma	Public	Agency	AG7	66 min	2/11/2023
Ayetu agricultural and trading PLC	AAT	Gera	Private	Business	BUS1	93 min	2/15/2023
Abana coffee PLC	ACP	Gera	Private	Business	BUS2	34 min	2/12/2023
Tracon Agricultural and Trading PLc	TAT	Gera	Private	Business	BUS3	39 min	1/20/2023
Fahm General Trading PLC	FGT	Gomma	Private	Business	BUS4	64 min	4/11/2023
BNT Industry and Trading PLc	BNT	Addis Abeba	Private	Business	BUS5	62 min	4/11/2022
Hadero Coffee Exporter	HCE	Addis Abeba	Private	Business	BUS6	59 min	12/4/2023
Starbucks Coffee Company	SBUX	Addis Abeba	Private	Business	BUS7	51 min	1/21/2023
Reducing Emissions from Deforestation and Forest Degradation	REDD+	Limu Seka	Private	Service organization	SO1	60 min	1/26/2023
Reducing Emissions from Deforestation and Forest Degradation	REDD+	Ale	Private	Service organization	SO2	53 min	1/31/2023

(Continues)

TABLE 2 | (Continued)

Name of institution	Abbreviation	Location	Institutional type	Institutional category	Code	Interview duration	Date of Interview
Sustainable Land Management Project	SLM	Yayu	Private	Service organization	SO3	47 min	1/27/2023
German Agency for International Cooperation	GIZ	Ale	Private	Service organization	SO4	57 min	1/28/2023
Environment and Coffee Forest Forum	ECFF	Yayu	Private	Service organization	SO5	90 min	1/31/2023
Reducing Emissions from Deforestation and Forest Degradation	REDD+	Yayu	Private	Service organization	SO6	65 min	2/01/2023
Nature and Biodiversity Conservation Union	NABU	Yayu	Private	Service organization	SO7	78 min	2/02/2023
Environment and Coffee Forest Forum	ECFF	Yayu	Private	Service organization	SO8	31 min	2/01/2023
EU-Coffee Action for Ethiopia	EU-CAfE	Yayu	Private	Service organization	SO9	62 min	2/24/2023
TechnoServe	TS	Gera	Private	Service organization	SO10	59 min	2/11/2023
Digital Green Foundation	DGF	Gera	Private	Service organization	SO11	30 min	2/23/2023
HUNDEE Oromo Grassroot Development Initiatives	HOGDI	Gomma	Private	Service organization	SO12	48 min	1/27/2023
Farm Africa	FA	Ale	Private	Service organization	SO13	78 min	2/03/2023
Ethio Wetlands and Natural Resources Associations	EWNRA	Yayu	Private	Service organization	SO14	70 min	4/12/2023
Environment and Coffee Forest Forum	ECFF	Addis Abeba	Private	Service organization	SO15	72 min	2/01/2023
Oromia Coffee Cooperative Farmers	OCCF	Yayu	Civil	Cooperative	CO1	60 min	5/24/2022
Sorgaba Coffee Farmers Cooperatives Union	SCFCU	Limmu kossa	Civil	Cooperative	CO2	57 min	10/5/2022
Katta Muduka Coffee Farmers Cooperatives Union	KMCFCU	Gomma	Civil	Cooperative	CO3	85 min	4/10/2023
Oromia Coffee Farmers Cooperatives Union LTD	OCFCU	Addis Abeba	Civil	Cooperative	CO4	37 min	4/11/2023
Ethiopian Coffee Exporter Association	ECEA	Addis Abeba	Civil	Membership organization	MO1	40 min	6/06/2022
Ethiopian Coffee Exporter Association	ECEA	Addis Abeba	Civil	Membership organization	MO2	65 min	1/21/2023
Oromia Coffee Cooperative Farmers	OCCF	Limu Seka	Civil	Cooperative	MO3	67 min	1/21/2023

cooperatives). These institutions play crucial roles in structuring risks and impacts, linking individual and collective actions, and mediating external interventions in response to climate change. Agrawal (2008) suggests that institutions can facilitate adaptation practices by transferring information, providing technology, investing in financials, and leadership development. The framework provides insights into the adaptation practices commonly used by rural communities. This includes mobility, storage, diversification, communal pooling, and market exchange. Nevertheless, climate adaptation practices vary depending on social, economic, environmental, and institutional factors. On that account, this study inductively analyzed institutional responses to climate change in the Ethiopian coffee sector using five fundamental adaptation methods, including water and soil conservation, shade tree management, energy-efficient technologies, diversification, processing technologies, and market exchange. In contrast, the adapted framework excluded mobility due to the absence of a pastoral community in the study area. Figure 2 further illustrates the institutional responses to climate change in the Ethiopian coffee sector. Here, the main emphasis is on the comprehensive involvement of institutions, including public, private, and civil society to build the coffee sector's resilience. Second, we have inductively analyzed the factors influencing institutional decision-making in climate change response, including financial constraints, human resource shortages, lack of modern equipment, and farmers' resistance. Finally, thematic analysis was used to identify and interpret themes within a data set, thereby providing a comprehensive understanding of the study problem (Braun and Clarke 2006; Castleberry and Nolen 2018). The analysis mainly focused on thematizing data aligning with institutional response mechanisms to climate change while identifying emerging patterns and themes related to climate adaptation practices.

The initial steps in analyzing qualitative data involve coding, organizing, and labeling it to identify the core themes (Creswell 2014). We used Nvivo (version 14) to code, label, thematize, and explore the subtheme's relationships. Data was coded into two major themes with a number of sub-themes. This enables the grouping of transcriptions into similar themes (Auld et al. 2007; Hou and Chan 2017). Data was coded into two major themes with a number of sub-themes. Accordingly, the institutional responses were grouped into four overarching themes: information, technology, finance, and leadership. Concurrently, four key determinant factors were also thematized for this study, including financial constraints, human resource shortages, lack of modern equipment, and farmers' resistance. Figure 2 also shows the entire flow of research methods designed to address the research question, including research design, sampling of participants, methods of data collection, and methods of data analysis.

