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Resilience of what and for whom? Climate change mitigation and adaptation in the global, Ethiopian, and Tanzanian coffee sectors

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A R T I C L E I N F O

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A B S T R A C T

Rapid climate change is making climate resilience a key concern in the agricultural sector. Yet, in practice, efforts to support resilience are often vague about ultimate goals, as well as which systems and perturbations need to be considered to achieve key objectives. This article presents a multi-scalar climate resilience framework that distinguishes between resilience at the sectoral, country, community, and household scale involved in coffee production. We then apply the framework by comparing the ambitions of climate resilience approaches pursued by companies and global development agencies with strategies driven by producing country institutions and coffee farming communities. We triangulate evidence from a novel dataset documenting climate-resilience interventions in the global coffee sector with original survey, interview, and focus group discussion data from fieldwork in Tanzania and Ethiopia. We find that interventions originating in importing countries primarily focus on ensuring continued coffee production in service of sectoral resilience, and rarely foreground alternative livelihood strategies that would benefit household-level resilience. Activities led by origin countries focus on productivity and quality improvements, but rarely center on climate resilience. Farmers themselves, while strongly valuing coffee as a livelihood strategy, highlight the need for diversification and pragmatic adjustments in the face of growing climate threats. We conclude that there is a need for more farmer-centric climate change interventions that strengthen not only absorptive and adaptive, but also transformative capacities.

1. Introduction

Climate change threatens smallholder livelihoods across the Global South. Coffee growers, whose crop is very sensitive to temperature and precipitation change, are especially at risk. Global warming may reduce yields, shrink optimal growing areas, and foment insect pest and disease outbreaks (Kweka & Ouma, 2020; Pham et al., 2019), affecting both Arabica and Robusta producers (Bunn et al., 2015; Craparo et al., 2015; Kath et al., 2020; Tournebize et al., 2022). Regardless of their cultivar, smallholder coffee growers have limited climate adaptation capacity, and therefore face increasing income and livelihood shocks (Guido, Knudson, Finan, et al., 2020; Quiroga et al., 2020).

The coffee industry and development actors, in response, have become concerned about coffee's climate resilience. Government agencies, research centers, roasters, traders, and development-focused NGOs are experimenting with climate mitigation and adaptation

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innovations, such as developing and distributing disease-resistant cultivars and promoting climate-smart farming and land-use strategies (Fischersworring et al., 2015; Todo & Takahashi, 2013). Cross-sectoral partnerships and supply chain collaborations seeking to strengthen farmer-buyer relationships have become increasingly important to improve farm-level climate resilience and support farmer entrepreneurialism in agri-food supply chains (Bezares et al., 2021; Dentoni et al., 2021; Kangogo et al., 2020; Manyise & Dentoni, 2021; Rosenstock et al., 2020).

Unfortunately, the distribution of power in coffee value chains has historically encouraged extractive business strategies, with the lion's share of economic benefits accruing in the Global North (Daviron & Ponte, 2005; Grabs & Ponte, 2019). Amid these structures, innovations such as in-house sustainability certifications have tended to reproduce power imbalances and generate limited producer benefits (Dietz et al., 2020; Giuliani et al., 2017). Some work questions whether supply chain collaborations are carried out for the benefit of farmers or simply to facilitate strategic sourcing (Richey & Ponte, 2021), while other research highlights the local inequalities that arise with them (Vicol et al., 2018), including smallholders' more limited access to supply chain collaborations compared to large estates (Quiroga et al., 2020).

Given that power asymmetries along the value chain make 'win–win-win' interventions unlikely to succeed (Bianco, 2020), how can current climate mitigation and adaptation actions boost farmers' livelihoods? Responding to calls to explicitly investigate scalar and power relations in resilience-related development interventions (Carpenter et al., 2001; Cutter, 2016; Jones et al., 2020; Tanner et al., 2015; van der Lee et al., 2022; Weichselgartner & Kelman, 2015; Wilson, 2018), in this article we ask critical questions about climate resilience efforts, particularly: What systems are actors trying to make resilient, in the first place? Who benefits from those systems? And what types of disruptions do actors want these systems to weather?

To organize our study, we introduce a multi-scalar framework of climate resilience in commodity production, arguing that the answers to these questions depend upon the scale at which the actors in question operate. Combining quantitative and qualitative datasets at global and local levels, we document how coffee sector actors across scales frame and pursue climate resilience. Specifically, we contrast the resilience efforts of farming communities' and local governments in origin countries with models developed by global coffee firms and development agencies originating in importing countries.

We compiled and analyzed a novel database of 160 climate-focused interventions in the global coffee sector. We found that the majority appear to be designed primarily to maintain stable coffee production and maintain the resilience of the global coffee system, rather than holistically supporting the sustainability of producers' livelihoods. Using an original survey of 1020 coffee farmers in Ethiopia and 1446 coffee farmers in Tanzania, alongside 227 qualitative interviews and 158 focus group discussions (all collected in 2023) to understand these communities' experiences of climate change, we document clear contrasts with the models emerging from the interventions database. In our study areas, many farmers are pursuing some type of climate adaptation practice, though only a few are supported by external actors. Perhaps not surprisingly, farmers prioritize livelihood resilience. While many stress the need for diversification to balance coffee-related risks, the support they receive generally focuses on coffee productivity and quality. We argue that more farmer-centric climate change interventions are needed. They need to strengthen not only adaptive and absorptive but also transformative capacities, in view of facilitating structural change and more equitable adaptation paths in global and national coffee sectors (Hochachka, 2023).

2. Climate change and the coffee sector

Research on climate change impacts in the coffee sector has grown substantially, capturing varied aspects of vulnerability, area suitability, adaptation, and mitigation. One stream focuses on modeling coffee trees' possible physiological response to future climates (DaMatta et al., 2018) and projected impacts on growing regions (Pham et al., 2019). Analyses exist at global (Bunn et al., 2015; Kath et al., 2022), regional (Jaramillo et al., 2011; Ovalle-Rivera et al., 2015; Tolessa Lemma & Gudisa Megersa, 2021), national (Camargo, 2010; Moat et al., 2017), and even subnational scales (Benti Chalchissa et al., 2022; Benti et al., 2022; Kasongi et al., 2024; Mamuye et al., 2024; Mamuye et al., 2025). Although climate impacts on coffee are variable, many regions face declining yields, quality reduction, shrinking optimal production areas, the shifting of suitable coffee-growing areas, and rising risks from pests and diseases (Pham et al., 2019).

A second research stream examines coffee-producing communities' climate change perceptions, vulnerabilities, and initial adaptation responses, mostly via single case studies (Bacon et al., 2017; Call et al., 2019; Guido, Knudson, Finan, et al., 2020; Guido, Knudson, & Rhiney, 2020; Jawo et al., 2023; Mbwambo et al., 2021; Morales et al., 2022; Rahn et al., 2014; Temba et al., 2020). Assuming farmers stick with their existing cultivars, increasing temperatures and more erratic rainfall may encourage producers to expand production at higher altitudes, potentially sparking land conflict, deforestation, and other socio-economic and socio-ecological pressures (Ovalle-Rivera et al., 2015). Farmers may also adapt by planting more drought- or disease-resistant cultivars, irrigating, intercropping, or shifting to alternative crops (Bracken et al., 2023; Gezie, 2019; Shapiro-Garza et al., 2020; Temba et al., 2020). Most existing work on climate-smart coffee focuses on agronomic strategies to support production (Jaramillo et al., 2011; Läderach et al., 2017; Pham et al., 2019), such as developing resilient cultivars (van der Vossen et al., 2015), rejuvenating old coffee trees, or promoting agroforestry (Bracken et al., 2023; Gomes et al., 2020).

It is difficult to make general statements about the overall effectiveness of adaptation practices, given their place- and context-specificity and relation to local vulnerability (see for instance Bacon et al., 2017; Donatti et al., 2019; Quiroga et al., 2020). Still, based on a review of the available evidence, recommended adaptation practices include multi-strata shade management, developing climate-resilient varieties, irrigation, crop and income diversification, soil and water conservation, pest and disease management, certification (to improve price levels and stability), and establishment of strong farmer institutions (Jawo et al., 2023; Rahn et al., 2014).

A third stream focuses on mitigation measures, for instance via quantifying carbon emissions from coffee production and processing (Kilian et al., 2013; Nab & Maslin, 2020). Although coffee farming is a minor contributor to climate change, research has been conducted to identify strategies for reducing net emissions (van Rikxoort et al., 2014), and to highlight the potential for carbon sequestration in shaded coffee systems (Andrade & Zapata, 2019). This literature indicates that some practices, such as planting trees along farm boundaries and restoring degraded areas with coffee agroforestry systems, can synergize climate change mitigation and adaptation (Rahn et al., 2014). While there is some preliminary evidence that well-educated consumers may be willing to pay premiums for climate-neutral coffee (Birkenberg et al., 2021), the first coffee cooperative that achieved a carbon neutrality certification nonetheless faced marketability challenges (Birkenberg & Birner, 2018).

Finally, a few studies identify possible synergies between corporate CSR programs and climate action, although firms' actions remain embryonic (Bianco, 2020; Bradley & Botchway, 2018). In the most comprehensive survey to date, Bager and Lambin (2020) conclude that climate change remains under-addressed (they cover a cross-section of 513 companies along the coffee value chain). While other value chain sustainability initiatives such as voluntary sustainability standards and in-house labels started to consider climate resilience (Thompson et al., 2022), there is little evidence on whether voluntary sustainability standards actually contribute to climate action and adaptation in the coffee sector (Rubio-Jovel, 2023).

3. Conceptualizing climate resilience in the coffee sector

A complex interdisciplinary literature provides a basis from which to consider what climate resilience might mean in the coffee sector (Carr, 2019; Weichselgartner & Kelman, 2015). Both the definition of resilience and its applicability to social systems, however, are controversial (Bahadur et al., 2013; Carr, 2019; Jones et al., 2020; Mikulewicz, 2019; Wilson, 2018). We draw on Béné et al. (2014, p. 600), who define resilience as the "ability to resist, recover from, or adapt to the effects of a shock or a change". Climate resilience, specifically, can be defined as "the ability to anticipate, absorb, accommodate, or recover from climate change in a timely and efficient manner" (Douxchamps et al., 2017, p. 10).

Social science perspectives – especially from human geography – highlight that resilience is highly political and has important (and often implicit) normative underpinnings (Jones et al., 2020; Wilson, 2018). In this context, it is particularly important to draw attention to power and scale imbalances in analyzing resilience-focused interventions (Adger et al., 2005; Carpenter et al., 2001; Cutter, 2016; Jones et al., 2020; Lebel et al., 2006; Tanner et al., 2015; Weichselgartner & Kelman, 2015; Wilson, 2018).

One way to address scalar and power relations is to be explicit about the processes to which resilience refers. Van der Lee et al. (2022) advise researchers to pose four questions:

(1) Resilience *of what*: What needs to be resilient?

Resilience research frequently analyses systems and their component parts, alongside their functions (van der Lee et al., 2022; Walker et al., 2004). Systems operate at numerous scales – the global food system, specific agri-food supply chains, local agroecosystems, farming systems, or individual farm households are all examples (Tanner et al., 2015; van der Lee et al., 2022). Previous research on coffee has examined on-farm coffee agroecosystems' climate resilience, and argued that, achieved equitably, climate resilience would support livelihood resilience (Bracken et al., 2023). Other work examined coffee sector resilience at a national scale while tracing multi-scalar influences (Hirons et al., 2018). In our multi-scalar framework, we consider four major scales: the global coffee sector, national sectors, coffee-growing communities, and coffee-growing households (see Fig. 1). While clearly interdependent, systemic resilience at any particular scale does not guarantee (and could even be at odds with) resilience at other scales.

Coffee production has different functions at different scales. At the scale of the global industry, commodity production aims to satisfy global demand for the specific product while providing economic returns for actors along the value chain (Pascucci, 2024). At the national scale, export commodities such as coffee provide important sources of national revenue, tax income, and foreign exchange (Behuria, 2020; Tamru et al., 2021). However, other exports may also achieve these goals, depending on the local production potential and global market conditions. At the community and individual household scales, coffee production ideally supports sustainable livelihoods while maintaining local environmental quality. However, persistent poverty, lack of living incomes, and environmental deterioration in some coffee-growing regions indicate that these objectives are not always met by coffee cultivation (Harvey et al., 2021; Ruben, 2023) – and actually might be better met by other income-generation activities.

From this perspective, importing country coffee firms may rely on the global coffee sector's resilience to a greater degree than origin country actors. Consequently, there may be trade-offs and tensions between resilience goals at different scales (Adger et al., 2005; Jones et al., 2020).

(2) Resilience *to what*: What shocks do we fear?

Agri-food systems are subject to biophysical forces (both related to climate change and not), alongside socioeconomic shocks like price fluctuations, supply shortages or gluts, shifts in global or local policy, or novel consumption trends. Yet, many assessments of climate adaptation in smallholder farming systems do not take other institutional, economic, and social factors into account (Burnham & Ma, 2016; Davidson, 2016), although they are highly relevant for individuals' decision-making (Carr, 2019; Dobler-Morales et al., 2021).

The coffee sector has a relatively stable demand profile, but variable supply due to a small number of dominant producing countries, particularly Brazil and Vietnam. Weather shocks such as droughts, floods, or frost events in dominant growing areas can cause short-term price spikes that encourage upswings in global coffee plantings, resulting in a long-term period of oversupply and low prices (Daviron & Ponte, 2005; Talbot, 2004). This price volatility has important impacts on the resilience of producer livelihoods (Guido, Knudson, Finan, et al., 2020). Other shocks arise from policy and market access changes, such as the recent EU Deforestation Regulation requiring products entering the bloc to be deforestation-free (Cesar de Oliveira et al., 2024; Gallemore et al., 2025). Other sources of instability (including market, supply chain, and policy fluctuations) may thus be even greater immediate threats to

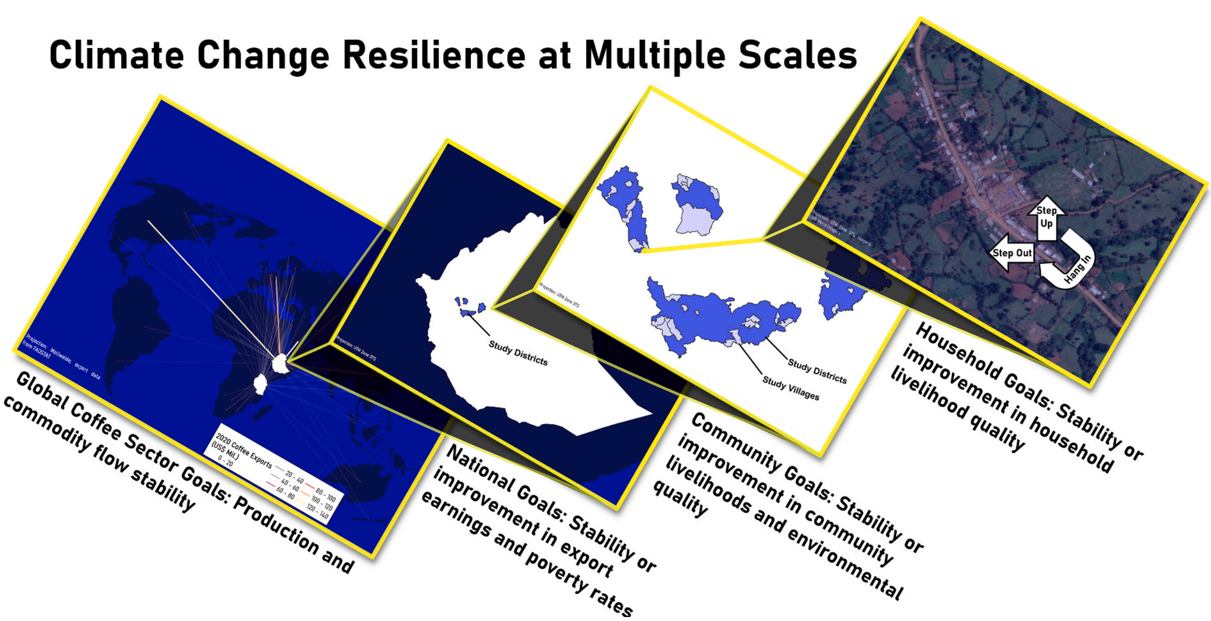


Fig. 1. Climate change resilience can have different goals at multiple analytical scales (own illustration).

resilience at various scales. While this article will focus primarily on responses to climate change, its results also demonstrate that resilience strategies at the producer level are difficult to disentangle from other kinds of shocks.

(3) Resilience *for what*: What *outcomes* do we want resilience to lead to?