3.5 | Ethical Considerations in Research

Our study received ethical approval from Jimma University after reviewing consent, data clarity, and risk mitigation. Participants were informed about the study's objectives and procedures and provided their consent for interviews and discussions. We used local language to their preferences, maintained anonymity, and encouraged privacy. Risks were minimized, and participants could withdraw at any time. We focused on honesty, clear communication, and respect for cultural norms while ensuring rigorous discussions.

4 | Results

4.1 | Institutional Responses to Climate Change in the Coffee Sector

Rural areas are highly vulnerable to climate change, necessitating multilevel institutional support. Agrawal has developed a framework for climate change adaptation focusing on the role of institutions in shaping communities' response to climate change impacts (Agrawal 2008). In Agrawal's conceptual framework, institutions are identified as the primary agents through which the mediation and facilitation of climate adaptations can be achieved. This is also true in Ethiopia, where most coffee farmers live in rural communities, necessitating institutional actions to improve climate resilience in coffee-producing areas. We have adapted Figure 3 from Agrawal's conceptual framework, as detailed in the research methods, to analyze the institutional response to climate change in the Ethiopian coffee sector. Institutions significantly contribute to climate interventions by providing information, disseminating technology, financially supporting, and developing leadership. The findings indicate that institutional interventions primarily focus on six adaptation practices: soil and water management, shade tree management, energy-saving technology, livelihood diversification, processing management, and market linkage. The analysis was also based on this conceptual framework, in which we assessed the roles of public, private, and civil institutions in climate interventions to enhance the resilience of the Ethiopian coffee industry. Table 2 also provides detailed information about these institutions, including their names, acronyms, locations, institutional types, codes, interview duration, and interview dates. In addition, we presented the list of institutions with their main functions in Table 3.

4.2 | Institutional Responses to Climate Change

4.2.1 | Information Provision

Institutions play a crucial role in providing relevant information to their intended targets to raise awareness, educate, inform, mobilize resources, foster collaborations, and promote innovations. We find that information provision primarily involves training farmers and experts to improve climate-resilient practices in the coffee sector. Accordingly, public government (BA), private businesses (FGT, BNT, SBUX), service organizations (SLM, GIZ, NABU, TS, EWNRA, FA, ECFF), and civil institutions (SCFCU, KMCFCU) have contributed to providing climate information. Here, most of the institutions involved in training belong to service organizations, with some private businesses and cooperative unions also providing targeted training (Table 4). Nevertheless, the information reaches farmers through extension agents, who serve as facilitators, educators, and technical assistants to farmers.

4.2.2 | Technology Transfer

The study found that institutions provide modern technologies to enhance the climate resilience of the Ethiopian coffee sector. Accordingly, public institutions (BA, ECTA, JARC), private institutions (BNT, SBUX, REDD+, SLM, GIZ, NABU, EU-Café, DGF, FA and ECFF, EWNRA), and civil institutions (KMCFCU,

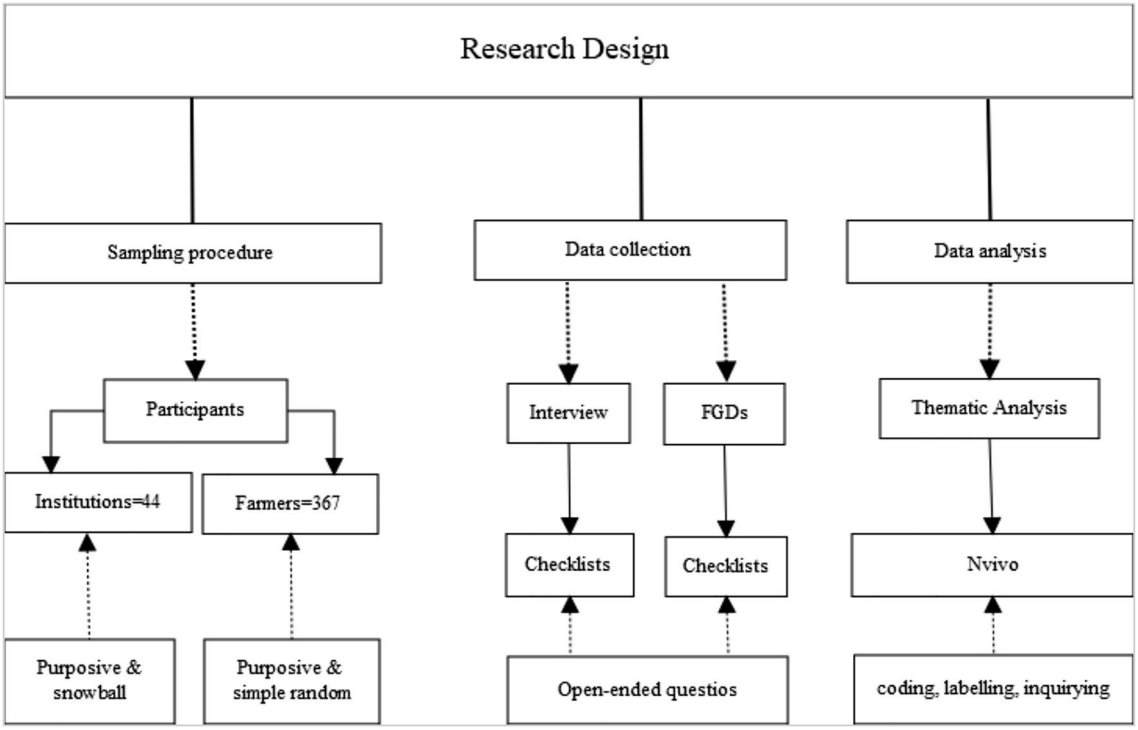

FIGURE 2 | The overall flow chart of the research methods.

OCFCU) are among the key actors in technology transfer. This indicates that service organizations and private businesses are the primary institutions contributing to technology provision. In most cases, the technologies reach farmers through extension agents (Table 5).

4.2.3 | Financial Support

The analysis reveals that public, private, and civil institutions have engaged in providing financial support to enhance climate resilience in the Ethiopian coffee sector. According to the findings, public (Federal, Oromia Regions, and Energy Institutions), private (SBUX, GIZ, USAID, and SLM), and civil (OCFCU) institutions are the primary actors in these initiatives. The initiatives are mainly aimed at improving coffee production by promoting sustainable farming practices, forest protection, and climate change mitigation. Table 6 depicts the institutional response strategies for providing financial support.