Resilience analyses stemming from engineering or ecology have traditionally prioritized long-run system stability (in its processes and functions) their primary goal, while trying to reduce the system's short-run vulnerability to perturbations (Urruty et al., 2016; van der Lee et al., 2022). The goal, then, would be for any given system to 'bounce back' to a pre-shock status quo. Yet, from a social science perspective, such a goal can be questioned. Particularly when it comes to community- and household-level resilience in the context of development interventions, a return to the pre-shock status quo of vulnerability and poverty is likely undesirable (Béné et al., 2014; Weichselgartner & Kelman, 2015). In consequence, a lively debate has emerged on whether the transformation into a different system state may be more desirable in response to repeated stressors than the continued absorption of such shocks by existing systems (Carr, 2019; Folke, 2006; Hochachka, 2023; Kuhl, 2018; Vicol et al., 2018).

The current organization of the coffee sector is defined by power differentials between large buyers in importing countries and (mostly smallholder) producers in origin countries (Daviron & Ponte, 2005; Grabs & Ponte, 2019; Ruben, 2023; Talbot, 2004; Wienhold & Roberts, 2025). Grabs and Ponte (2019) show that these power inequities between Northern buyers and Southern producers have taken multiple forms, ranging from direct marketplace bargaining power to more indirect demonstrative power to define desirable product criteria. The authors also show that despite the rise of product differentiation (i.e. distinguishing a product via certain attributes to make it more appealing and garner higher prices, e.g. via the specialty coffee movement and the rise of sustainability certification), power inequities remained fundamentally unchanged over a 30-year period (see also Grabs, 2020). Current-day efforts to improve producer prices continue to focus on high-quality differentiation, though research confirms that producers for specialty markets receive similar shares of consumers prices compared to their conventional peers (Wienhold & Roberts, 2025).

In this context, desirable resilience outcomes and relevant strategies will differ across scales and actors. Actors benefitting from current power structures are likely to prefer the status quo, while disadvantaged actors might prefer more fundamental systemic changes. As an intermediate step toward such changes, producing countries, regions, and individual producers have aimed to gain greater control over their product and pricing by differentiating their products on the basis of geography, quality, or sustainability (Barjolle et al., 2017; Behuria, 2020; Grabs, 2021). Global coffee buyers might aim to achieve climate resilience (and stability of the status quo) in two ways. They might strengthen and deepen (captive) supplier relationships to guarantee coffee supply. Conversely, they could encourage further commodification, making coffee origins more substitutable in order to improve sourcing flexibility in the event of weather shocks and shifts in suitable production regions (Morales et al., 2022).

(4) Resilience *due to what*: What *factors* are hypothesized to contribute to resilience?

Scholars have distinguished three capacities relevant to resilience. Absorptive capacity is an ability to moderate the impacts of shocks on livelihoods and needs. Adaptive capacity involves learning and adjusting to potential damage while seizing opportunities. Transformative capacity, finally, is the ability to create something fundamentally new should an existing system become untenable (Béné et al., 2014; Folke, 2006; van der Lee et al., 2022; Walker et al., 2004). As Béné et al. (2012, 2014) argue, the applicability of these capacities is linked to the intensity of changes. Households or systems may be able to absorb lower-intensity or one-off shocks, but larger shocks may necessitate concerted adaptation or even comprehensive transformation (see Table 1).

Table 1
Overview of absorptive, adaptive, and transformative capacity (adapted from Béné et al., 2012, 2014).

	Absorptive capacity	Adaptive capacity	Transformative capacity
Intensity of change	Stability	Flexibility	Change
Outcomes	Persistence	Incremental adjustment	Transformational responses
Examples at household and community level	Savings, maintain a diversified income base	Adopt new farming techniques, change in farming practices, ability to move into additional diversification options	Switch to new primary income source, creation of new local norms (e.g. recognition of women as money earners) or institutions (e.g. village assistance committees)

Research in climate change and agriculture has similarly defined adaptation gradients ranging from incremental adjustment (e.g. best agricultural practices related to the target crop) to transformation (toward new products and income diversification) depending on the likely suitability of a given area subject to climate change (Morales et al., 2022; Rickards & Howden, 2012).

Although distinct, absorptive, adaptive, and transformative capacity are not in opposition, and should be strengthened together at various scales (Béné et al., 2014). Previous studies have shown that coffee farmers' absorptive capacities (i.e. coping strategies) are shaped inter alia by their experience, farm size, and off-farm employment opportunities (Bacon et al., 2017). Farmers' adaptive capacities tend to be rather low (Call et al., 2019), inter alia due to their low resource endowment, territorial dependence and asymmetric power relations with buyers (Guido, Knudson, Finan, et al., 2020; Morales et al., 2022). To our knowledge, no previous research has examined transformative capacities in coffee-growing regions.

At the farm household level, some authors such as Dorward et al. (2009) distinguish between the livelihood strategies of 'hanging in', 'stepping up', and 'stepping out' which people may pursue in the face of recurrent shocks. These concepts closely parallel absorptive, adaptive, and transformative capacities. According to this distinction, in hanging-in strategies, actors hold onto their assets and persist in ongoing activities to maintain livelihood levels despite adverse circumstances. Stepping-up strategies involve investing in expanding current activities to improve household livelihoods. Stepping-out strategies see actors moving into different activities that promise higher or more stable returns (Dorward et al., 2009; see also Hellin & Fisher, 2018). To be sure, reality might be more complex. For instance, farmers may become unable to sell into global markets because of increasing buyer demands (for quality and sustainability; for example Minten et al. 2018; Ponte 2002). In turn, they may be forced to step out without this being their preferred strategy (Ponte & Ewert, 2009). Farmers may also partially step out, for example by decreasing coffee cultivation and diversifying into other crops or livelihood activities while waiting for better times, when prices or access to capital are more favorable.

By applying these four questions to the coffee sector, we can uncover distinctions in climate resilience goals across actors and scales. Table 2 below summarizes some of these differences.

In the rest of this article, we apply this framework to existing climate resilience strategies in the coffee sector. We compare climate-related projects carried out by international firms, organizations and NGOs based in importing countries to origin country-led projects and independent adaptation strategies of Tanzanian and Ethiopian coffee producers. We cover both climate mitigation and adaptation actions, given that climate-resilient development pathways should include both according to the IPCC (Werners et al., 2021). Furthermore, certain climate mitigation actions in the coffee sector may also have strong synergies with adaptation actions, or provide access to funding resources necessary for adaptation (Rahn et al., 2014). However, we also acknowledge

Table 2
Climate resilience at multiple scales within the coffee sector (own elaboration).

Scale	Global coffee industry	National coffee sector	Communities	Individual households
Function	Commodity production	Commodity income generation	Sustainable livelihoods, environmental quality	Sustainable livelihoods
Resilience to what perturbations?	Increased frequency of climate shocks, changes in long-term local outputs due to changing micro-climate PLUS policy changes	Climate shocks PLUS market and supply chain changes PLUS policy changes	Climate shocks PLUS market and supply chain changes PLUS policy changes	Climate shocks PLUS market and supply chain changes PLUS policy changes PLUS individual-level shocks (illness, conflict, crime, death of household members)
What is the (ideal) outcome of resilience?	Stability: Global supply that can meet current and future demand for coffee (with appropriate quality)	Transformation: Maintenance or increase of commodity-related national income, foreign exchange generation, rural development, sector competitiveness	Transformation: Improve level and stability of community livelihoods, ensure environmental quality and access to resources (e.g. water, forest products) for all community members	Transformation: Improve level and stability of livelihood outcomes in terms of food security, income, health, exit from poverty, life satisfaction
Potential pathways to resilience	Ensure survival and increase productivity of many origins Flexible and diversified sourcing strategy Recommodification (including of specialty-grade) Deepen (captive) supplier relationships	Ensure maintenance of coffee production in country, unless substitutable by different export crop Product differentiation of national and local offer Decommodification	Aim for improved incomes via collective mechanisms (group formation, building of centralized processing infrastructure, group certification) Support diversification to decrease community dependency on coffee	Choice of hanging in, stepping-up or stepping-out strategies depending on location, land size, assets and capabilities Decommodification OR diversification/exit

the ongoing conceptual debate over whether climate resilience should include mitigation as well as adaptation action, and whether the duality of mitigation and adaptation should be dissolved by talking about climate (compatible) action more broadly (Werners et al., 2021).

4. Data and methods

Our analysis was designed to allow us to compare the resilience priorities of coffee actors across scales of operation. Rather than relying on surveys of downstream actors, which could easily inflate reported resilience priorities due to social desirability bias (Roxas & Lindsay, 2012; Tan et al., 2021), we documented the resilience priorities revealed in concrete activities. To start, we generated a global database of farmer-focused projects or interventions in the coffee sector that addressed climate change mitigation, adaptation, or resilience. We first conducted a structured search of the websites of three types of organizations: Organizations active in the coffee industry (including private firms as well NGOs focused on coffee sector sustainability and development); organizations active on climate change issues (mainly focusing on international organizations, NGOs, and business coalitions focusing on climate change-related action); and organizations focusing on development, particularly in coffee-producing countries. Finally, we conducted a keyword search on Google (in English, German, and Spanish) to identify additional interventions that might have been missed by the structured website search. Appendix 1 provides further detail on our keywords and search strategy, while Appendix 2 summarizes the major organizations and countries involved in interventions. We identified 84 interventions from the structured website search, and an additional 76 results from the keyword search.

We coded intervention characteristics, including their starting and ending years, their implementing and financing organizations, and their geographical target (at a national and, if specified, subnational scale). We summarized each intervention's description, its target outcomes and theory of change, and achieved outcomes. We then conducted an inductive coding of mitigation, adaptation, product differentiation, and other activities pursued by each project/intervention. Grabs (2022) provides greater detail on this dataset and in-depth summary statistics.

While it was beyond the feasible scope of this project to survey national and producer-level resilience priorities across the global coffee sector, we collected data from two smallholder-dominant coffee-producing countries. We conducted primary research in the Tanzanian and Ethiopian coffee sectors, with an emphasis on understanding challenges related to climate change and potential adaptation strategies. As part of a larger research project (see Bekele et al. (2023)), we comprehensively mapped the coffee sectors of both countries and conducted document analysis, focus group discussions with farmer groups, and semi-structured interviews with key stakeholders (including government officials, NGO representatives, coffee union and cooperative representatives, and private sector representatives of coffee exporters and roasters) between 2022 and 2023. In total, we conducted 114 interviews and 30 focus group discussions in Ethiopia and 113 interviews and 128 focus group discussions in Tanzania. We coded our data in NVivo using a deductive set of codes related to climate change experiences, mitigation and adaptation activities, and on-the-ground experiences related to interventions. Appendix 3 shows an overview of our coding results.

In addition to these data sources, in 2023, we surveyed 1020 coffee farmers in Ethiopia and 1446 farmers in Tanzania (1071 Arabica coffee farmers and 375 Robusta coffee farmers). To select appropriate sample sites in the two countries, the project members adopted a two-stage sampling strategy. First, we selected study regions in the two countries where the highest levels of smallholder coffee production took place. After selecting these regions, we used governmental data on coffee production from Ethiopia and estimates of suitable elevations for coffee cultivation in Tanzania to identify communities in the selected regions engaged in coffee production that would be representative of various agro-ecological experiences. This led us to select the districts of Kyerwa (Kagera region – the main Robusta-growing region in Tanzania), Mbozi (Songwe region), Mbinga (Ruvuma region), and Rombo (Kilimanjaro region) in Tanzania, as well as the districts of Ale, Gomma, Yayu, Limu Seka, and Gera in Ethiopia. Second, we randomly selected villages (Tanzania) and kebeles (Ethiopia) with existing coffee farming areas on the basis of a double stratification: high, middle, and low elevation levels, and high, middle, and low precipitation change, arriving at a total of 30 villages/kebeles in each country. We conducted a face-to-face survey (using tablets and the open-source tool KoboCollect for digital data collection) on climate change experiences, mitigation and adaptation measures, as well as livelihood strategies. Additional details on the site selection and sampling approaches are given in Bekele et al. (2023).

5. Global climate resilience strategies

Most climate-related projects or interventions we identified in the

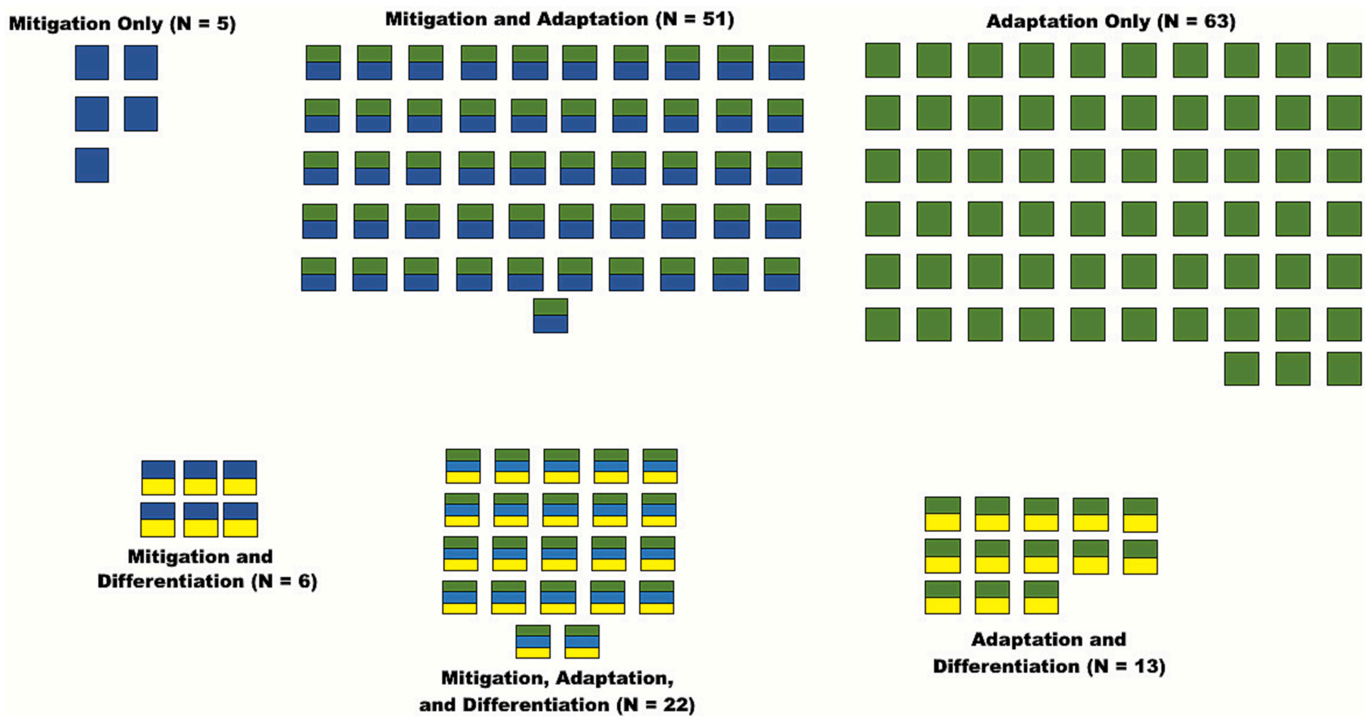


Fig. 2. Overview of interventions and their focus on mitigation, adaptation, and/or product differentiation (own elaboration).

coffee sector (149/160) focus on climate change adaptation, although many also integrate mitigation measures (Fig. 2). Only 41 interventions (one-quarter of the total) include clear value-adding or product differentiation activities as part of the intervention. Purely mitigation-focused interventions, of which there are only 5, are comparatively rare.

To mitigate climate change, the largest number of interventions focus on encouraging on- or off-farm tree planting, closely followed by measures to reduce fossil fuels, chemical inputs, and deforestation. Instances of improving soil carbon sequestration (e.g. via the use of specific organic inputs or the use of biochar) and focusing on greenhouse gas mitigation during harvest and postharvest are comparatively rare (see Fig. 3).

Water conservation is the most common objective for projects supporting climate adaptation, with planting shade trees and adopting agroforestry a close second (Fig. 4). Support for soil management, diversification, and cultivating resistant varieties are also common objectives. By comparison, irrigation support is relatively rare, and only 3 projects in our dataset support farmers to switch from coffee to alternative crops. Providing adaptation credit/financing or climate insurance are other emergent strategies.

Forty-one global interventions are intended to support farmers in adding value or product differentiation (Fig. 5). Of those, twelve support farmers' efforts to achieve certification. Some interventions further support farmers to improve both product quality and climate resilience. A few projects encourage access to innovative climate-related markets such as the carbon credit or offsetting market or that for low-carbon or

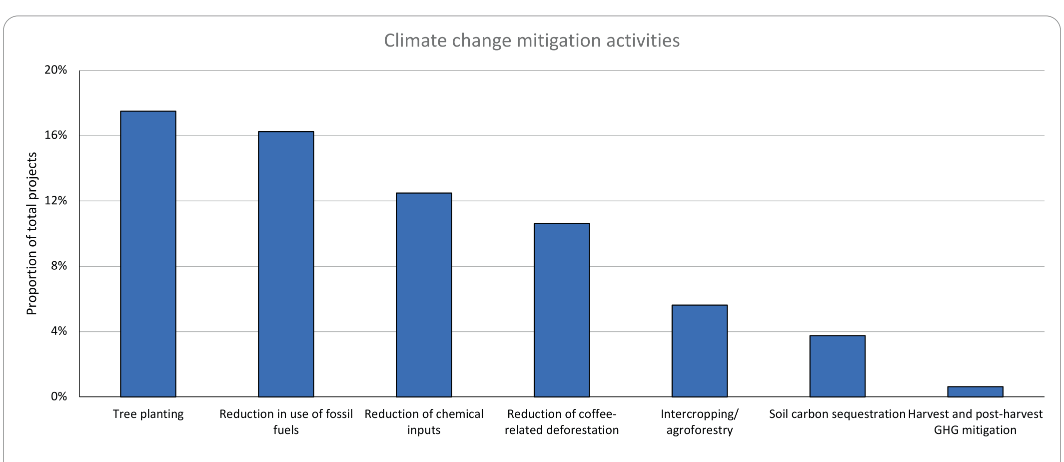


Fig. 3. Overview of global climate change mitigation activities (own elaboration).