4.2.4 | Leadership

In our investigation, we observed that government organizations are primarily responsible for policy formulation and advice, while service and membership organizations support the government in formulating and implementing policies. Public (MoA, ECTA, JU), private (ECFF), and civil (ECEA) institutions are participating in advocating for or empowering communities and stakeholders. Table 7 illustrates the institutional mechanism used through leadership development in climate intervention initiatives.

4.3 | Factors Influencing Institutional Responses to Climate Change

Institutions can take various measures to mitigate the impacts of climate change on the coffee sector, thereby enhancing climate coffee resilience. However, institutions face numerous challenges that hinder their ability to achieve the desired outcomes. Our case study revealed that institutions face financial challenges in mitigating the impacts of climate change on the coffee sector. Government organizations (BA, EPA, JARC), agencies (EPA), cooperative unions (OCFCU), and service organizations (SLM, REDD+, USAID) are primarily facing financial constraints. The lack of climate experts who can assess climate data, conduct research, translate findings into actionable solutions, and inform policymakers often hinders institutional efforts to address climate change impacts. Government organizations (ECRGE), agencies (EPA), private businesses (HCE), and service organizations (NABU, TS) are the primary institutions encountering a shortage of human resources to ensure climate interventions in the Ethiopian coffee sector. According to the BP, EPA, HCE, and REDD+ reports, the Ethiopian coffee sector is currently facing significant challenges due to a lack of modern technologies that enable coffee producers to mitigate climate change. Furthermore, institutions such as BA, ERDD+, HOGDI, TAT, FGT, EPA, FA, TMD, and BA have observed that farmers' lagging to adopt new technologies impedes their efforts to ensure sustainable coffee production (Table 8). This study thus emphasizes the need to address these institutional challenges and the necessity of strong collaboration efforts among individuals and institutions to enhance the climate resilience of the Ethiopian coffee sector.

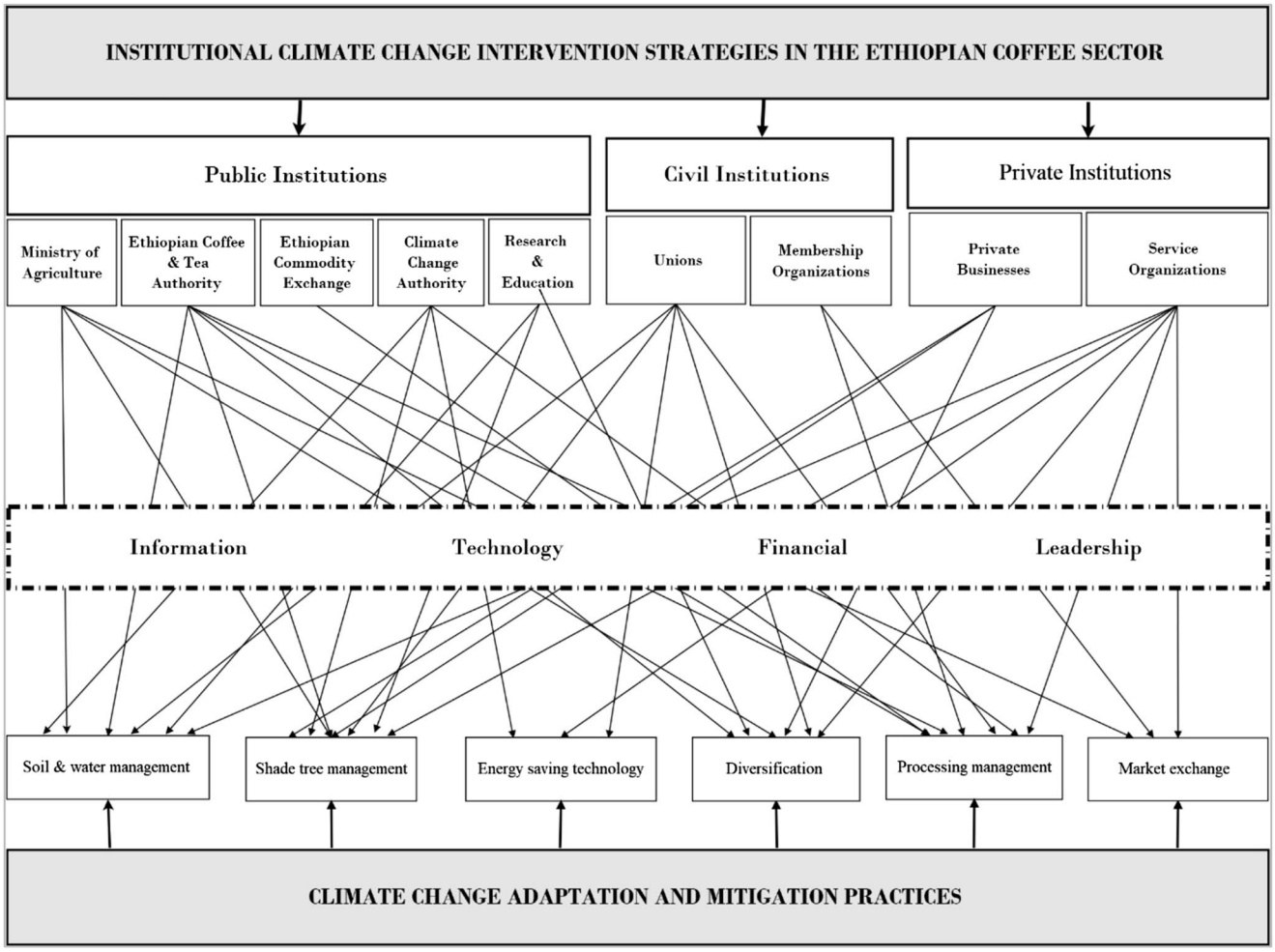

FIGURE 3 | Institutional external interventions to enhance the climate resilience of the Ethiopian coffee industry, adapted from Agrawal (2008).

5 | Discussion

In this study, we found that public institutions (Ministry of Agriculture, Ethiopian Coffee and Tea Authority, Ethiopian Commodity Exchange, Environmental Protection Authority, Research and Education), civil institutions (Unions, Membership organizations), and private institutions (Private Businesses, Service Organizations) involved in climate intervention activities. These institutions contribute to climate change adaptation and mitigation through information sharing, technology dissemination, financial support, and community empowerment, which help coffee farmers cope with climate change. Despite their significant contributions, they faced challenges in achieving targeted goals in addressing climate change due to sociocultural, economic, environmental, and institutional barriers. The consecutive paragraphs provide a comprehensive discussion of all the findings.