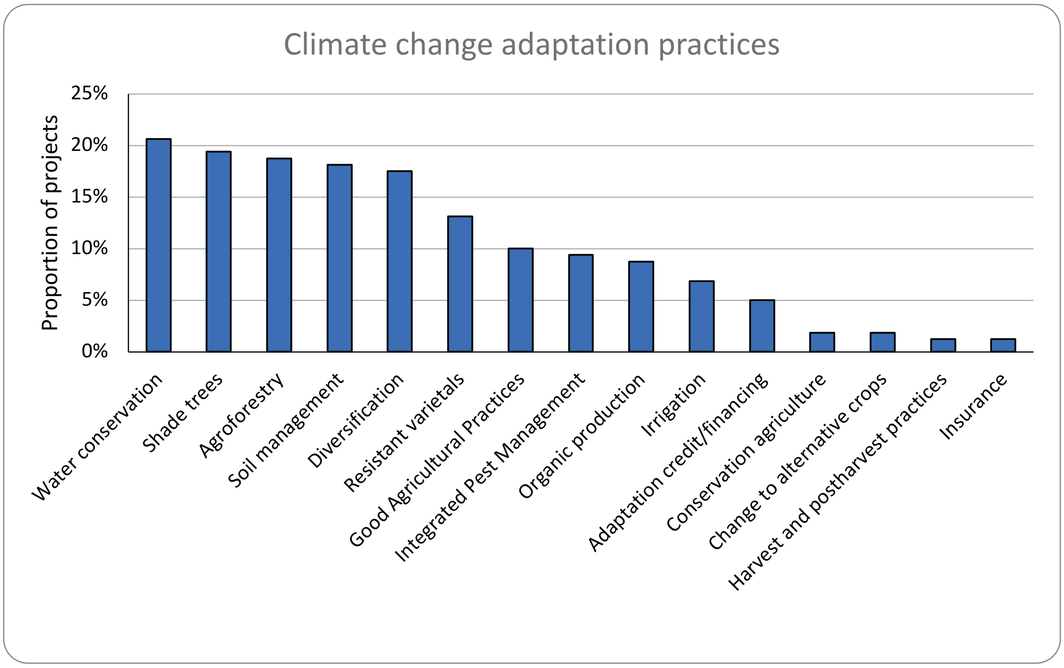


Fig. 4. Overview of global climate change adaptation strategies (own elaboration).

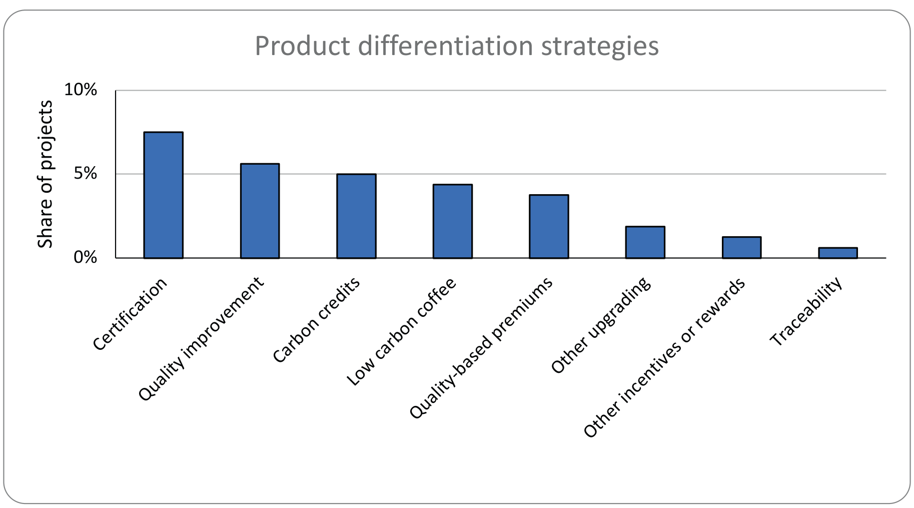


Fig. 5. Overview of global product differentiation strategies (own elaboration).

carbon–neutral coffee.

Many interventions list additional activities (Fig. 6). The most common is gender empowerment, pursued by around one-third of all interventions in our database. Youth inclusion is also common. Twenty-five projects address productivity, while a small number support access to finance, financial literacy, or crop rejuvenation/stumping.

What do these objectives tell us about major downstream coffee sector actors' resilience priorities? First, very few projects support producers' transformative capacities to step out from coffee to another crop or to alternative off-farm employment opportunities. Instead, most try to bolster producers' absorptive or adaptive capacity – encouraging them to hang in, or step up in terms of productivity or quality, while adjusting their growing methods to new biophysical conditions such as drought or novel pests. While it is perhaps not surprising that coffee roasting companies would not support coffee growers' potential exit from coffee, projects supported by development organizations similarly prioritize absorptive and adaptive capacity.

Some projects encourage diversification into food production or livelihoods activities beyond coffee, but this is primarily intended to boost absorptive capacity, rather than as an aid in stepping out. Projects in this realm highlight the need to maintain redundant income sources from multiple crops, but they nevertheless generally adopt a traditional approach to resilience, aiming to stabilize coffee supply as it currently functions, rather than imagining large-scale transformations. Twenty-three percent of interventions support differentiation-based stepping up strategies, hoping to boost farmers' incomes via climate- or quality-

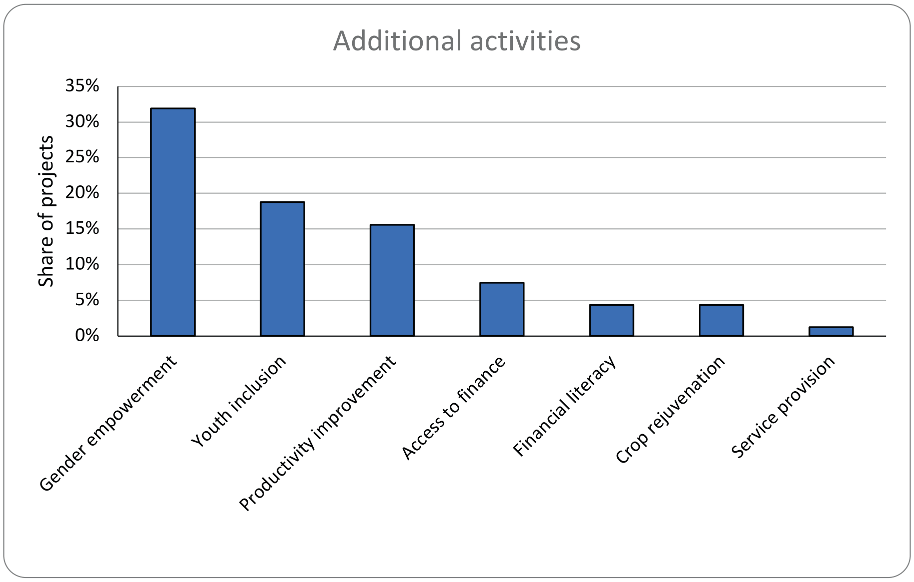


Fig. 6. Overview of additional activities of global interventions (own elaboration).

based decommodification. Twenty-one percent also hope to promote stepping up by making farms more productive, efficient and 'business-like' as they continue to produce coffee in the face of adverse biophysical conditions.

The remainder of the interventions – more than half of the projects in our database – have no identifiable theory of change for farmer livelihood improvements beyond the status quo. While in some cases this may simply reflect a lack of reported information in available materials, it nevertheless suggests climate change interventions originating in importing countries generally maintain a narrow focus on building select absorptive and adaptative skills without considering farmers' livelihood improvement more broadly. Rather, the interventions appear to be mainly focused on helping farmers to 'hang in' by maintaining their current situation and avoiding the worst climate-related impacts. They also seem to focus narrowly on addressing resilience to the biophysical stressor of climate change, rather than other perturbations against which farmers might hope to be insulated. Overall, the interventions attempt to preserve stable coffee production, rather than protecting the functioning of individual community or farm systems to ensure sustainable livelihoods.

6. Case studies of Ethiopia and Tanzania

In the previous section, we mapped the strategies on offer from global actors. But how do they relate to national and local resilience priorities in origin countries? Individual case studies allow us to identify fault lines and distinct interests in climate resilience at various scales using our multi-scalar framework. We illustrate this approach with case studies of climate change resilience in Ethiopia and Tanzania (see Table 3).

6.1. Country and national climate policy characteristics

Coffee is Ethiopia's dominant export good and generator of foreign currency. Ethiopia is the world's fifth-largest coffee producer – accounting for about 4.5 % of global coffee production – and the top producer in Africa (ICO, 2023). Ethiopian coffee is cultivated by over 6 million smallholder farmers. About 15 million people, more than 20 % of the country's economically active population, are employed in the coffee sector (Tefera, 2022). Despite its importance as an export crop, around 50–55 % of Ethiopia's coffee production is locally consumed, and coffee holds high cultural significance (Tefera, 2022). Continued coffee production and coffee variety biodiversity protection are thus of high priority to both national and international actors (Regasa Megerssa et al., 2025).

Ethiopia developed a Climate Resilient Green Economy (CRGE) strategy in 2011 and a Climate Adaptation Plan (CAP) in 2019. The CRGE aspires to enhance resilience to climate change impacts, reduce greenhouse gas emissions from 2010 levels, and make Ethiopia a middle-income country by 2025. CAP aims to promote climate change adaptation and mitigation strategies. Both documents lack a coffee-specific climate change adaptation and mitigation strategy (Hirons

Table 3
Climate resilience at multiple scales: Comparative priorities (own elaboration).

Resilience of…	Global coffee industry	National coffee sector	Communities	Individual households
Ethiopia	Maintain Ethiopia as Arabica origin; maintain a variety of specialty flavors	Ensure continued or increased exports; build specialty coffee offerings	Improve livelihoods; maintain coffee forests; maintain access to coffee for local consumption	Identify crop mix that generates the highest income (e.g. khat); improve livelihoods
Tanzania	Maintain origin diversity, though coffee is interchangeable with other East African origins	Increase production and poverty alleviation, though coffee is not a dominant export good	Improve livelihoods; maintain the tradition of growing coffee; but identify the best combination of livelihood strategies	Identify a crop mix that generates the highest income; improve livelihoods

et al., 2018). The recently released comprehensive Ethiopian coffee strategy (2019–2033), however, intends to boost the country's exports of high-quality, climate-friendly coffee, improving incomes for coffee farmers.

Tanzania is Africa's fourth-largest coffee producer, following Ethiopia, Uganda, and Côte d'Ivoire. Both Arabica and Robusta coffee varieties are grown on an estimated 265,000 ha. While Arabica production is widespread, Robusta is confined to northwest Tanzania, mainly in Kagera region (Ruben et al., 2018). The country's coffee sector generates about US$100 million annually, around 5 % of the total exports (TCB, 2021). The sector supports over 450,000 smallholder farming households. These households, whose average coffee plot size is between 0.5 and 1.0 ha in the northern zone and 2–3 ha in the southern zone, are estimated to account for 90 % of production (TCB, 2017). Of these, 120,000 farmers operate in Kagera region. An estimated 2.4 million additional people are locally, but indirectly, engaged in the industry (Kangile et al., 2021; TCB, 2017).

Tanzania has various climate change plans, including the National Climate Change Strategies (2012–2018) and (2021–2026), the National Climate Change Communication Strategy (2013), the National Environmental Action Plan (NEAP) of 2013 and 2020 as well as National Guidelines for Mainstreaming Gender into Climate Change Adaptation related Policies, Plans, Strategies, Programmes and Budgets (2014). Yet, these priorities have not been integrated into coffee policy. Instead, the core objectives of the Coffee Industry Development Strategies (CIDS 2011–2021 and 2021–2025) are to increase national coffee production and quality to improve incomes across the industry, particularly for coffee farmers (TCB, 2012, 2021). CIDS 2011–2021 called for doubling coffee production from 50,000 MT in 2011 to 100,000 MT in 2021, but missed its target by a large margin. Its successor, CIDS 2021–2025, aspired to increase coffee production from 68,000 MT in 2021 to 300,000 MT in 2025, increase the share of high-quality coffee from 40 % to 70 % of the total production, improve Tanzanian coffee's international market position, increase domestic coffee consumption from 7 % to 10 %, and grow the percentage of value-added coffee by 15 % – all quite lofty targets (TCB, 2021).

6.2. *Producers' experiences of training and skill enhancement*

Among our survey respondents, 39 % of Tanzanian and 68 % of Ethiopian farmers had experienced some form of coffee-related training in the previous five years, primarily provided by local institutions. Four-fifths of Ethiopian and 36 % of Tanzanian respondents mentioned the government as training provider, while cooperatives were the most common training provider in Tanzania (47 % of respondents; respondents could mention several providers). NGOs were more active in Ethiopia (with 47 % of mentions) than in Tanzania (16 %). Only 0.4 % and 2 % of respondents in Tanzania and Ethiopia, respectively, reported receiving trainings from buyers – though it is possible that cooperatives or NGOs were perceived as training providers even if the training was designed and funded by downstream companies.

Fig. 7 shows the topics farmers reported were covered in those trainings. Consistent with national priorities, yield and quality improvements are by far the most common topics, followed in Ethiopia by resistant variety cultivation, post-harvest storage and processing, and shade tree nurseries, planting and management. In Tanzania, pest and disease management is the second most common training topic, while the use of resistant varieties and soil management are also common. In striking contrast to Ethiopia, agroforestry and shade trees are comparatively absent from trainings in Tanzania, though some focus group participants mentioned institutional efforts to encourage tree planting: "*Even our hills, which used to be bare, now have young trees. Local cooperatives […] provide seedlings to farmers, including [for] planting trees on the farms and establishing dedicated tree farms for future precautions or environmental conservation*" (Tanzania, FGD, Mbinga Utiri).

Trainings addressing diversification and alternative livelihood strategies were both mentioned by 23 % of surveyed Ethiopian farmers, but only by 12 % (diversification) and 7 % (alternative livelihood strategies)

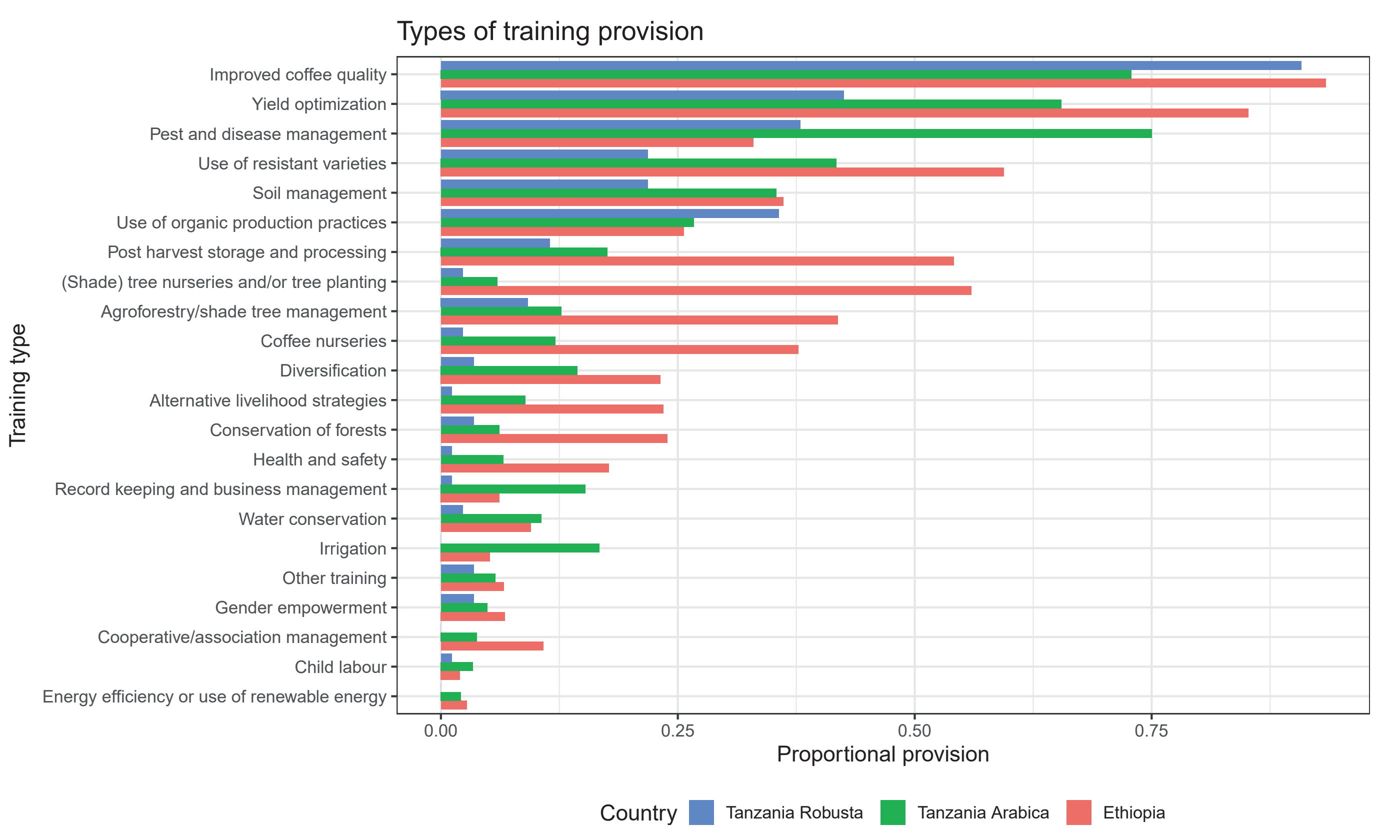


Fig. 7. Training types experienced by surveyed farmers (own elaboration).

of Tanzanian farmers. Overall, only selected climate-change related topics (pest and disease management in Tanzania, resilient varieties in Ethiopia) are strongly represented in training curricula to date, while other topics remain marginal. In both countries, productivity and quality improvements take center stage in local training.