Sustainable development in agriculture aims to combat climate change, conserve the environment, and reduce biodiversity loss (Kasem and Thapa 2012; Rauw et al. 2023; Streimikis and Baležentis 2020). However, sustainable development in Africa faces significant challenges such as climate change, environmental degradation, and biodiversity loss (Webersik and Wilson 2009). This cumulative effect exacerbates the impact of climate change on agriculture, particularly coffee production, which requires institutions to enhance resilience through information provision, technology transfer, financial assistance, and leadership development (Agrawal 2008). Institutions can help farmers become more resilient to climate change through information dissemination to enhance sustainable farming practices (Gentle et al. 2018; Makate 2019). Institutions can provide capacity building training to organizations, extension workers, and farmers for information, education, and follow-up. We also find that training was targeted at advancing climate intervention strategies for coffee production, processing, and storage. This enabled coffee growers to effectively manage climate change and enhance sustainable coffee production. However, the training program focused on climate issues rather than topics tailored to farmers' needs. The training provided to farmers is not entirely effective as it is given vertically, rather than focusing on their needs (Amaru and Chhetri 2013). Hence, top-down adaptation measures may not significantly improve local resilience in the long term, while bottom-up approaches require robust collaborative efforts. This necessitates government investment in capacity building to increase collaborative efforts in both vertical and horizontal networks, thus improving the climate governance system (Sibiya et al. 2023). Research in Kenya (Musafiri et al. 2022) and Ghana (Alidu et al. 2022) shows access to climate-related information enhances farmers' adoption

TABLE 3 | List of institutions with their functions.

List of institutions	Major functions
Primary Coffee Farmers Cooperatives	Collect red and dry cherry coffees and selling to foreign buyers through unions. They also engage in value additional functions such as sorting, fermentations, hulling, packing, warehousing, polishing, and blending and transporting
Coffee Farmers Cooperative Unions	Buy coffee from growers, supply farm inputs, arrange transport, collect, process, facilitate savings, provide warehouses, promote, and export organic coffee, seeking global markets and sharing dividends with cooperative members
Private Coffee Exporters	Buy coffee from farmers, collectors, unions, and suppliers, and reprocess and market to international buyers. They perform cleaning, sorting, grading, cupping, exporting, hulling, and value-adding tasks like color sorting, polishing, and blending
Ministry of Agriculture	Develop policies and strategies for improving coffee production and marketing, conducts research on sustainable practices, promotes sustainable farming, provides capacity building services, enforces climate adaptation policies, offers financial assistance to farmers, and ensures coffee quality meets global market standards
Ethiopian Coffee and Tea Authority	Formulate policies, regulating market activities, promoting coffee industry growth, supervising production processes, research and development, and providing international grades and certificates
Ethiopian Commodity Exchange	Connect coffee sellers and buyers efficiently, sets quality criteria, streamlines buying and selling processes, ensures market integrity, provides infrastructure for exports, and collects market-related information for policymakers
Ethiopian Coffee Exporters Association	Promote global coffee, advocates for policies and regulations, provides member information, supports capacity building, and collaborates with international organizations like ICO to expand market opportunities
Agricultural Growth Program of Ethiopia	Work on improving agricultural productivity, value addition, and market access, income, and food security, promoting environmental conservation, and implementing climate mitigation initiatives
United States Agency for International Development	Provide modern coffee production equipment, eco-friendly processing machines, certification laboratories, training, investment in the coffee value chain, funding for research, and financial support for climate adaptation and mitigation interventions for coffee farmers
TechoServe	Work on how to improve coffee supply chain performance, provide training on sustainable farming practices, support farmers in business planning, and advocate for sustainable production and marketing policies
Hunde Oromo Grassroot Development Initiatives	Work on to increasing farmers' income by improving coffee production and managing natural resources, combat climate change through conservation, provide sustainable practices, loans, and support for government nursery sites
Digital Green Foundation	Work on promoting shade tree management, demonstrate sustainable coffee production through video-based extension systems, and empower farmers to improve their livelihoods and overcome poverty
Reducing Emissions from Deforestation and Forest Degradation	Promote sustainable forest management, providing farmers with training on sustainable coffee production, and implementing climate mitigation and adaptation strategies
Japan International Cooperation Agency	Engage in protecting highland forests, support farmers in marketing non-timber forest products, provide wire mesh, modern machinery, improved seeds, capacity building training, and promote coffee agroforestry practices
Starbucks Coffee Company	Provide training to farmers on organic coffee production systems, climate adaptation and mitigation practices, coffee quality improvement, environmental conservation, and afforestation activities. The company also supports coffee producers by providing affordable loans, promoting agronomic practices, addressing environmental sustainability, waste management, climate, and labor issues, and providing international certificates
German Agency for International Cooperation	Provide training on coffee quality, agronomy practices, and sustainable production practices to coffee farmers. They also promote sustainable coffee value chains by improving production, quality, and market linkages; promoting wild coffee and honey production, providing modern equipment, and recognizing coffee farmers through certification
Environment and Coffee Forest Forum	Engage in research and development projects, livelihood development, management conservation, climate mitigation, sustainable forest management, and serve as interfaces between science, policy, and practice
EU-Coffee Action for Ethiopia organization	Work on improving coffee production, processing, and marketing, promoting sustainable production, empowering women and youth, supporting research, facilitating public-private dialogue, increasing income for smallholder farmers, promoting organic coffee production, advancing international coffee certification requirements, and providing efficient extension services
Development Smart Innovation Through Research in Agriculture	Provide training to farmers on sustainable coffee production practices, promotes agro-ecology, provides equipment, and work towards a climate-resilient coffee sector

(Continues)

TABLE 3 | (Continued)

List of institutions	Major functions
Hanns R. Neumann Foundation	Provide technical assistance, farmer training, and support for coffee cooperatives, focusing on improving the restoration business model, supplying improved coffee varieties, and promoting garden coffee
Jimma University	Conduct advanced coffee research, provide consultancy services, technical support, policy advice, and problem-solving research, and providing community information
Jimma Agricultural Research Center	Focus on coffee research, agronomy, breeding, protection, and extension services; coordinating, producing, and disseminating findings through extension services

of climate adaptation practices. In contrast, climate adaptation practices in Tanzania have been unsuccessful due to inadequate climate information (Mugabe 2019). This underscores the necessity of institutional reforms in assuring farmers' access to climate information.