These results are consistent with evidence from key informant interviews analyzing the national-scale intervention landscape. Overall, interventions focusing on access to climate-related markets are still relatively rare and, where they exist, nascent. In Ethiopia, respondents were aware of some very early-stage concepts, such as introducing efficient cookstoves to mitigate emissions, while none came up in Tanzania. Across both countries, very few projects focused mainly on alternative livelihoods and ways to step out from coffee. Rather, interventions focus on maintaining or improving productivity – and, less frequently, boosting quality – to protect the country's market position.

Surprisingly, though water conservation was a central focus for global projects (see Fig. 4), in neither country do we see much focus on this issue in trainings. Nor did the respondents report much content on nature conservation, farmer professionalization and business management (e.g. via bookkeeping or establishment of a savings plan or practice, which could be key to boost absorptive capacity), or regulatory or organizational formalization and improvements (e.g. via land tenure acquisition or establishing farmer groups, which might be a basis to increase collective transformative capacities).

6.3. Local adaptation measures

As noted above, only one-third of Tanzanian and two-thirds of Ethiopian respondents had experienced any type of training in the previous five years, and these trainings focused only to a limited extent on climate resilience. So what do farmers do to adapt to climate change themselves? Fig. 8 provides an overview of all adaptation practices reported in our surveys. While many are also generally good agricultural practices, farmers themselves explicitly identified them as climate adaptation practices adopted, as the survey put it, "to respond to changing or more extreme weather conditions".

Soil management and the use of shade trees

Tanzanian Arabica and Robusta farmers have distinctly different adaptation profiles. Both Tanzanian and Ethiopian farmers reported using soil management (i.e. mulching), shade trees, and tree rejuvenation (replacing poorly performing or diseased trees) as their most frequent climate adaptation practices, though we can see from Fig. 8 that farmers in Ethiopia tend to adopt all these practices (and many more) at a higher rate than those in Tanzania.

Many farmers have historically been involved in agroforestry, especially in Ethiopia. They prefer trees that facilitate airflow, provide partial sun coverage, and grow leaves suitable for mulching: "*Shade trees should be planted for climate resilience. […] The shade of a tree provides some protection for coffee during heavy rain or sleet. During the dry season, it provides shelter for the coffee to prevent it from drying out*" (Ethiopia, FGD, Ale Kundi).

Overall, over two thirds of Ethiopian and one third of Tanzanian qualitative interviews mentioned soil management and restoration techniques. To nourish the soil and increase moisture retention, respondents preferred mulching and trace bunds. In some locations, they terrace.

Choice of species and varieties

Although Tanzania hosts both Arabica and Robusta-growing regions, and Robusta has been considered more climate-resilient, there is no evidence of farmers abandoning Arabica coffee for Robusta (though regulation also prevents this). However, in both countries governmental agencies or research institutes breed different Arabica (and, in the case of Tanzania, Robusta) varieties, hoping to boost yields, resistance to specific diseases such as coffee leaf rust or coffee berry disease, or drought tolerance. Tanzania's Coffee Research Institute's priority has been developing varieties combining high yields, good beverage quality,

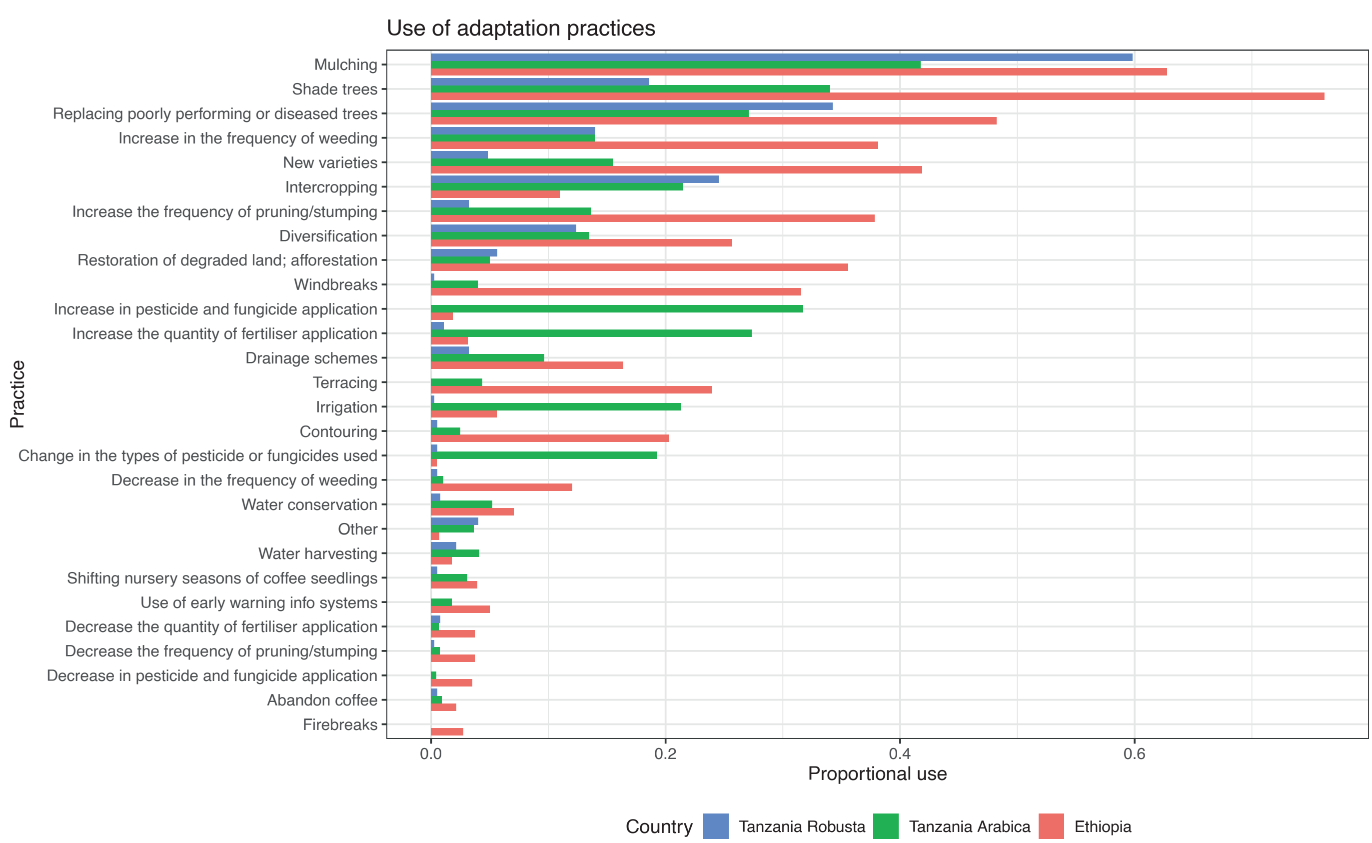


Fig. 8. Local use of adaptation practices, based on farmer surveys (own elaboration).

and resistance to the main diseases of concern (coffee leaf rust and coffee berry disease for Arabica and coffee wilt disease for Robusta). The Institute also has started developing drought-tolerant varieties. In Ethiopia, the Jimma Agricultural Research Center has similarly focused on varieties resistant to coffee leaf rust, coffee berry disease, and good cup quality. Yet, community members often lack access to the information necessary to distinguish which varieties they are growing. Farmers tend to make a general distinction between using traditional, 'old local' varieties and the 'new scientifically-developed' or 'modern' ones. In reporting the results of our surveys, we adopt the farmers' classification.

Overall, only 29 % of Tanzanian Arabica and 9 % of Robusta respondents have planted at least some modern/resistant varieties, while the Ethiopian sample was split evenly between farmers whose plots had only traditional varieties (31 %), only modern/resistant varieties (30 %), or a mixture of the two. Over 40 % of surveyed Ethiopian farmers, but only 15 % of Tanzanian Arabica and a mere 5 % of Robusta producers, explicitly mentioned using modern varieties as a climate adaptation practice. Amongst farmers interested in switching to modern varieties, both Ethiopian and Tanzanian farmers noted that they struggled with "*the lack of supply of improved coffee seeds. There is no improved coffee seed in the village,*" one Ethiopian focus group member reported, "*but even if there were, there is little chance that all the farmers would obtain it*" (Ethiopia, FGD, Ale Sambe Enole). "*We were really eager to get those [modern] plants for our farms,*" noted a Tanzanian focus group member. "*[…] We really want it, but it is difficult for us to access it*" (Tanzania, FGD, Mbinga Maguu).

The vast majority (80 % in Ethiopia and 83 % in Tanzania) of survey respondents using modern varieties reported they are satisfied with their performance. Still, discussants in our focus groups also raised a range of concerns. In Tanzania, respondents appreciated modern varieties' higher yields and disease resistance, yet also pointed out that they require more – and more precisely applied – fertilizers and irrigation to perform well. One Tanzanian focus group member likened modern seeds to "*a modern chicken that requires close monitoring to be the best, and this seed needs a lot of improvement, needs to be closely monitored, and it doesn't have many diseases*" (Tanzania, FGD, Mbinga Buruma). They also perceived coffee trees from modern varieties to have higher peak yields but shorter life spans, while traditional varieties could produce reasonable yields for longer.

In Ethiopia, a number of farmers in our focus groups doubted the resilience, superiority and local suitability of the more modern varieties, and reported a preference of sticking to their traditional varieties: "*The coffee seedlings supplied through the agriculture office are largely incompatible with the local climate and are not beneficial for production. […] When we compare the modern coffee varieties with the natural [traditional] one, the natural one can withstand any problems better than the improved. The modern one yields quickly but has a tendency to dry quickly. The natural is the most resilient to climate change. The modern one has a very short life span*" (Ethiopia, FGD, Gomma Ganji Ilbu). Such perceptions translate into a reluctance to replant new varieties even where they are available.

Irrigation

Many farmers see irrigation as a key adaptation measure, but they lack access to waterpipes and/or water sources. Irrigation appears to be more critical for Tanzanian than Ethiopian farmers (given that coffee on average is grown at lower altitudes), as it is one of the few practices that is more common among Tanzanian than Ethiopian farmers in our survey (16 % versus 6 %). However, 7 % of Ethiopian versus 4 % of Tanzanian respondents adopt water conservation practices for adaptation. Thus, water availability appears to be a common concern that is differently addressed: "*Some farms, where there are drainage systems, can divert water to save at least a little. But in areas where there is no water access, farmers face a lot of difficulties. In our village, we don't have water pipes, so if we had water pipes, it would mean we could irrigate*" (Tanzania, FGD, Mbinga Utiri).

Income diversification and crop replacement

Between 76 % and 89 % of surveyed farmers rely on coffee as their main income source. A major exception to this trend are farmers that we surveyed in the Kilimanjaro region of Tanzania, which used to be a major coffee-producing region but has come under pressure from climate change and urbanization. In this region, most farmers have switched to earning their main income from coffee to grains and food crops, including bananas, as well as off-farm income (see Table 4).

Overall, household income diversification is quite low in both countries, with the main income source accounting, on average, for 73 % of Tanzanian and 72 % of Ethiopian farmers' income. 25 % of Ethiopian and 13 % of Tanzanian survey respondents explicitly referred to diversification as an adaptation practice. One farmer framed their perspective on diversification by observing that "*it's true that [coffee is] a cash crop, but personally, my idea is this: farmers should be educated that their job is not just about coffee. Their job is to raise livestock, dig fish ponds, etc., so that their income becomes significant and it becomes easier for them to manage when they earn their income*" (Tanzania, FGD, Mbinga Maguu). Similarly, focus group participants in Ethiopia perceived diversification – for instance into mango, avocado, or papaya production – as crucial in order to have other sources of income besides coffee production should climate change become overwhelming (Ethiopia, FGDs, Ale Yubimari and Gomma Kadamansa).

Both our survey and interviews suggest outright abandonment of coffee cultivation remains rare. Coffee retains cultural significance in most of the surveyed communities, and households without coffee trees can see their social status greatly affected. When crop change does occur, it may be partially in response to climate change (given the trends, for instance, in Kilimanjaro region), but also appears to be mainly driven by wider land-use changes as well as market dynamics (such as the interplay of coffee prices, input prices, and labor availability). "*Currently, we have returned to avocados, and they have become our substitute for coffee,*" one focus group member explained. "*[C]offee requires a lot of fertilizer to yield good quality. However, coffee production is declining because even fertilizers are scarce. We used to rely on grazing in our Kilimanjaro mountain area known as a "half mile." After the government took over the "half mile" and gave it to KINAPA [Kilimanjaro National Parks], we no longer have that opportunity. The availability of manure has also been affected by poor cattle feeding practices*" (Tanzania, FGD, Rombo Ushiri). In Ethiopia, the stimulant khat is seen as a potential replacement for coffee: "*the environment for coffee and khat is almost the same. Because of the price our farmers are just replacing coffee with khat. They can harvest khat three or four times a year. They get better prices from khat. Even the management is very simple or not very difficult. When they are planting coffee, they should wait for at least three years and beyond. Moreover, they get a very small amount of money even sometimes [when] it is offseason. Because of this it is challenging for us to keep the farmers to plant the coffee. But we are influencing them with premium price*" (Ethiopia, interview). These two examples show that while crop changes happen, farmers so far shared few examples of such crop-switching being precipitated by

Table 4
Main income sources of surveyed farmers (own elaboration).

Main income source	Ethiopia	Tanzania Arabica North	Tanzania Arabica South	Tanzania Robusta
Coffee	89 %	8 %	85 %	76 %
Grains and foodcrops	6 %	62 %	12 %	14 %
Off-farm income	1 %	10 %	2 %	5 %
Horticulture	0.6 %	11 %	0.4 %	1.3 %
Perennials	0.1 %	4 %	0.1 %	0 %
Cattle and other animals	0.7 %	3 %	0.4 %	1 %
Timber and agroforestry products	0.1 %	0 %	0.1 %	0.3 %
Other	2 %	0.3 %	0.1 %	1 %

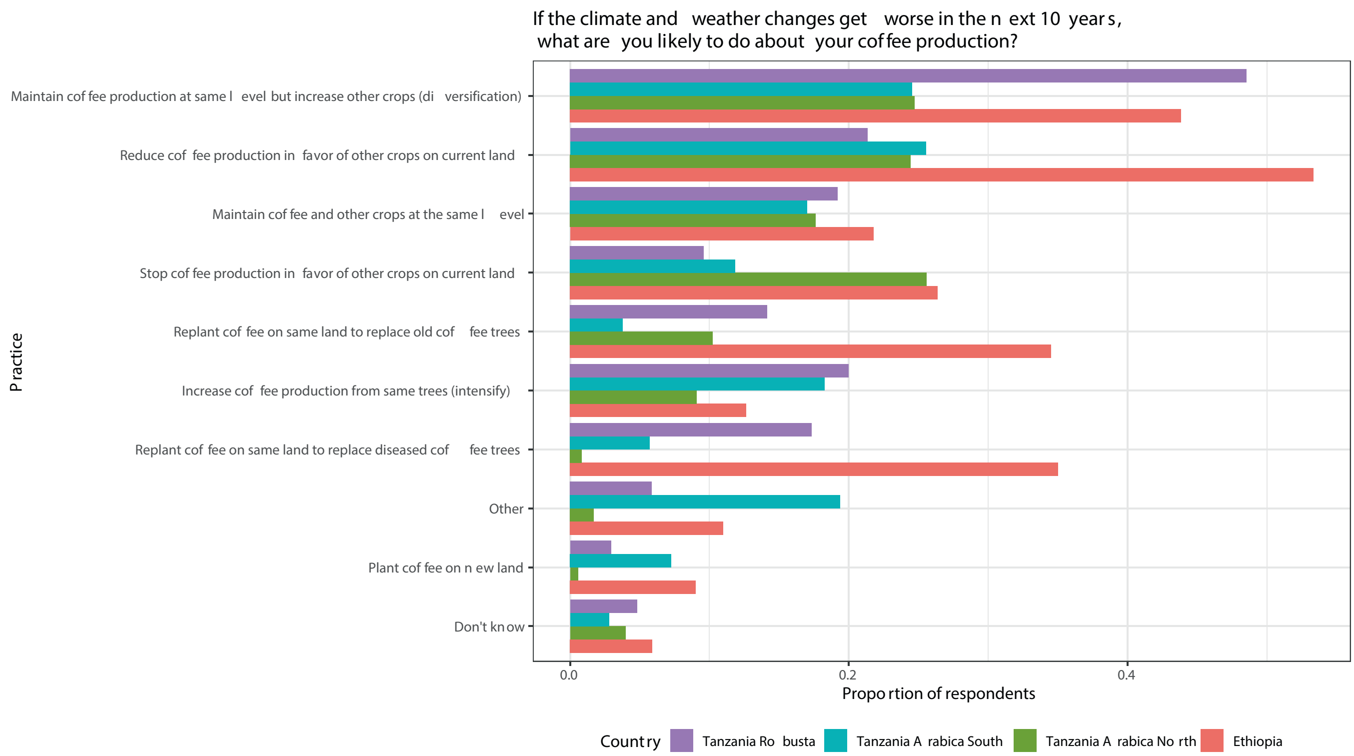


Fig. 9. Farmers' plans for coffee production in case of worsening climate change (own elaboration).

climate change. Instead, economic reasons predominate.

Finally, a small number of interviews in Ethiopia report coffee shifting to higher altitudes: "*Because of the climate, coffee is currently shifting to the highland areas. People living in desert areas are missing the coffee crops. People living in highland areas can get better yields from the coffee if they take care of the coffee properly.*" (Ethiopia, FGD, Gomma Getabore). Only one estate interviewee mentioned this possibility in Tanzania, noting that while they stopped growing coffee at lower altitudes, it is impossible to go much higher in the Kilimanjaro region because the area above 1400 m is a national park (Tanzania, interview).

When asked what farmers would do with their coffee plots if climate change worsened, the most common response was to diversify into other products, while either maintaining or reducing current coffee areas (See Fig. 9). Attempting maintenance and/or renovation was the second-most common response. Between 10 % (Tanzanian Robusta) and 26 % (Ethiopian Arabica) of survey respondents would also consider replacing their coffee with other crops. Tanzanian Arabica producers in the North, who have more experience with crop diversification and alternative main crops, are more inclined to stop coffee production in favor of other crops than other Tanzanian coffee growers. It is interesting that despite their high reliance on coffee for the main livelihood income, Ethiopian farmers are most likely to consider moving completely out of coffee (with more than a quarter considering this option). Intensification or expansion were among the least chosen responses – even though there is large academic and policy concern that coffee farmers would extend into other (potentially forested) areas in the future.

6.4. Implications for climate resilience at different scales

What can our case studies tell us about climate resilience? When considering what support farmers report receiving, there is a strong bias towards stepping up strategies seeking to improve productivity and quality. Notably, governments and cooperatives, rather than external buyers or NGOs, provide most training. Few trainings are explicitly focused on climate change adaptation or vulnerability reduction. Certain climate adaptation practices, such as improved pest and disease management or the adoption of resistant varieties, are pursued with the aim of maintaining sectoral productivity. Many trainings also support quality improvements that could increase farmers' product differentiation, though these do not necessarily go hand-in-hand with meaningful price premiums. Overall, the support provided to farmers seems to mainly serve national sector-level resilience, with its aim to heighten high-value commodity exports. While this can certainly be in line with the interests of farmers (especially those hoping to step up coffee production), such alignment is not guaranteed. To help interests align, it is necessary to ensure that quality-related price improvements reach the farm gate; that yield and quality improvement efforts do not inadvertently undermine climate resilience goals; and that farmers who are interested in exploring alternatives to coffee are also receiving institutional support.

Overall, we find that the vast majority of surveyed farmers are already adjusting to climate change, although only a few benefit from outside support. Farmers apply numerous adaptation strategies, including soil management and the use of shade trees, resistant varieties, irrigation, and income diversification. While farmers recognize these as climate adaptation actions, they respond to multiple stressors, including market and supply chain-related changes, sales prices, as well as input and labor availability and costs. Perhaps not surprisingly, farmers' priority appears to be livelihood resilience, with many farmers in our focus groups stressing the need for diversification. Downstream actors may be relieved that crop abandonment remains rare, as coffee continues to serve as an important source of income and status, and a fallback option when favorable weather prevails. There is also a strong cultural attachment to coffee that constrains perceived available alternatives. Nevertheless, crop changes do occur in some regions such as around Kilimanjaro in Tanzania, where alternative income sources are becoming important and peri-urbanization is expanding to coffee-growing areas. In these areas, farmers have switched to other crops such as avocados or carrots, though it is uncertain if these are good climate-resilient bets. Crop changes to date appear to be motivated more by the availability of marketing options and relative prices and labor intensity, and are not yet framed as explicitly climate change-related transformations. They are also rarely accompanied by projects and institutional support measures.

7. Discussion and conclusion

In this article, we presented a multi-scalar framework for climate resilience in the coffee sector that distinguishes resilience at the global scale, which prioritizes the continued production of the target commodity; resilience at the national sectoral scale, which emphasizes continued export earnings and rural development opportunities from the target commodity or possible alternatives; and resilience at the community and individual household scale, where achieving or maintaining sustainable livelihoods takes center stage. We responded to calls to take scale seriously when investigating resilience (Adger et al., 2005; Cutter, 2016; Jones et al., 2020; Weichselgartner & Kelman, 2015). While previous studies frequently equate coffee crop and livelihood resilience (Bracken et al., 2023), or take uncritical approaches to the potential of agri-food companies to find solutions that drive benefits at multiple scales (Bezares et al., 2021; Bianco, 2020), we highlight the need to critically assess whose particular interests shape how resilience (and related interventions) in commodity systems is framed. Our results draw attention to four issue areas, which also have implications for future research along those lines.

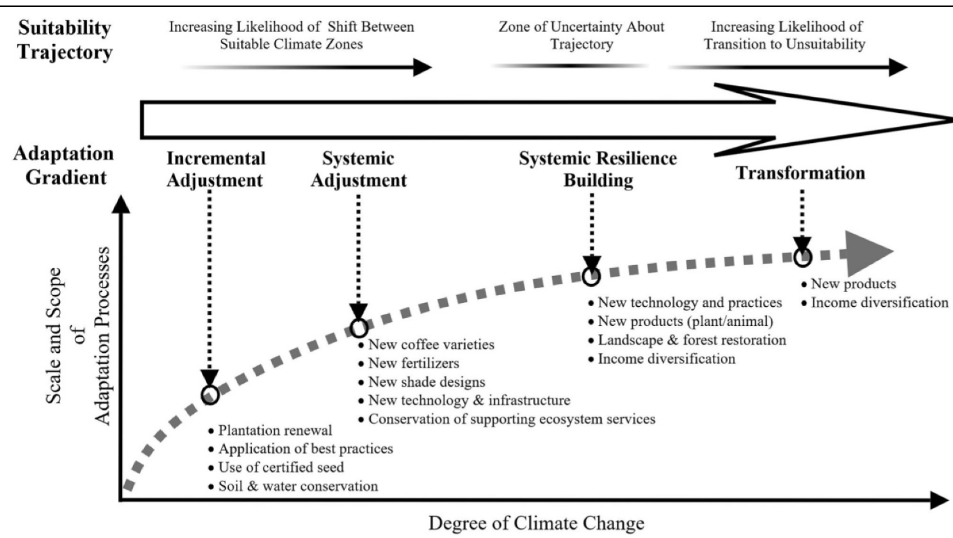
7.1. Power and the political economy of climate resilience in the coffee sector

Our results show that the challenge of climate resilience in the coffee sector is addressed in ways that reflects and reproduces pre-existing power asymmetries along the global value chain in the context of North-South inequities (cf. Grabs & Ponte, 2019). Most funding for climate-related projects in the global coffee sector comes from the Global North via coffee companies, development organizations, or multilateral institutions (see Appendix 2). On the ground, these projects shape priorities for climate action, with a focus on an impressive range of farm-level adaptation activities. Yet, such projects only rarely include steps toward product differentiation and even more infrequently tackle more fundamental challenges related to value distribution in the chain. Our case studies in Ethiopia and Tanzania also illustrate that such projects fail to reach a significant number of farmers. Generally, if farmers receive support, it comes from national governments and cooperatives. When such national- and local-level actors initiate producer support action, these actions are still aligned with the interests (when it comes to productivity improvements) and market signals (when it comes to quality characteristics) issued by coffee buyers in importing countries. In sum, given the dominant bargaining power of importing country actors in the coffee value chain, the main interpretation of climate resilience tends to be aligned with the global-scale framing of resilience which primarily aims to keep the supply of coffee (and, to a lesser extent, the global number of coffee farmers) stable.

7.2. The difficulty of isolating climate resilience measures in the context of multi-faceted recurring shocks in the coffee sector

While our top-down analysis of projects recognized a wide variety of climate-related measures, when assessing actions at the farm-level it becomes clear that farmers prioritize their own livelihood resilience, which is affected by numerous external trends and shocks (see also Bacon et al., 2017; Donatti et al., 2019; Quiroga et al., 2020). Decisions to increase farm diversification, for instance, may be a response to climate change, but may also be related to reducing income variability due to coffee price volatility. Decisions to switch away from coffee to other crops, similarly, may be related to improvements in net earnings due to changes in input costs, crop prices, or marketing opportunities. Many of the on-farm climate adaptation practices, furthermore, are also sustainable agriculture practices that have long been recommended for improved soil health, biodiversity and ecosystem conservation. While many farmers we interviewed perceived worrying signs of climate change, they were equally concerned about other aspects of coffee production – in particular farm-gate prices and their volatility. This points toward the need for a holistic assessment of resilience, particularly at the community and household level, that takes into account

Table 5
Level of alignment of household and global climate resilience priorities along the adaptation gradient. Adapted from Morales et al. (2022).



Capacity needed	Adaptive capacity (climate change)	Transformative capacity (climate change)
Level of alignment with global climate resilience priorities	High	Low
	Absorptive capacity (climate change + market shocks)	
	Medium	
	Transformative capacity (market organization, value distribution)	
	Low	

climate change among other factors.

7.3. Conflicts and alignment in (climate) resilience goals across scales

Are the goals of (climate) resilience at global, national, community, and household scales fundamentally in conflict? We suggest that, first, this depends on where farming communities are situated on the adaptation gradient (Morales et al., 2022), and hence what types of capacities they need to build (see Table 5). Producers who are situated in areas that only require incremental adjustments primarily need to build adaptive capacities (to step up coffee production). These can be well served by projects aiming to stabilize coffee production. In such areas, the challenge is how to scale up projects to reach more producers.

In contrast, producers in areas becoming less suitable for coffee production require transformative capacities. They have been comparatively underserved by climate-related interventions to date. Perhaps this is because only few coffee-producing regions have already become unsuitable for coffee cultivation thus far. Still, with projections of future suitability and climate impacts reaching ever-greater granularity, future interventions should also include actions to mitigate the livelihood impacts of stepping out of coffee cultivation. Such interventions would also be able to warn against potential maladaptation, that is, action taken to adapt to climate change that reinforces, rather than reduces, vulnerability (Barnett & O'Neill, 2010, p. 211; Dobler-Morales et al., 2021; Nava et al., 2025).

With most funding for climate adaptation projects in coffee areas coming from private sector actors, who have little incentive to facilitate transformative adaptation, we join calls (like those of Morales et al., 2022) for more coordinated and cohesive planning efforts from national and international public sector actors. Such efforts should involve the dissemination of not only agronomic, but also marketing knowledge related to alternative crops, the forging of new supply chain relationships, and the strengthening of local institutions and collective action arenas (such as cooperatives) to help producers to make such difficult strategic decisions themselves. All projects should also integrate elements that also strengthen producers' absorptive capacities with regard to both climate and market-related shocks that could affect producing households. Such absorptive capacities were generally underrepresented in the projects we surveyed.

Finally, whether coffee value chains will move towards recommodification (flexibilization of sourcing, reinforcement of market relationships) or decommodification (deepening long-term sourcing relationships; recognizing and financially compensating differences between origins; moving away from fungibility of products) will ultimately depend on global coffee firms' strategic choices. Should the incentives for sourcing flexibility increase alongside climatic shocks, downstream actors will likely face further pressures to pursue recommodification. Such cut-and-run strategies that aim to spread risk across many origins untether importing country firms from the local climate impacts that producers face (Morales et al., 2022).

While a recommodification strategy thus seems unlikely to support long-run producer livelihoods, the few *decommodification* alternatives offered by global climate and coffee projects (via certification and quality improvements) also may be inadequate. Given the extensive evidence that product differentiation is not always linked to price premiums and improved economic outcomes (Estrella et al., 2022; Grabs, 2020; Meemken, 2020; Minten et al., 2018), expanding existing certification into climate resilience and climate-smart practices could merely offer more of the same. However, climate resilience could also be tied to innovative business models that prioritize profit sharing and novel forms of business co-ownership (Bennett & Grabs, 2025; Doherty, 2018). Deepening supplier relationships and a movement toward more solidarity in the face of climate change could thus induce transformative capacities also on a more systemic level and ultimately create long-run supply maintenance in more equitable ways.

7.4. Empowerment of producer choice along adaptation gradients

Finally, our work raises the question of how to approach forward-looking climate resilience in smallholder farming contexts – in locally appropriate ways that empower producer households to make their own (informed) choices about their livelihood portfolios. Our data show that very few projects actually breach the topics of stepping out of coffee cultivation; simultaneously, most Ethiopian and Tanzanian coffee producers in our study maintained a strong attachment to coffee production and expressed an interest to stick to coffee. Still, climate change in the long run may bring some producers to the brink of adaptation limits (Dow et al., 2013). In such situations, producers may need to consider increasingly radical changes, including off-farm employment (Jones et al., 2020), and transformative capacities will become more important than ever.

Like 'hanging in' and 'stepping up' strategies, however, 'stepping out' strategies come with their own challenges. Carr (2019, pp. 71–72) argues that agrarian livelihoods are a socio-ecological project that privileges the stability of the existing social order as well as material safety. Interventions that undermine current socio-ecological projects to create space for transformative action might thus inadvertently increase risk and vulnerability in the short run (Carr, 2008, 2019). Kuhl (2018) further alerts us that while attention to climate resilience may support a focus on alternative livelihood options in development interventions, opening new and lucrative markets for crop diversification or substitution may require producers to invest and specialize in a novel-to-them crop, which increases their risk. Moving further into diversified subsistence farming or only targeting local markets, in turn, is a lower-risk, but low-return option (Tanner et al., 2015). Silver bullets thus seem rare, and the risk of (spontaneous or project-based) maladaptation should be more systematically investigated (Nava et al., 2025).

The evidence presented here also speaks to the growing need for context-specific, farmer-centric approaches to building climate resilience. Given the diverse socio-ecological and economic contexts across coffee-growing regions, as well as the differentiated exposure and interests across scales in the coffee sector, a one-size-fits-all approach is unlikely to be effective. Farming households have different risk and adaptation pathways – some might benefit most from further developing their adaptive capacities, while others might benefit most from absorptive or transformative capacities. Integrating adaptive, absorptive, and transformative capacities within a localized and context-sensitive framework that empowers producers to mix and match 'hanging in', 'stepping up', and 'stepping out' strategies might better address the specific needs of different farming communities. Additionally, participatory approaches, where farmers actively co-design resilience interventions, could lead to more sustainable and equitable outcomes (cf. Shapiro-Garza et al., 2020). Building such participatory approaches at scale into climate-focused interventions would take one step toward ensuring that global development actually reduces vulnerability and provides viable adaptation options (cf. Schipper et al., 2020).