The most vulnerable agricultural areas to climate change necessitate the use of modern technology (Baig et al. 2023; Sethi et al. 2024). To reduce such vulnerabilities, institutions should reform sustainable agricultural practices by promoting climate-resilient technologies. Hence, institutions and technology are inextricably linked in a sustainable development context (Burch 2011). Technology can address issues such as climate change, sustainability, economy, and food security (Pandey and Pandey 2023; Xing et al. 2023). Institutions can enhance the coffee sector's resilience by transferring technologies to growers. This allows farmers to improve their farm management skills, increase yields, and boost their incomes. We find public, private, and civil institutions have provided farmers with technologies to enhance climate resilience. Nevertheless, strong policy and institutional innovation should be available to ensure the success of technology adoption in the community (Lybbert and Sumner 2012). Research in Honduras (Kuhl 2020), Ethiopia (Diro et al. 2022), and Kenya (Autio et al. 2021) revealed that climate-resilient technologies had increased farmers' adoption of sustainable agricultural practices, thereby improving their income and livelihoods. However, studies in Ghana (Nachibi et al. 2024) and Kenya (Autio et al. 2021) show that sociocultural, infrastructural, technical, policy, and financial challenges hinder the success of climate adaptations. These challenges call for policy and institutional reforms to improve the diffusion of climate-resilient technologies in agriculture, particularly in the coffee sector. Moreover, Webersik and Wilson (2009) suggest that African countries must prioritize environmentally friendly science and technology to meet sustainable development goals.

Financial support also plays a crucial role in inducing climate change interventions. Institutions, particularly private ones, have contributed to financial support for input provision, capacity building, and technical support for climate intervention efforts. The study shows that despite financial support, institutional efforts to tackle climate change remain insufficient. We noticed that limited financial access, a large number of farmers, and a lack of separate funds for the coffee sector are contributing factors. To address this issue, a financial inclusion system should be initiated to promote sustainable growth and make society more inclusive (Negera et al. 2025; Oanh 2024). Moreover, the study indicates that while new technology adoption often requires substantial financial investment, few institutions are actively supporting it, indicating a call for more institutional collaborations. This implies that the impact of climate change on coffee production necessitates urgent financial support for its sustainable production (Sher et al. 2024). This also obligates Ethiopia to get financial support through collaboration efforts for climate adaptation and mitigation projects for the coffee sector. Empirical literature shows that improved access to credit has improved farmers' climate adaptation practices in Ghana (Nachibi et al. 2024) and Nigeria (Olutumise 2023). However, insufficient financial resources have hampered the execution of climate adaptation projects in Tanzania and South Africa (Mugabe 2019; Sibiya et al. 2023). Therefore, this study underscores the significance of climate adaptation finance in enhancing climate resilience through institutional collaborations of national and international financing sources.

Institutions are instrumental in shaping and implementing policies, enabling societies to effectively manage potential risks (Burch 2011). The findings reveal that few coffee institutions have engaged in developing policies and strategies to intervene in the effects of climate change, thereby enhancing the livelihoods of coffee farmers. Institutions have played a crucial role in providing training, allocating funds, providing modern equipment, and creating collaborations. However, leadership has received much attention at the top but not at the bottom line, notably at the farmer level. While the leadership given to farmers is partly beneficial, the actual work has been less than anticipated. Thus, the study underscores the importance of enhancing the roles of policy makers, agricultural practitioners, and other organizations in enhancing leadership among coffee farmers to enhance their self-reliance on climate interventions. Conversely, the lack of institutional framework in Sri Lanka (Panditharatne 2016), the exclusion of stakeholders from climate policy development in Pakistan (Masud and Khan 2024), and the poor coordination among stakeholders in Uganda (Ampaire et al. 2017) have impeded institutional innovation and reform, limiting community empowerment for climate adaptation. Similarly, Ethiopian cooperative coffee farmers were not fully empowered to improve their sustainable coffee productions (Tikuneh et al. 2023). This research suggests policy and institutional reforms to improve climate intervention strategies in the coffee sector and beyond.

The successes of institutional interventions in mitigating climate change depend on social, economic, and ecological aspects (Leal Filho et al. 2016). The global market needs to get high-quality coffee from coffee-producing countries. Farmers in Nepal, for example, have effectively used sustainable coffee production practices to be competitive in the global market (Kharel and Adhikari 2021). Institutions can support coffee farmers to use the most effective agronomic practices to meet the market demand. This shows market pressure can influence

TABLE 4 | Institutional responses to climate change through information provision.

Intervention mechanisms	Examples	Representative quotes	Institutions participated
Participatory forest management	Training farmers about participatory forest management for climate change mitigations	"We trained coffee farmers on climate resilience practices such as agroforestry, compost preparation, irrigation practices, soil and water conservation, and forest management methods to mitigate the impact of climate change." (SO10)	FA ECFF NABU
Sustainable coffee production	Training coffee farmers on organic coffee production systems, climate adaptation practices, environmental conservation, and afforestation activities	"We trained coffee farmers on practices that enhance climate resilience such as agroforestry, compost preparation, irrigation, soil and water conservation, and forest management methods to mitigate the impact of climate change." (SO10)	SBUX
Soil management	Training coffee farmers on how to manage soil fertility with vermicompost and compost	"Our company has trained farmers on preparing natural fertilizer from coffee husks, pulps, and vermicompost to improve the resilience of coffee farms to climate change." (BUS5)	GIZ BA TS BNT
Using eco-friendly machines	Training coffee farmers on how to use eco-friendly coffee depulping machines to reduce environmental impact	"We have provided training to farmers and staff to enhance their technical skills on coffee processing, wet mill operations, and environmental conservation practices." (CO3)	EWNRA SCFCU GIZ
Income diversification	Institutions provide training to charcoal makers on how to diversify their sources of income and conserve forests	"NABU and BA trained charcoal makers to engage in alternative income-generating activities like honey, poultry production, and marketing traditional home materials and reduce their dependence on firewood and charcoal making for their livelihoods." (FGD28)	NABU BA
Capacity building training	Provide training opportunities for agricultural experts to improve their knowledge and skills in the coffee sector	"We have also supported agricultural experts by sending them to Dilla University to upgrade their skills and knowledge on the best agronomic farm practices to improve their knowledge and expertise in climate smart coffee production." (SO4)	GIZ KMCFCU
Human resource development	Hired climate experts to assist governmental organizations in addressing climate-related problems to sustainable coffee production	"We have hired climate experts to assist governmental organizations in addressing climate-related problems to sustainable coffee production." (BUS4)	FGT
Irrigation usability	Provide training for agricultural experts to enhance coffee climate resilience	"Our organization created awareness for farmers and experts on how and why irrigation is important for coffee production." (SO4)	GIZ