CRediT authorship contribution statement

Janina Grabs: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Data curation, Conceptualization. **Gezahegn Berecha Yadessa:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Funding acquisition. **Marc Castellón Durán:** Writing – review & editing, Project administration, Investigation, Data curation. **Adugna Eneyew Bekele:** Writing – review & editing, Writing – original draft, Methodology, Investigation. **Caleb Gallemore:** Writing – review & editing, Visualization, Methodology, Investigation, Data curation, Conceptualization. **Weyessa Garedew Terefe:** Writing – review & editing, Writing – original draft, Methodology, Investigation. **Shitaye Gure Lemessa:** Writing – review & editing, Project administration, Investigation. **Marta Hailemariam Mamo:** Writing – review & editing, Investigation. **Ng'winamila Donald Kasongi:** Writing – review & editing, Writing – original draft, Methodology, Investigation. **Melkamu Mamuye Kebede:** Writing – review & editing, Writing – original draft, Methodology, Investigation. **Daniel Andwale Mwalutolo:** Writing – review & editing, Writing – original draft, Methodology, Investigation. **Ina Niehues:** Writing – review & editing, Project administration, Investigation. **Christine Noe:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Funding acquisition. **Stefano Ponte:** Writing – review & editing, Methodology, Investigation, Conceptualization. **Guta Regasa Megerssa:** Writing – review & editing, Writing – original draft, Methodology, Investigation. **Pilly Silvano:** Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation. **Nestory Yamungu:** Writing – review & editing, Writing – original draft, Methodology, Investigation. **Kristjan Jespersen:** Writing – review & editing, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix 1. Search and coding strategy for climate intervention database

Inclusion and exclusion criteria

We only listed and analyzed projects or interventions that fulfilled two inclusion criteria:

First, in their description/aims the projects needed to mention explicitly one of three sets of terms: climate (change, adaptation, mitigation, resilience); farm/farmer resilience; or carbon (cycle, sequestration, credits). This inclusion criteria was set to differentiate projects that self-identify as having a climate change focus from other types of interventions that might be pursuing activities tangential to climate adaptation and resilience, but which do not themselves frame it as climate-related. One part of our analysis provides an inductively coded overview of all activities that projects pursue in order to construct an overview of what is currently seen as appropriate or desirable climate mitigation, adaptation, or resilience action. Had we not focused on self-identification, but included projects on the basis of their activities, we would have had to a priori decide what we consider climate-related activities, which would have biased that later overview. However, this inclusion criteria means that our database may not capture select projects that pursued climate-related activities if the project descriptions never mentioned climate or any of the other keywords above.

Second, to be included the initiative had to be focused on coffee farmers or at the very least the upstream supply chain (including, for example, efforts aimed at mills). This meant, for instance, that interventions that solely focused on long-term sectoral policy planning, without any pilot projects or farmer outreach, were not included in the analysis.

In contrast, we did not exclude interventions on the basis of the year they were executed, the country where they were implemented, or the actors that planned, implemented, or financed a project, and thus provide a comprehensive overview of climate mitigation and adaptation actions across time, space, and actor fields.

In addition to specific projects, we also reviewed one of the most common forms of farmer support – certification and verification schemes – for their climate-related content. To a certain extent, this step makes up for the drawback of our inclusion criteria for the interventions mentioned above as it enables us to assess to what extent non-climate programming might still include climate modules. We will assess the certification in a separate step, rather than mixing them in as part of the interventions.

Search protocol

We took a two-pronged strategy in our search for interventions, in which we first conducted a directed website search of specific organizations, and then moved to a structured keyword search to fill in the gaps left by our directed website search.

For the directed website search, we focused on organizations in three institutional arenas related to the topic at hand: Organizations in the coffee space (including private firms as well as non-governmental organizations (NGOs) focused on coffee sector sustainability and development); organizations in the climate change realm (mainly focusing on international organizations, NGOs, and business coalitions focusing on climate change-related action); and organizations focusing on (sustainable) development, particularly in coffee-producing countries. We constructed a list of organizations for each institutional arena based on secondary literature (Grabs, 2017; Grabs & Carodenuto, 2021; Grabs & Ponte, 2019) combined with the expertise of the team members and reviewed each organization's website in order to find interventions that fall within the inclusion criteria, which were subsequently included in our database and coded. This search strategy yielded 84 interventions that were included in our database.

In a second step, we conducted a structured keyword search on Google in English, German, and Spanish to supplement our directed website search. We screened the first 10 pages of search results for relevant projects we did not yet include in our database. This yielded an additional 55 results in English, 7 results in German and 14 results in Spanish, for a total of 160 interventions.

Coding and analysis

We first coded interventions by their key characteristics such as the year they started and ended, the key organizations involved in implementing and financing them, their geographical target (at a national and, if specified, subnational level), the numbers of farmers targeted, and the total and per-farmer budget spent. We furthermore summarized information about the description of the intervention, its target outcomes and theories of change, as well as (where available) first evidence of outcomes.

Once all this information was assembled, we engaged in an inductive coding exercise to identify and structure the activities pursued by climate-related interventions in the coffee sector as follows. We created four categories of activities – 'Climate change mitigation activities', 'climate change adaptation activities', 'Value chain/upgrading activities' and 'Other activities' that may be part of the projects – and generated a first range of activity subcategories within each category on the basis of a first scan of all interventions. Thereafter, we reviewed each project description, theory of change and evidence of outcome and coded the types of activities that were present in each intervention by adding detailed information in the relevant subcategory field. If an activity was not yet represented among the subcategories, we added a new subcategory and filled in the relevant information. Once we had coded all activities and reached exhaustiveness in terms of subcategories, we first compared and merged some subcategories, adjusting their name to reflect a similar level of aggregation of activities. We then reviewed all interventions again and complemented the coding to ensure that all final subcategories were accounted for.

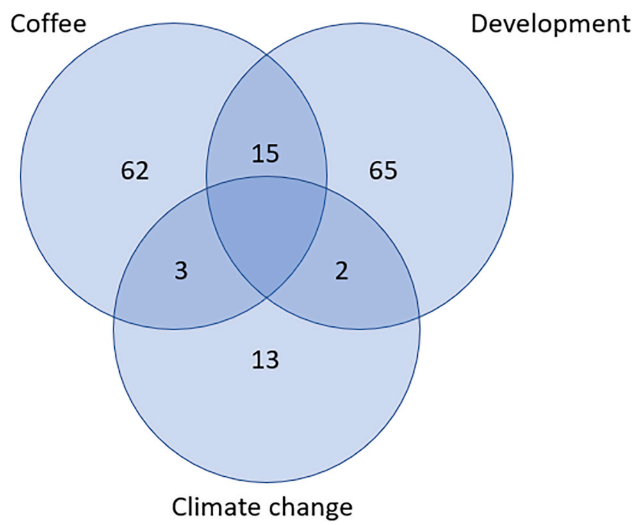
1. Identification of key governance arenas and institutions to review

- Coffee governance arena
  - o International Coffee Organization
  - o Sustainable Coffee Challenge
  - o Global Coffee Platform
  - o International Coffee Partners
  - o Specialty Coffee Association
  - o Promecafe
  - o IACO (Inter-African Coffee Association?)
  - o ASEAN Coffee Federation
  - o European Coffee Federation
  - o Initiative for climate and coffee
  - o Coalition for Coffee Communities
  - o Sustainable Agriculture, Food and Environment (SAFE) Platform
  - o Sustainable Agriculture Initiative Platform
  - o Coffee company action and foundations
    - ■ Hanns R. Neumann Stiftung (HRNS)
    - ■ JDE Foundation
    - ■ Other major roasters and trading companies
- Development (governance) arena
  - o UNDP
  - o World Bank
  - o Inter-American Development Bank
  - o Other development banks
  - o USAID
  - o GIZ
  - o UK DFID
  - o Japanese development agency
  - o IDH
  - o Coalition Sustainable Livelihoods (Conservation International + IDH)
  - o FarmAfrica
- Climate change/deforestation/biodiversity governance arena
  - o UNFCCC
    - ■ Nationally Determined Contributions (NDCs)
    - ■ Nationally Appropriate Mitigation Actions (NAMAs)
    - ■ Lima-Paris Action Agenda
    - ■ Marrakech Partnership for Global Climate Action
    - ■ Global Climate Action Portal (GCAP, also known as NAZCA portal)
    - ■ Climate Action Methodologies, Data and Analysis (CAMDA)
    - ■ Momentum for Change initiative
    - ■ Action for Climate Empowerment

- o Race to Zero campaign
- o Race to Resilience
- o Global Climate Action Summit 2018
- o One Planet Summit 2017, 2018, 2019
- o Global Environment Facility [especially Food, Land Use and Restoration GEF-7 FOLUR]
- o LandScale (Rainforest Alliance)
- o SourceUp (IDH)
- o CDP
- o We Mean Business
- o Natural Climate Solutions Alliance
- o Nature4Climate
- o Tropical Forest Alliance
- o Business for Nature
- o OP2B (One Planet Business for Biodiversity)
- o World Business Council for Sustainable Development
- o We Are Still In/America Is All In coalitions
- o Business Declares

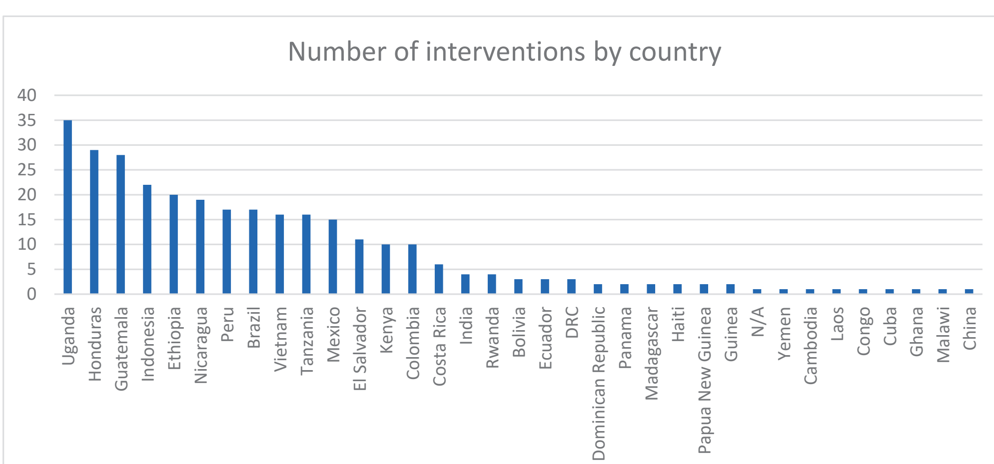
Appendix 2. Additional results of climate intervention database

On the basis of the main project proponents/implementers, we grouped them into three main institutional governance arenas they originated in: Coffee, development, and climate change. Interventions originated mainly in the coffee and development arenas, with climate change-related institutional actors and funders (e.g. GEF) not yet stepping up to focus on coffee production as focal area.



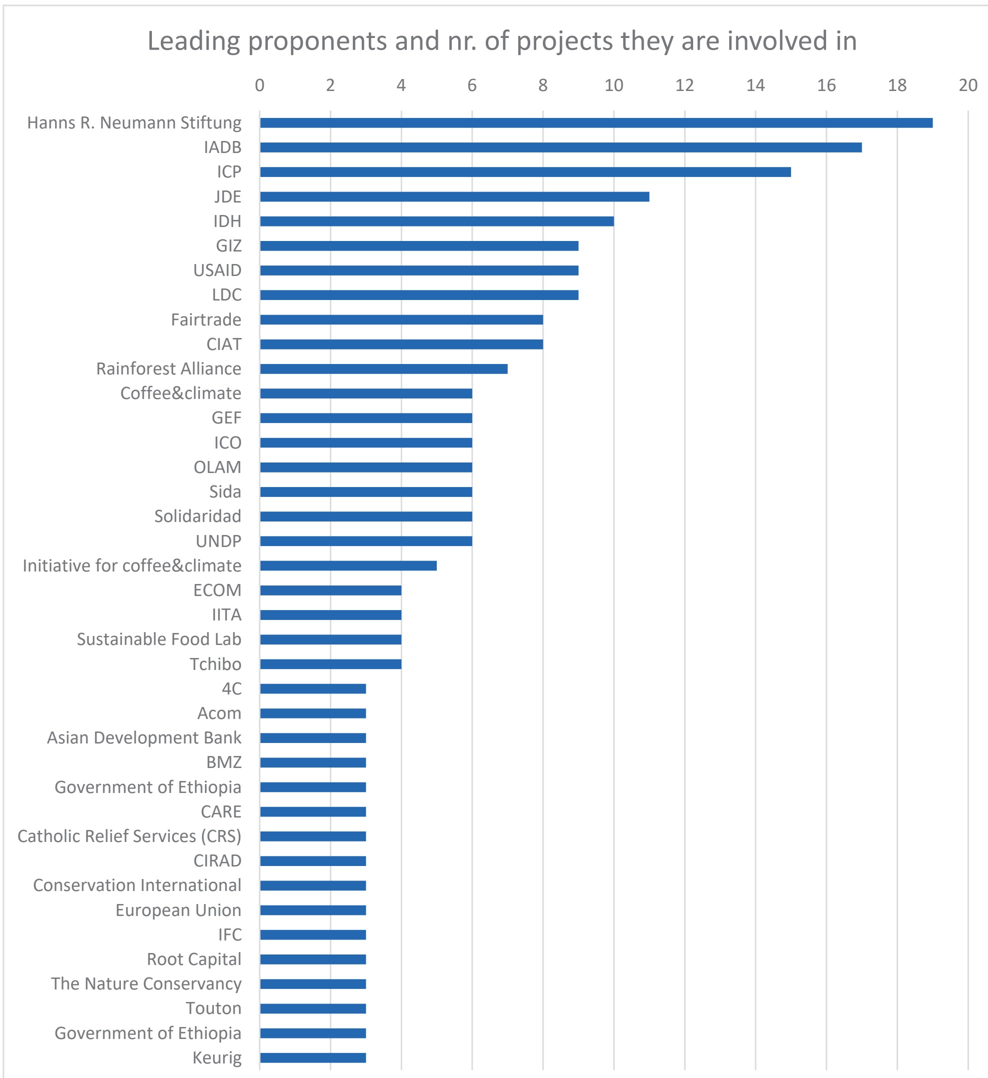
Overview of institutional governance arenas in which climate interventions originated (own elaboration).

The projects have a broad geographical spread, though a few countries stand out: Uganda, Honduras, Guatemala, Indonesia and Ethiopia each have over 20 interventions each.



Number of climate interventions by country (own elaboration).

We find that the space is very clearly dominated by a few institutions. Leading in the field is the Hanns R. Neumann Stiftung, the foundation of the coffee trader NKG, which co-created the coffee&climate initiative together with the International Coffee Partners (a small group of mainly German coffee roasters) in the early 2000s. We further identify the Inter-American Development Bank, the GIZ and USAID as major funders and/or implementers of climate-focused interventions in the coffee space. JDE, the second-largest roaster after Nestlé, is also involved in a large number of projects that are climate-oriented. IDH and Fairtrade are dominant civil society organizations. We also note a number of other traders involved in this space, such as Louis Dreyfus, Ecom and Olam.



Number of climate interventions by proponent organization (own elaboration).

Appendix 3. Overview of interview analysis

Country comparison: % and n° of interviews mentioning
Total interviews: 144 (Ethiopia) and 240 (Tanzania)

Family	Code	Ethiopia	Tanzania
Climate change adaptation activities	Agroforestry and shade tree planting	78 % (113)	32 % (77)
	Change to alternative crop (abandon coffee)	0 % (0)	12 % (28)
	Conversion of new (uphill) areas to coffee	15 % (21)	0 % (1)
	Diversification in coffee (Robusta)	0 % (0)	0 % (0)
	Diversification in non-ag activities	15 % (22)	5 % (12)

(continued on next page)

(*continued*)

Family	Code	Ethiopia	Tanzania
	Diversification in non-coffee agriculture (intercropping)	29 % (42)	43 % (103)
	Downstream (roasting, manufacturing, retail) adaptations	1 % (2)	0 % (0)
	Harvest and postharvest adaptation	1 % (1)	0 % (0)
	Integrated pest management	1 % (1)	0 % (0)
	Irrigation	10 % (14)	40 % (95)
	Midstream (storage, processing, shipping) adaptation	4 % (6)	0 % (0)
	Organic production	3 % (4)	7 % (17)
	Resistant and productive varieties	51 % (73)	37 % (89)
	Soil management and restoration	72 % (104)	34 % (81)
	Water conservation and management	65 % (94)	33 % (80)
Climate change experiences (farm-level)	Changing rain and temperature patterns	76 % (110)	71 % (171)
	Coffee disease and plague	33 % (47)	57 % (137)
	Hail, snow and frost	29 % (42)	5 % (11)
	Knowledge sharing	30 % (43)	12 % (28)
	Landslides	13 % (19)	0 % (1)
	Soil degradation and desertification	17 % (25)	11 % (27)
Climate change mitigation activities	Afforestation	22 % (32)	6 % (14)
	Carbon footprint calculation	0 % (0)	0 % (0)
	Harvest and post-harvest GHG mitigation	0 % (0)	0 % (0)
	Intercropping and agroforestry for mitigation	0 % (0)	0 % (0)
	Reduction in fossil fuel use	1 % (1)	0 % (0)
	Reduction of chemical inputs	0 % (0)	0 % (0)
	Reduction of coffee-related deforestation	15 % (21)	0 % (0)
	Soil carbon sequestration	1 % (1)	0 % (1)

Data availability

Data will be made available on request.

References

Adger, W. N., Arnell, N. W., & Tompkins, E. L. (2005). Successful adaptation to climate change across scales. *Global Environmental Change, 15*(2), 77–86. https://doi.org/10.1016/j.gloenvcha.2004.12.005

Andrade, H. J., & Zapata, P. C. (2019). Mitigation of climate change of coffee production systems in Cundinamarca, Colombia. *Floresta e Ambiente, 26*. https://doi.org/10.1590/2179-8087.012618

Bacon, C. M., Sundstrom, W. A., Stewart, I. T., & Beezer, D. (2017). Vulnerability to cumulative hazards: coping with the coffee leaf rust outbreak, drought, and food insecurity in Nicaragua. *World Development, 93*, 136–152. https://doi.org/10.1016/j.worlddev.2016.12.025

Bager, S. L., & Lambin, E. F. (2020). Sustainability strategies by companies in the global coffee sector. *Business Strategy and the Environment, 29*(8), 3555–3570. https://doi.org/10.1002/bse.2596

Bahadur, A. V., Ibrahim, M., & Tanner, T. (2013). Characterising resilience: Unpacking the concept for tackling climate change and development. *Climate and Development, 5*(1), 55–65. https://doi.org/10.1080/17565529.2012.762334

Barjolle, D., Quiñones-Ruiz, X. F., Bagal, M., & Comoé, H. (2017). The Role of the State for Geographical Indications of Coffee: Case Studies from Colombia and Kenya. *World Development, 98*, 105–119. https://doi.org/10.1016/j.worlddev.2016.12.006

Barnett, J., & O'Neill, S. (2010). Maladaptation. *Global Environmental Change, 20*(2), 211–213. https://doi.org/10.1016/j.gloenvcha.2009.11.004

Behuria, P. (2020). The domestic political economy of upgrading in global value chains: How politics shapes pathways for upgrading in Rwanda's coffee sector*. *Review of International Political Economy, 27*(2), 348–376. https://doi.org/10.1080/09692290.2019.1625803

Bekele, A. E., Berecha, G., Gallemore, C., Grabs, J., Jespersen, K., Kasongi, N., Mamuye, M., Mathe, A., Regasa Megerssa, G., Mwalutolo, D., Noe, C., Ponte, S., Silvano, P., Tereffe, W., Terry, S., Yamungu, N. (2023). *Site selection strategy for the PACSMAC project*. Working paper 2.1, PACSMAC Project, Copenhagen Business School. https://pacsmac.com/resources/.

Béné, C., Newsham, A., Davies, M., Ulrichs, M., & Godfrey-Wood, R. (2014). Review article: Resilience, poverty and development. *Journal of International Development, 26*(5), 598–623. https://doi.org/10.1002/jid.2992

Béné, C., Wood, R. G., Newsham, A., & Davies, M. (2012). Resilience: New utopia or new tyranny? Reflection about the potentials and limits of the concept of resilience in relation to vulnerability reduction programmes. *IDS Working Papers, 2012*(405), 1–61. https://doi.org/10.1111/j.2040-0209.2012.00405.x

Bennett, E. A., & Grabs, J. (2025). How can sustainable business models distribute value more equitably in global value chains? Introducing "value chain profit sharing" as an emerging alternative to fair trade, direct trade, or solidarity trade. *Business Ethics, the Environment & Responsibility, 34*(2), 581–601. https://doi.org/10.1111/beer.12666

Benti Chalchissa, F., Diga, G. M., & Tolossa, A. R. (2022). Modeling the responses of Coffee (Coffea arabica L.) distribution to current and future climate change in Jimma Zone, Ethiopia. Article 1 *SAINS TANAH - Journal of Soil Science and Agroclimatology, 19*(1) https://doi.org/10.20961/stjssa.v19i1.54885.

Benti, F., Diga, G. M., Feyisa, G. L., & Tolesa, A. R. (2022). Modeling coffee (Coffea arabica L.) climate suitability under current and future scenario in Jimma zone, Ethiopia. *Environmental Monitoring and Assessment, 194*(4), 271. https://doi.org/10.1007/s10661-022-09895-9

Bezares, N., Fretes, G., & Martinez, E. M. (2021). The role of food and beverage companies in transforming food systems: Building resilience at multiple scales. *Current Developments in Nutrition, 5*(9), Article nzab110. https://doi.org/10.1093/cdn/nzab110

Bianco, G. B. (2020). Climate change adaptation, coffee, and corporate social responsibility: Challenges and opportunities. *International Journal of Corporate Social Responsibility, 5*(1), 3. https://doi.org/10.1186/s40991-020-00048-0

Birkenberg, A., & Birner, R. (2018). The world's first carbon neutral coffee: Lessons on certification and innovation from a pioneer case in Costa Rica. *Journal of Cleaner Production, 189*, 485–501. https://doi.org/10.1016/j.jclepro.2018.03.226

Birkenberg, A., Narjes, M. E., Weinmann, B., & Birner, R. (2021). The potential of carbon neutral labeling to engage coffee consumers in climate change mitigation. *Journal of Cleaner Production, 278*, Article 123621. https://doi.org/10.1016/j.jclepro.2020.123621

Bracken, P., Burgess, P. J., & Girkin, N. T. (2023). Opportunities for enhancing the climate resilience of coffee production through improved crop, soil and water management. *Agroecology and Sustainable Food Systems, 47*(8), 1125–1157. https://doi.org/10.1080/21683565.2023.2225438

Bradley, O. J., & Botchway, G. O. (2018). Communicating corporate social responsibility (CSR) in the coffee industry: An examination of indicators disclosed. *Sustainability Accounting, Management and Policy Journal, 9*(2), 139–164. https://doi.org/10.1108/SAMPJ-02-2017-0015

Bunn, C., Läderach, P., Rivera, O. O., & Kirschke, D. (2015). A bitter cup: Climate change profile of global production of Arabica and Robusta coffee. *Climatic Change, 129*(1–2), 89–101. https://doi.org/10.1007/s10584-014-1306-x

Burnham, M., & Ma, Z. (2016). Linking smallholder farmer climate change adaptation decisions to development. *Climate and Development, 8*(4), 289–311. https://doi.org/10.1080/17565529.2015.1067180

Call, M., Gray, C., & Jagger, P. (2019). Smallholder responses to climate anomalies in rural Uganda. *World Development, 115*, 132–144. https://doi.org/10.1016/j.worlddev.2018.11.009

de Camargo, M. B. P. (2010). The impact of climatic variability and climate change on arabic coffee crop in Brazil. *Bragantia, 69*, 239–247. https://doi.org/10.1590/S0006-87052010000100030

Carpenter, S., Walker, B., Anderies, J. M., & Abel, N. (2001). From metaphor to measurement: Resilience of what to what? *Ecosystems, 4*(8), 765–781. https://doi.org/10.1007/s10021-001-0045-9

Carr, E. R. (2008). Between structure and agency: Livelihoods and adaptation in Ghana's Central Region. *Global Environmental Change, 18*(4), 689–699. https://doi.org/10.1016/j.gloenvcha.2008.06.004

Carr, E. R. (2019). Properties and projects: Reconciling resilience and transformation for adaptation and development. *World Development, 122*, 70–84. https://doi.org/10.1016/j.worlddev.2019.05.011

Cesar de Oliveira, S. E. M., Nakagawa, L., Lopes, G. R., Visentin, J. C., Couto, M., Silva, D. E., d'Albertas, F., Pavani, B. F., Loyola, R., & West, C. (2024). The European Union and United Kingdom's deforestation-free supply chains regulations: Implications for Brazil. *Ecological Economics, 217*, Article 108053. https://doi.org/10.1016/j.ecolecon.2023.108053

Craparo, A. C. W., Van Asten, P. J. A., Läderach, P., Jassogne, L. T. P., & Grab, S. W. (2015). Coffea arabica yields decline in Tanzania due to climate change: Global implications. *Agricultural and Forest Meteorology, 207*, 1–10. https://doi.org/10.1016/j.agrformet.2015.03.005

Cutter, S. L. (2016). Resilience to what? Resilience for whom? *The Geographical Journal, 182*(2), 110–113. https://doi.org/10.1111/geoj.12174

DaMatta, F. M., Avila, R. T., Cardoso, A. A., Martins, S. C. V., & Ramalho, J. C. (2018). Physiological and agronomic performance of the coffee crop in the context of climate change and global warming: A review. *Journal of Agricultural and Food Chemistry, 66* (21), 5264–5274. https://doi.org/10.1021/acs.jafc.7b04537

Davidson, D. (2016). Gaps in agricultural climate adaptation research. *Nature Climate Change, 6*(5), 433–435. https://doi.org/10.1038/nclimate3007

Daviron, B., & Ponte, S. (2005). *The Coffee Paradox: Global Markets, Commodity Trade and the Elusive Promise of Development*. Zed Books.

Dentoni, D., Pinkse, J., & Lubberink, R. (2021). Linking sustainable business models to socio-ecological resilience through cross-sector partnerships: a complex adaptive systems view. *Business & Society, 60*(5), 1216–1252. https://doi.org/10.1177/0007650320935015

Dietz, T., Estrella Chong, A., Grabs, J., & Kilian, B. (2020). How effective is multiple certification in improving the economic conditions of smallholder farmers? Evidence from an impact evaluation in colombia's coffee belt. *The Journal of Development Studies, 56*(6), 1141–1160. https://doi.org/10.1080/00220388.2019.1632433

Dobler-Morales, C., Álvarez Larrain, A., Orozco-Ramírez, Q., & Bocco, G. (2021). Grounding maladaptation: Agricultural change as a source of climatic risks in small farms of the Mixteca Alta, Mexico. *Geoforum, 127*, 234–245. https://doi.org/10.1016/j.geoforum.2021.11.001

Doherty, B. (2018). Gender equality and women's empowerment through fair trade social enterprise: Case of divine chocolate and Kuapa Kokoo. In *Entrepreneurship and the sustainable development goals* (Vol. 8, p. 0). Emerald Publishing Limited. https://doi.org/10.1108/S2040-724620180000008014.

Donatti, C. I., Harvey, C. A., Martinez-Rodriguez, M. R., Vignola, R., & Rodriguez, C. M. (2019). Vulnerability of smallholder farmers to climate change in Central America and Mexico: Current knowledge and research gaps. *Climate and Development, 11*(3), 264–286. https://doi.org/10.1080/17565529.2018.1442796

Dorward, A., Anderson, S., Bernal, Y. N., Vera, E. S., Rushton, J., Pattison, J., & Paz, R. (2009). Hanging in, stepping up and stepping out: Livelihood aspirations and strategies of the poor. *Development in Practice, 19*(2), 240–247. https://doi.org/10.1080/09614520802689535

Douxchamps, S., Debevec, L., Giordano, M., & Barron, J. (2017). Monitoring and evaluation of climate resilience for agricultural development – a review of currently available tools. *World Development Perspectives, 5*, 10–23. https://doi.org/10.1016/j.wdp.2017.02.001

Dow, K., Berkhout, F., Preston, B. L., Klein, R. J. T., Midgley, G., & Shaw, M. R. (2013). Limits to adaptation. *Nature Climate Change, 3*(4), 305–307. https://doi.org/10.1038/nclimate1847

Estrella, A., Navichoc, D., Kilian, B., & Dietz, T. (2022). Impact pathways of voluntary sustainability standards on smallholder coffee producers in Honduras: Price premiums, farm productivity, production costs, access to credit. *World Development Perspectives, 27*, Article 100435. https://doi.org/10.1016/j.wdp.2022.100435

Fischersworring, B., Schmidt, G., Linne, K., Pringle, P., & Baker, P. S. (2015). *Climate change adaptation in coffee production. A step-by-step guide to supporting coffee farmers in adapting to climate change*. coffee & climate.

Folke, C. (2006). Resilience: The emergence of a perspective for social–ecological systems analyses. *Global Environmental Change, 16*(3), 253–267. https://doi.org/10.1016/j.gloenvcha.2006.04.002

Gallemore, C., Berecha, G., Eneyew, A., Grabs, J., Jespersen, K., Kasongi, N., 'gwinamila, Mamuye, M., Maskell, G., Mathe, A., Mwalutolo, D., Niehues, I., Terry, S., & Yamungu, N. (2025). Avoiding access inequity due to classification errors in zero-deforestation value chains: Coffee and the European Union deforestation regulation. *Land Use Policy, 157*, Article 107609. https://doi.org/10.1016/j.landusepol.2025.107609

Gezie, M. (2019). Farmer's response to climate change and variability in Ethiopia: A review. *Cogent Food & Agriculture, 5*(1), Article 1613770. https://doi.org/10.1080/23311932.2019.1613770

Giuliani, E., Ciravegna, L., Vezzulli, A., & Kilian, B. (2017). Decoupling standards from practice: The impact of in-house certifications on coffee farms' environmental and social conduct. *World Development, 96*, 294–314.

Gomes, L. C., Bianchi, F. J. J. A., Cardoso, I. M., Fernandes, R. B. A., Filho, E. I. F., & Schulte, R. P. O. (2020). Agroforestry systems can mitigate the impacts of climate change on coffee production: A spatially explicit assessment in Brazil. *Agriculture, Ecosystems & Environment, 294*, Article 106858. https://doi.org/10.1016/j.agee.2020.106858

Grabs, J. (2017). The rise of buyer-driven sustainability governance: Emerging trends in the global coffee sector (SSRN Scholarly Paper No. ID 3015166). *Social Science Research Network*. https://papers.ssrn.com/abstract=3015166.

Grabs, J. (2020). *Selling Sustainability short? The private governance of labor and the environment in the coffee sector*. Cambridge University Press.

Grabs, J. (2021). Signaling Southern sustainability: When do actors use private or public regulatory authority to market tropical commodities? *Journal of Environmental Management, 285*, Article 112053. https://doi.org/10.1016/j.jenvman.2021.112053

Grabs, J. (2022). *An overview and analysis of global climate-related interventions in the coffee sector*. Working paper 1.1, PACSMAC Project, Copenhagen Business School. https://pacsmac.com/resources/.

Grabs, J., & Carodenuto, S. L. (2021). Traders as sustainability governance actors in global food supply chains: A research agenda. *Business Strategy and the Environment, 30*(2), 1314–1332. https://doi.org/10.1002/bse.2686

Grabs, J., & Ponte, S. (2019). The evolution of power in the global coffee value chain and production network. *Journal of Economic Geography, 19*(4), 803–828. https://doi.org/10.1093/jeg/lbz008

Guido, Z., Knudson, C., Finan, T., Madajewicz, M., & Rhiney, K. (2020). Shocks and cherries: The production of vulnerability among smallholder coffee farmers in Jamaica. *World Development, 132*, Article 104979. https://doi.org/10.1016/j.worlddev.2020.104979

Guido, Z., Knudson, C., & Rhiney, K. (2020). Will COVID-19 be one shock too many for smallholder coffee livelihoods? *World Development, 136*, Article 105172. https://doi.org/10.1016/j.worlddev.2020.105172

Harvey, C. A., Pritts, A. A., Zwetsloot, M. J., Jansen, K., Pulleman, M. M., Armbrecht, I., Avelino, J., Barrera, J. F., Bunn, C., García, J. H., Isaza, C., Munoz-Ucros, J., Pérez-Alemán, C. J., Rahn, E., Robiglio, V., Somarriba, E., & Valencia, V. (2021). Transformation of coffee-growing landscapes across Latin America. A review. *Agronomy for Sustainable Development, 41*(5), 62. https://doi.org/10.1007/s13593-021-00712-0

Hellin, J., & Fisher, E. (2018). Building pathways out of poverty through climate smart agriculture and effective targeting. *Development in Practice, 28*(7), 974–979. https://doi.org/10.1080/09614524.2018.1492516

Hirons, M., Mehrabi, Z., Gonfa, T. A., Morel, A., Gole, T. W., McDermott, C., Boyd, E., Robinson, E., Sheleme, D., Malhi, Y., Mason, J., & Norris, K. (2018). Pursuing climate resilient coffee in Ethiopia – a critical review. *Geoforum, 91*, 108–116. https://doi.org/10.1016/j.geoforum.2018.02.032

Hochachka, G. (2023). Climate change and the transformative potential of value chains. *Ecological Economics, 206*, Article 107747. https://doi.org/10.1016/j.ecolecon.2023.107747

ICO. (2023). Total production by all exporting countries. International Coffee Organization. http://www.ico.org/historical/1990%20onwards/Excel/1a%20-%20Total%20production.xlsx.

Jaramillo, J., Muchugu, E., Vega, F. E., Davis, A., Borgemeister, C., & Chabi-Olaye, A. (2011). Some like it hot: The influence and implications of climate change on coffee berry borer (Hypothenemus hampei) and coffee production in East Africa. *PLoS One1, 6*(9), Article e24528. https://doi.org/10.1371/journal.pone.0024528

Jawo, T. O., Kyereh, D., & Lojka, B. (2023). The impact of climate change on coffee production of small farmers and their adaptation strategies: A review. *Climate and Development, 15*(2), 93–109. https://doi.org/10.1080/17565529.2022.2057906

Jones, L., Kuhl, L., & Matthews, N. (2020). Addressing power and scale in resilience programming: A call to engage across funding, delivery and evaluation. *The Geographical Journal, 186*(4), 415–423. https://doi.org/10.1111/geoj.12362

Kangile, J. R., Kadigi, R. M. J., Mgeni, C. P., Munishi, B. P., Kashaigili, J., & Munishi, P. K. T. (2021). The role of coffee production and trade on gender equity and livelihood improvement in Tanzania. Article 18 *Sustainability, 13*(18). https://doi.org/10.3390/su131810191.