Abbreviations: BA, Bureau of Agriculture; BNT, BNT Industry and Trading PLc; ECFF, Environment and Coffee Forest Forum; EWNRA, Ethio Wetlands and Natural Resources Associations; FA, Farm Africa; FGT, Fahm General Trading PLC; GIZ, German Agency for International Cooperation; KMCFCU, Katta Muduka Coffee Farmers Cooperatives Union; NABU, Nature and Biodiversity Conservation; SBUX, Starbucks Coffee Company; SCFCU, Sorgaba Coffee Farmers Cooperatives Union; TS, TechnoServe.

the production decisions of coffee farmers. If coffee growers can produce coffee in response to market demand, institutional roles would be successful. This implies that market demand forces coffee producers, exporters, and institutions to use the best climate intervention practices. For instance, countries with advanced technologies and climate-smart practices are thriving in coffee production, making them top global market competitors. Ethiopian coffee farmers, however, lack modern technology, making it difficult for them to compete with countries such as Brazil, Colombia, Vietnam, Indonesia, and so forth. For example, Vietnam experienced a slowdown in its coffee share growth, while the global coffee share increased, resulting in a lost opportunity position (Rosiana et al. 2018). This indicates the failure to effectively implement climate adaptation measures could severely affect the survival of coffee growers in the global market. Therefore, collaborations among policymakers, businesses, and researchers are key to the sustainability of coffee production and meeting global market demand.

Institutions often rely heavily on human resources for the successful implementation of climate coffee resilience measures. However, the findings reveal that Ethiopia has a shortage of climate experts, resulting in an inefficient flow of skills, knowledge, and technology to extension agents and farmers. Political instability and low salaries often force professional experts to leave their institutions or countries without investing their knowledge. These factors have hindered institutions from effectively tackling the challenges posed by climate change. The challenges are most visible in international organizations, particularly those initiating new projects in the country. This implies that addressing the impact of climate change requires the involvement of climate experts to ensure the sustainability

TABLE 5 | Institutional responses to climate change through technology transfer.

Intervention mechanisms	Examples	Representative quotes	Institutions participated
Farm demonstration and input supply	Providing farmers with coffee polyethylene tubes, free vetiver grass seedlings, demonstrating planting techniques, providing necessary equipment, covering all its operational costs, and establishing three nursery sites	"The vetiver grass, which we locally name 'mismaara lafaa', is a highly effective method for reducing soil erosion. We produced the seedlings and distributed them to the coffee farmers to prevent soil erosion." (BUS2) "We have helped government organizations in establishing demonstration sites and showing model farmers how to prepare compost to improve climate resilience on coffee farms." (SO12)	GIZ NABU SLM JARC EU-CAfE
Coffee agroforestry restorations	Promote climate-smart practices and improve coffee production, particularly in areas with severely degraded shade trees	"We have contributed to climate change by providing our farmers with Indigenous trees such as Cordia Africana, Millettia Ferruginea, and Albizia Gummifera for coffee shade. These trees have made a greater contribution to climate change adaptations than exotic ones. We also advised the coffee farmers to not cut down but conserve them." (SO2)	REDD+
Income diversification	Provide grevilia seedlings, banana, and avocado trees to the community to generate more income	"We supplied the community with grevillea, banana, and avocado trees to cope with climate change by generating more income. This helps to conserve the environment and also protect the ecosystem and get better income." (GO5)	FA BA SLM DGF
Improved coffee varieties	Provide climate-resilient coffee varieties (disease and drought tolerant) for farmers to enhance adaptation to climate change	"We provided farmers highly resistant coffee to disease and drought. This helps to produce high-quality coffee beans and ensure long-term sustainable coffee production." (SO15)	SBUX JARC
Certification provision	Certifying coffee farmers who have implemented the best climate resilience practices	"We certified farmers who meet the company's standards for producing high-quality coffee, avoiding discrimination and child labor, and promoting environmentally friendly practices." (BUS7)	ECFF ECTA
Promoting eco-friendly machines	Provide machines such as tracking energy and water consumption machines, moisture testing equipment, wire mesh, plastic film, and building coffee storage warehouse to minimize environmental impacts and promote sustainable coffee production	"Our organization recruited experts who could demonstrate the operations to farmers. We also supported coffee farmers by providing coffee quality equipment such as coffee wire mesh, plastic film, moisture testing equipment, and building coffee storage warehouses." (SO4)	KMCFCU GIZ EWNRA
Carbon credit and marketing	Initiating carbon credit projects to generate more income by reducing carbon emissions to enhance climate-resilient coffee farming	"The price of carbon is currently incredibly alluring. If farmers are prepared to adopt and utilize such a modern cooking stove, we anticipate being able to support them. Since the number of primary cooperatives is currently increasing, it is essential to develop technologies that cater to all their members." (CO4)	OCFCU ECFF
Irrigation initiatives	Promote irrigation for sustainable coffee production	"Ethiopia has never produced coffee using irrigation before, but the government has recently initiated the activities. Our coffee production wouldn't be affected due to climate change if we had access to irrigation." (BUS5)	BNT

Abbreviations: BA, Bureau of Agriculture; BNT, BNT Industry and Trading PLc; DGF, Digital Green Foundation; ECFF, Environment and Coffee Forest Forum; ECTA, Ethiopian Coffee and Tea Authority; EU-café, EU-Coffee Action for Ethiopia; EWNRA, Ethio Wetlands and Natural Resources Associations; FA, Farm Africa; GIZ, German Agency for International Cooperation; JARC, Jimma Agricultural Research Center; KMCFCU, Katta Muduka Coffee Farmers Cooperatives Union; NABU, Nature and Biodiversity Conservation; OCFCU, Oromia Coffee Farmers Cooperatives Union LTD; REDD+, Reducing Emissions from Deforestation and Forest Degradation; SBUX, Starbucks Coffee Company; SLM, Sustainable Land Management Project.