Kangogo, D., Dentoni, D., & Bijman, J. (2020). Determinants of farm resilience to climate change: The role of farmer entrepreneurship and value chain collaborations. Article 3 *Sustainability, 12*(3). https://doi.org/10.3390/su12030868.

Kasongi, N., Yamungu, N., Gallemore, C., & Jespersen, K. (2024). Projected rising temperatures and vapour pressure deficit threaten Arabica coffee production Tanzania's burgeoning coffee region: Empirical insight from Mbinga district, Tanzania. *Environmental Challenges, 16*, Article 100974. https://doi.org/10.1016/j.envc.2024.100974

Kath, J., Byrareddy, V. M., Craparo, A., Nguyen-Huy, T., Mushtaq, S., Cao, L., & Bossolasco, L. (2020). Not so robust: Robusta coffee production is highly sensitive to temperature. *Global Change Biology, 26*(6), 3677–3688. https://doi.org/10.1111/gcb.15097

Kath, J., Craparo, A., Fong, Y., Byrareddy, V., Davis, A. P., King, R., Nguyen-Huy, T., van Asten, P. J. A., Marcussen, T., Mushtaq, S., Stone, R., & Power, S. (2022). Vapour pressure deficit determines critical thresholds for global coffee production under climate change. *Nature Food, 1–10*. https://doi.org/10.1038/s43016-022-00614-8

Kilian, B., Rivera, L., Soto, M., & Navichoc, D. (2013). Carbon footprint across the coffee supply chain: The case of costa rican coffee. *Journal of Agricultural Science and Technology, B, 3*(3), 151–170.

Kuhl, L. (2018). Potential contributions of market-systems development initiatives for building climate resilience. *World Development, 108*, 131–144. https://doi.org/10.1016/j.worlddev.2018.02.036

Kweka, O. L., & Ouma, S. (2020). "Changing beyond Recognition"?: Reimagining the future of smallholder farming systems in the context of climate change. *Geoforum, 115*, 153–155. https://doi.org/10.1016/j.geoforum.2019.05.029

Läderach, P., Ramirez-Villegas, J., Navarro-Racines, C., Zelaya, C., Martinez-Valle, A., & Jarvis, A. (2017). Climate change adaptation of coffee production in space and time. *Climatic Change, 141*(1), 47–62. https://doi.org/10.1007/s10584-016-1788-9

Lebel, L., Anderies, J. M., Campbell, B., Folke, C., Hatfield-Dodds, S., Hughes, T. P., & Wilson, J. (2006). Governance and the capacity to manage resilience in regional social-ecological systems. *Ecology and Society, 11*(1). https://www.jstor.org/stable/26267807.

Mamuye, M., Gallemore, C., Jespersen, K., Kasongi, N., & Berecha, G. (2024). Changing rainfall and temperature trends and variability at different Spatiotemporal scales threaten coffee production in certain elevations. *Environmental Challenges, 15*, Article 100950. https://doi.org/10.1016/j.envc.2024.100950

Mamuye, M., Gallemore, C., Kasongi, N., Jespersen, K., & Berecha, G. (2025). Local-scale analysis of projected climate change impact on Arabica coffee distribution in selected districts of southwestern Ethiopia: Are the future production areas commercially viable? *Ecological Informatics, 91*, Article 103392. https://doi.org/10.1016/j.ecoinf.2025.103392

Manyise, T., & Dentoni, D. (2021). Value chain partnerships and farmer entrepreneurship as balancing ecosystem services: Implications for agri-food systems resilience.

Ecosystem Services, 49, Article 101279. https://doi.org/10.1016/j.ecoser.2021.101279

Mbwambo, S. G., Mourice, S. K., & Tarimo, A. J. P. (2021). Climate change perceptions by smallholder coffee farmers in the northern and southern highlands of Tanzania. Article 6 *Climate, 9*(6). https://doi.org/10.3390/cli9060090.

Meemken, E.-M. (2020). Do smallholder farmers benefit from sustainability standards? A systematic review and meta-analysis. *Global Food Security, 26*, Article 100373. https://doi.org/10.1016/j.gfs.2020.100373

Mikulewicz, M. (2019). Thwarting adaptation's potential? a critique of resilience and climate-resilient development. *Geoforum, 104*, 267–282. https://doi.org/10.1016/j.geoforum.2019.05.010

Minten, B., Dereje, M., Engida, E., & Tamru, S. (2018). Tracking the quality premium of certified coffee: Evidence from Ethiopia. *World Development, 101*, 119–132. https://doi.org/10.1016/j.worlddev.2017.08.010

Moat, J., Williams, J., Baena, S., Wilkinson, T., Gole, T. W., Challa, Z. K., Demissew, S., & Davis, A. P. (2017). Resilience potential of the Ethiopian coffee sector under climate change. Article 7 *Nature Plants, 3*(7). https://doi.org/10.1038/nplants.2017.81.

Morales, L. V., Robiglio, V., Baca, M., Bunn, C., & Reyes, M. (2022). Planning for adaptation: A system approach to understand the value chain's role in supporting smallholder coffee farmers' adaptive capacity in Peru. *Frontiers in Climate, 4*. https://doi.org/10.3389/fclim.2022.788369

Nab, C., & Maslin, M. (2020). Life cycle assessment synthesis of the carbon footprint of Arabica coffee: Case study of Brazil and Vietnam conventional and sustainable coffee production and export to the United Kingdom. *Geo: Geography and Environment, 7*(2), Article e00096. https://doi.org/10.1002/geo2.96

Nava, L., Chiapetti, J., da Rocha, R. B., & Tampe, M. (2025). Die now of hunger or later of thirst: Understanding climate change adaptation decisions in vulnerable contexts. *Strategic Management Journal, 46*(8), 1861–1893. https://doi.org/10.1002/smj.3709

Ovalle-Rivera, O., Läderach, P., Bunn, C., Obersteiner, M., & Schroth, G. (2015). Projected shifts in Coffea arabica suitability among major global producing regions due to climate change. *PLoS One, 10*(4), Article e0124155. https://doi.org/10.1371/journal.pone.0124155

Pascucci, F. (2024). The state of the global coffee sector. In F. Pascucci (Ed.), Sustainability in the coffee supply chain: Tensions and paradoxes (pp. 57–75). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-72502-9_4.

Pham, Y., Reardon-Smith, K., Mushtaq, S., & Cockfield, G. (2019). The impact of climate change and variability on coffee production: A systematic review. *Climatic Change, 156*(4), 609–630. https://doi.org/10.1007/s10584-019-02538-y

Ponte, S. (2002). The "latte revolution"? Regulation, markets and consumption in the global coffee chain. *World Development, 30*(7), 1099–1122. https://doi.org/10.1016/S0305-750X(02)00032-3

Ponte, S., & Ewert, J. (2009). Which way is "up" in upgrading? Trajectories of change in the value chain for South African wine. *World Development, 37*(10), 1637–1650. https://doi.org/10.1016/j.worlddev.2009.03.008

Quiroga, S., Suárez, C., Diego Solís, J., & Martinez-Juarez, P. (2020). Framing vulnerability and coffee farmers' behaviour in the context of climate change adaptation in Nicaragua. *World Development, 126*, Article 104733. https://doi.org/10.1016/j.worlddev.2019.104733

Rahn, E., Läderach, P., Baca, M., Cressy, C., Schroth, G., Malin, D., van Rikxoort, H., & Shriver, J. (2014). Climate change adaptation, mitigation and livelihood benefits in coffee production: Where are the synergies? *Mitigation and Adaptation Strategies for Global Change, 19*(8), 1119–1137. https://doi.org/10.1007/s11027-013-9467-x

Regasa Megerssa, G., Garedew, W., Eneyew Bekele, A., Grabs, J., & Jespersen, K. (2025). How do institutions shape the resilience of the Ethiopian coffee sector amidst the pressures of climate change? *Sustainable Development, early view.*. https://doi.org/10.1002/sd.70065

Richey, L. A., & Ponte, S. (2021). Brand aid and coffee value chain development interventions: Is starbucks working aid out of business? *World Development, 143*, Article 105193. https://doi.org/10.1016/j.worlddev.2020.105193

Rickards, L., & Howden, S. M. (2012). Transformational adaptation: Agriculture and climate change. *Crop and Pasture Science, 63*(3), 240–250. https://doi.org/10.1071/CP11172

Rosenstock, T. S., Lubberink, R., Gondwe, S., Manyise, T., & Dentoni, D. (2020). Inclusive and adaptive business models for climate-smart value creation. *Current Opinion in Environmental Sustainability, 42*, 76–81. https://doi.org/10.1016/j.cosust.2019.12.005

Roxas, B., & Lindsay, V. (2012). Social desirability bias in survey research on sustainable development in small firms: An exploratory analysis of survey mode effect. *Business Strategy and the Environment, 21*(4), 223–235. https://doi.org/10.1002/bse.730

Ruben, R. (2023). Why do coffee farmers stay poor?: Breaking vicious circles with direct payments from profit sharing. *Journal of Fair Trade, 4*(2), 11–30.

Ruben, R., Allen, C., Boureima, F., Mhando, D. G., & Dijkxhoorn, Y. (2018). *Coffee value chain analysis in the southern highlands of Tanzania: Final report.* Wageningen University & Research.

Rubio-Jovel, K. (2023). The voluntary sustainability standards and their contribution towards the achievement of the sustainable development goals: A systematic review on the coffee sector. *Journal of International Development, 35*(6), 1013–1052. https://doi.org/10.1002/jid.3717

Schipper, E. L. F., Tanner, T., Dube, O. P., Adams, K. M., & Huq, S. (2020). The debate: Is global development adapting to climate change? *World Development Perspectives, 18*, Article 100205. https://doi.org/10.1016/j.wdp.2020.100205

Shapiro-Garza, E., King, D., Rivera-Aguirre, A., Wang, S., & Finley-Lezcano, J. (2020). A participatory framework for feasibility assessments of climate change resilience strategies for smallholders: Lessons from coffee cooperatives in Latin America. *International Journal of Agricultural Sustainability, 18*(1), 21–34. https://doi.org/10.1080/14735903.2019.1658841

Talbot, J. M. (2004). *Grounds for agreement: The political economy of the coffee commodity chain.* Rowman & Littlefield Publishers.

Tamru, S., Minten, B., & Swinnen, J. (2021). Trade, value chains, and rent distribution with foreign exchange controls: Coffee exports in Ethiopia. *Agricultural Economics, 52*(1), 81–95. https://doi.org/10.1111/agec.12608

Tan, H. C., Ho, J. A., Teoh, G. C., & Ng, S. I. (2021). Is social desirability bias important for effective ethics research? a review of literature. *Asian Journal of Business Ethics, 10*(2), 205–243. https://doi.org/10.1007/s13520-021-00128-9

Tanner, T., Lewis, D., Wrathall, D., Bronen, R., Cradock-Henry, N., Huq, S., Lawless, C., Nawrotzki, R., Prasad, V., Rahman, M. A., Alaniz, R., King, K., McNamara, K., Nadiruzzaman, M., Henly-Shepard, S., & Thomalla, F. (2015). Livelihood resilience in the face of climate change. *Nature Climate Change, 5*(1), 23–26. https://doi.org/10.1038/nclimate2431

TCB. (2012). *Tanzania Coffee Industry Development Strategy 2011/2021.* Ministry of Agriculture and Cooperatives: Tanzania Coffee Board.

TCB. (2017). *Report of the Midterm Evaluation of the Tanzanian Coffee Industry Development Strategy 2011-2021. Bureau of Agricultural Consultancy and Advisory Service Sokoine.* University of Agriculture.

TCB. (2021). *Tanzania's Coffee Industry Development Strategy 2020–2025.* Ministry of Agriculture and Cooperatives: Tanzania Coffee Board.

Tefera, A. (2022). *Coffee Annual—Ethiopia.* Foreign Agricultural Service: United States Department of Agriculture.

Temba, P. L., Pauline, N. M., & Ndaki, P. M. (2020). Living and responding to climate variability and change among coffee and banana farmers in the highlands of Moshi rural district, Tanzania. In P. Z. Yanda, C. G. Mung'ong'o, & E. B. Mabhuye (Eds.), *Climate Change Impacts and Sustainability: Ecosystems of Tanzania* (pp. 9–22). CABI.

Thompson, W. J., Blaser-Hart, W. J., Joerin, J., Krütli, P., Dawoe, E., Kopainsky, B., Chavez, E., Garrett, R. D., & Six, J. (2022). Can sustainability certification enhance the climate resilience of smallholder farmers? The case of Ghanaian cocoa. *Journal of Land Use Science, 17*(1), 407–428. https://doi.org/10.1080/1747423X.2022.2097455

Todo, Y., & Takahashi, R. (2013). Impact of farmer field schools on agricultural income and skills: Evidence from an aid-funded project in rural Ethiopia. *Journal of International Development, 25*(3), 362–381. https://doi.org/10.1002/jid.1819

Tolessa Lemma, D., & Gudisa Megersa, H. (2021). Impact of climate change on East African coffee production and its mitigation strategies. *World Journal of Agricultural Sciences, 17*(2), 81–89. https://doi.org/10.5829/idosi.wjas.2021.81.89

Tournebize, R., Borner, L., Manel, S., Meynard, C. N., Vigouroux, Y., Crouzillat, D., Fournier, C., Kassam, M., Descombes, P., Tranchant-Dubreuil, C., Parrinello, H., Kiwuka, C., Sumirat, U., Legnate, H., Kambale, J.-L., Sonké, B., Mahinga, J. C., Musoli, P., Janssens, S. B., & Poncet, V. (2022). Ecological and genomic vulnerability to climate change across native populations of Robusta coffee (Coffea canephora). *Global Change Biology, 28*(13), 4124–4142. https://doi.org/10.1111/gcb.16191

Urruty, N., Tailliez-Lefebvre, D., & Huyghe, C. (2016). Stability, robustness, vulnerability and resilience of agricultural systems. A review. *Agronomy for Sustainable Development, 36*(1), 15. https://doi.org/10.1007/s13593-015-0347-5

van der Lee, J., Kangogo, D., Gülzari, Ş.Ö., Dentoni, D., Oosting, S., Bijman, J., & Klerkx, L. (2022). Theoretical positions and approaches to resilience assessment in farming systems. A review. *Agronomy for Sustainable Development, 42*(2), 27. https://doi.org/10.1007/s13593-022-00755-x

van der Vossen, H., Bertrand, B., & Charrier, A. (2015). Next generation variety development for sustainable production of arabica coffee (Coffea arabica L.): A review. *Euphytica, 204*(2), 243–256. https://doi.org/10.1007/s10681-015-1398-z

van Rikxoort, H., Schroth, G., Läderach, P., & Rodríguez-Sánchez, B. (2014). Carbon footprints and carbon stocks reveal climate-friendly coffee production. *Agronomy for Sustainable Development, 34*(4), 887–897. https://doi.org/10.1007/s13593-014-0223-8

Vicol, M., Neilson, J., Hartatri, D. F. S., & Cooper, P. (2018). Upgrading for whom? Relationship coffee, value chain interventions and rural development in Indonesia. *World Development, 110*, 26–37. https://doi.org/10.1016/j.worlddev.2018.05.020

Walker, B., Holling, C. S., Carpenter, S. R., & Kinzig, A. (2004). Resilience, adaptability and transformability in social–ecological systems. *Ecology and Society, 9*(2). https://www.jstor.org/stable/26267673.

Weichselgartner, J., & Kelman, I. (2015). Geographies of resilience: Challenges and opportunities of a descriptive concept. *Progress in Human Geography, 39*(3), 249–267. https://doi.org/10.1177/0309132513518834

Werners, S. E., Sparkes, E., Totin, E., Abel, N., Bhadwal, S., Butler, J. R. A., Douxchamps, S., James, H., Methner, N., Siebeneck, J., Stringer, L. C., Vincent, K., Wise, R. M., & Tebboth, M. G. L. (2021). Advancing climate resilient development pathways since the IPCC's fifth assessment report. *Environmental Science & Policy, 126*, 168–176. https://doi.org/10.1016/j.envsci.2021.09.017

Wienhold, K., & Roberts, P. W. (2025). Is the rising tide of specialty coffee lifting all boats? *World Development, 195*, Article 107103. https://doi.org/10.1016/j.worlddev.2025.107103

Wilson, G. A. (2018). "Constructive tensions" in resilience research: Critical reflections from a human geography perspective. *The Geographical Journal, 184*(1), 89–99. https://doi.org/10.1111/geoj.12232