TABLE 6 | Institutional responses to climate change through financial support.

Intervention mechanisms	Examples	Representative quotes	Institutions participated
Funding government	Promoting sustainable farming practices, forest protection, and climate change intervention initiatives	"Our institution has funded government organizations to establish demonstration sites, soil and water conservation, and soil fertility with vermicompost and compost. We have also provided financial support for the government for climate change interventions to set up and monitor participatory forest management to promote deforestation-free supply chains." (SO4)	GIZ
Carbonizing coffee husks	Supporting farmers financially on the project converting coffee husks into charcoal and reducing air pollution. In addition to climate mitigation, it also creates job opportunities for the youth and women	"We collaboratively work with Federal, Oromia Regions, and Energy Institutions to convert coffee husks into charcoal and reduce air pollution." (CO4)	OCFCU FOREI
Funding to enhance capacity building training	Financially supporting communities for capacity building training, enabling them to effectively protect forests	"We contributed significantly to climate change resilience by providing capacity building on water and soil conservation practices through terrace construction, planting different tree species, and financially supporting the communities to protect forests." (SO3)	SLM
Financial credits and compensations	Financially supporting, providing compensation, forming women's self-help groups for forest conservation and savings facilitation	"Our company provided affordable loans to coffee producers, enabling them to adopt sustainable production practices and diversify their income sources." (BUS7)	USAID SBUX

Abbreviations: FOREI, Federal, Oromia Regions and Energy Institutions; GIZ, German Agency for International Cooperation; OCFCU, Oromia Coffee Farmers Cooperatives Union LTD; SBUX, Starbucks Coffee Company; SLM, Sustainable Land Management Project; USAID, United States Agency for International Development.

of coffee production. The government should provide advanced training opportunities for coffee experts to enhance climate resilience strategies in the coffee sector, as education holds the most potent and transformative force in humanity (Agbedahin 2019). Nevertheless, this necessitates extensive collaboration among institutions to provide educational opportunities. Prior studies showed that human capital increased the adoption of coffee shade trees in Peru (Jezeer et al. 2019), but its shortage obstructed climate interventions in Ethiopia and South Africa (Sibiya et al. 2023; Tikuneh et al. 2023). The study emphasizes the significance of human capital in achieving successful climate change interventions at the grassroots level, suggesting that the government should provide educational opportunities.

Finally, human behavior has the potential to either accelerate or hinder the development of individuals, institutions, and communities. This implies that positive attitudes can enhance technology adoption, while negative attitudes hinder success (Mhlanga and Ndhlovu 2023). If farmers choose to adopt sustainable practices to boost coffee production, it will take time as these methods are closely related to traditional practices. Nonetheless, the failure of farmers to adopt new technology to curb climate change could potentially decrease coffee production. These factors push the supportive institutions to face challenges that necessitate a new approach to shaping farmers' behavior. However, a study in Vietnam revealed that the positive attitudes of coffee farmers improved sustainable agricultural practices (Nguyen and Drakou 2021). Thus, comprehensive training, trust-building, and group learning methods can increase the adoption rates of new climate intervention initiatives.

6 | Limitations of the Study

Our study had several limitations: it could have been more comprehensive by including coffee-producing countries from other regions, but was restricted by project objectives and budget constraints. Additionally, while it focused on formal functions, it gave less attention to informal institutions in climate interventions. Some relevant institutions were not included due to the study's scope, and a few were reluctant to participate in audio-recorded interviews. However, these limitations did not hinder the achievement of our research objectives.

TABLE 7 | Institutional responses to climate change through leadership development.

Intervention mechanisms	Examples	Representative quotes	Institutions participated
Developing policy and strategy	Preparing climate policy and strategies to enhance climate resilience. Initiating, influencing, guiding, advising, and leading stakeholders	"We have developed policies and strategies and prepared documents to implement climate change adaptation and mitigation strategies." (GO6)	MOA ECTA
Empowering coffee actors	Encourage farmers to adopt sustainable coffee farming practices. Work on bringing the attention of farmers, exporters, producers, and suppliers to put the EU's new regulation into practice	"We have developed policies and strategies to assure climate change adaptation and mitigation strategies while managing total coffee production activities. We are also currently working on bringing the attention of farmers, exporters, producers, and suppliers to put the EU's new regulation into practice." (AG2)	ECTA
Research and development	Focus on research and development, especially on conservation planning and implementation. This includes management conservation, livelihood development, and climate mitigation	"We serve as a bridge that interfaces between science, policy, and practice. We organized local communities to manage forests by groups and cooperatives to improve climate resilience to enhance coffee production." (SO15)	ECFF
Empowering community	Encouraging farmers to work more on climate-smart agriculture	"They also engage in promoting climate-smart agriculture such as coffee agroforestry, beekeeping, small-scale irrigation, promoting vermicompost, producing organic compost at home, etc." (SO15)	ECFF
Policy Advocacy	Advocates for organizations on policy concerns, provides research paper information and supports capacity building and services Evidence-based policy advice to various stakeholders, including policy makers, farm managers, subject matter specialists, development agents, and community-based organizations	"To achieve the desired target, we are currently promoting coffee in the international market and advocating for and supporting coffee exporters regarding issues of policy, economy, and environment. We are also promoting coffee in the international market and advocating for and supporting coffee exporters regarding issues of policy, economy, and environment." (MO1)	ECEA JU

Note: ECEA = Ethiopian Coffee Exporter Association; ECFF = Environment and Coffee Forest Forum; ECTA = Ethiopian Coffee and Tea Authority; JU = Jimma University; MOA = Ministry of Agriculture.

TABLE 8 | Factors influencing institutional responses to climate change.

Main challenges	Representative quotes	Institutions faced
Inadequate financial resources		
Institutions assist farmers in developing sustainable coffee farming practices by providing farm inputs and capacity-building training, but they encounter budget and infrastructural problems	"We supported coffee farmers in mitigating climate change by providing drought-tolerant coffee varieties and other technical supports, but we have budget constraints in planning and implementation." (GO4) "We have engaged in climate change interventions but faced infrastructural problems, budget shortages, and a lack of Human Resources during the implementations." (AG1)	BA EPA JARC SLM
Institutions invest in promoting solar energy to reduce deforestation activities, but they encounter financial shortages	"We invest in the promotion of solar energy to reduce deforestation activities. Though the initiative is remarkable, the contribution of this project is low due to financial shortages, which results in low achievement." (CO4)	OCFCU
Institutions provide farmers with training, seed distribution, tree planting, and nursery establishment, but financial constraints hinder their full implementation	"We don't have issues with planning, but there is a shortage of budget during the implementation. Because of limited financial support, a project was halted from its intended completion." (GO3)	BA REDD+ USAID
Lack of human resources		
The country faces challenges in addressing climate change due to a shortage of climate experts and a limited number of efficient coffee roasters	"We have limited expertise in Climate Smart Agriculture [...] The existing experts do not stay long and leave the job. This is due to factors such as low wages, political instability, shortages of inputs, and work overload." (GO6)	ECRGE HCE
Resource constraints not only exacerbate climate mitigation measures but also pose significant challenges when hiring climate experts	"We helped farmers by providing improved climate-tolerant seeds to the community and other technical support on sustainable coffee production practices; however, the main challenge we have is the lack of qualified professionals to carry out these activities." (GO4)	EPA HCE
The political instability is currently escalating, posing a significant challenge to climate experts	"Climate experts do not stay in the coffee sectors for a long time because of the ongoing political unrest in the nation; instead, they either leave willingly or are summoned up by the government. When experts quit their positions, the staff turnover rate rises." (SO7)	NABU TS
Lack of modern equipment		
The lack of innovative technology in coffee cultivation and processing, including drying, washing, and roasting, poses a significant challenge to combating climate change	"We don't have the modern machinery or tools necessary to test or reduce the impacts of climate change while roasting coffee beans. This issue is a serious concern for all coffee farmers, particularly for exporters." (BUS6)	BA EPA REDD+ HCE
Farmers' resistance to change		
Farmers' resistance to adopting sustainable coffee production methods hinders climate resilience due to their rigid behavior and resistance to change	"We are concerned that the failure to adopt modern production methods has led to a decline in coffee production." (SO1) "We created awareness-raising work because changing people's minds is a priority in agricultural activities before adopting any technology." (SO13)	BA ERDD+ HOGDI TAT FGT EPA FA TMD
Farmers often perceive taking new coffee production strategies or policies as serving the government's advantage rather than their benefit	"We work on promoting climate change resilience measures to increase community understanding of sustainable conservation practices. However, the underlying challenge with putting ideas into action is that the community does not consider this as their responsibility and benefit, instead relying on the government." (GO5)	BA

Abbreviations: BA, Bureau of Agriculture; ECRGE, Ethiopian Climate Resilient Green Economy; EPA, Environmental Protection Authority; FA, Farm Africa; FGT, Fahm General Trading PLC; HCE, Hadero Coffee Exporter; HOGDI, HUNDEE Oromo Grassroot Development Initiatives; JARC, Jimma Agricultural Research Center; NABU, Nature and Biodiversity Conservation Union; OCFCU, Oromia Coffee Farmers Cooperatives Union LTD; REDD+, Reducing Emissions from Deforestation and Forest Degradation; SLM, Sustainable Land Management Project; TAT, Tracon Agricultural and Trading PLc; TMD, Trade and Market Development; TS, Technoserve; USAID, United States Agency for International Development.

7 | Conclusion

To conclude, climate change poses a significant challenge to governments, communities, and individuals (Leal Filho et al. 2016). The impact of climate change on agricultural production, particularly in the coffee sector, necessitates robust institutional responses. The findings reveal that although facing severe hurdles, various institutions have embarked on measures to prevent the damage from escalating to the point of coffee annihilation. Hence, institutions can enhance environmental governance by addressing climate change and promoting sustainable development (Beunen and Patterson 2019; Patterson and Beunen 2019).

Climate change poses a significant challenge to governments, communities, and individuals (Leal Filho et al. 2016). The impact of climate change on agricultural production, particularly in the coffee sector, necessitates robust institutional responses. The findings reveal that although facing severe hurdles, various institutions have embarked on measures to prevent the damage from escalating to the point of coffee annihilation. Institutions can enhance environmental governance by addressing climate change and promoting sustainable development (Beunen and Patterson 2019; Patterson and Beunen 2019). These institutions are categorized into three major groups in the Ethiopian coffee sector: public, private, and civil institutions. They can embrace information provision, technology transfer, financial support, and leadership development. We analyzed that public institutions mostly focus on improving the capacity of coffee farmers to adapt to and mitigate climate change by transferring up-to-date information and technologies. Despite being limited, they also provided farmers with funds to facilitate training and extension services. They have also contributed to community empowerment through policy development, strategy formulation, and monitoring of climate change interventions. Private institutions were more involved in climate resilience than others in terms of information sharing, technology dissemination, funding, and community empowerment. Finally, civil institutions transfer information, provide equipment, and share resources, but they have no financial contributions. Coffee exporter associations often provide their members with timely advocacy, lobbying, and updates on new research findings. Despite significant efforts made, the institutions have not fully addressed the climate-related issues in the coffee sector due to financial constraints, lack of human resources, lack of modern equipment, and farmers' resistance to change. Therefore, this study suggests that institutions should explore ways to address climate interventions by expanding funding networks, promoting capacity building, acquiring modern equipment, and reducing farmer resistance to technology adoption.

Therefore, this study advances scientific knowledge by providing insights into the sustainable coffee value chain, focusing on how institutions contribute to climate resilience in the coffee industry. Identifying institutional challenges will also aid policymakers and practitioners in refining and developing more sustainable strategies for enhancing climate intervention. Moreover, the newly developed framework helps to analyze institutional roles in climate adaptation mitigation, not only in the coffee sector but also in other agricultural sectors.

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