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RESEARCH

The Changing Features of Governance in Agro-Food Value Chains: How Climate Change and Domestic Regulation Are Reshaping the Tanzanian Coffee Industry

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Abstract
Climate change and domestic regulatory interventions in producing countries are transforming the mechanisms of governance in agro-food value chains. The suitability of biophysical conditions for the cultivation of different crops in different areas is changing. At the same time, domestic reforms in several producing countries are seeking to empower smallholder farmers. In this paper, drawing from primary data collected for a collaborative research project, we assess the combined impacts of these factors on the governance of the Tanzanian coffee value chain. We show that, while climate change initiatives and domestic market reforms could have led to a more active role for smallholder farmers and their cooperatives in governing the value chain vis-a-vis international coffee traders, in reality they have further weakened their position. We conclude that the dominant role of global buyers in governing coffee value chains is likely to remain intact and that smallholder farmers are likely be bearing much of the cost of climate change adaptation and mitigation.

Keywords Climate change · Global value chains · Governance · Regulation · Coffee · Tanzania

Résumé
Le changement climatique et les interventions réglementaires nationales dans les pays producteurs modifient les mécanismes de gouvernance des chaînes de valeur agroalimentaires. L'adéquation des conditions biophysiques à la culture de différentes cultures dans diverses régions évolue. Parallèlement, des réformes nationales dans plusieurs pays producteurs visent à renforcer le pouvoir des petits exploitants agricoles. Dans cet article, à partir de informations primaires recueillies dans le cadre d'un projet de recherche collaboratif, nous évaluons les impacts conjoints de ces facteurs sur la gouvernance de la chaîne de valeur du café en Tanzanie. Nous montrons que, bien que les initiatives liées au changement climatique et les

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réformes du marché intérieur auraient pu conduire à un rôle plus actif des petits producteurs et de leurs coopératives dans la gouvernance de la chaîne de valeur face aux négociants internationaux de café, elles ont en réalité encore affaibli leur position. Nous concluons que le rôle dominant des acheteurs mondiaux dans la gouvernance des chaînes de valeur du café devrait rester inchangé et que les petits exploitants agricoles continueront probablement à supporter une grande partie des coûts liés à l'adaptation et à l'atténuation du changement climatique.

Resumen
El cambio climático y las intervenciones regulatorias internas en los países productores están modificando los mecanismos de gobernanza en las cadenas de valor agroalimentarias. La idoneidad de las condiciones biofísicas para el cultivo de diferentes cultivos en distintas zonas está cambiando. Al mismo tiempo, las reformas internas en varios países productores buscan empoderar a los pequeños agricultores. En este artículo, a partir de datos primarios recolectados para un proyecto de investigación colaborativo, evaluamos los impactos combinados de estos factores en la gobernanza de la cadena de valor del café en Tanzania. Mostramos que, si bien las iniciativas frente al cambio climático y las reformas del mercado interno podrían haber propiciado un papel más activo de los pequeños productores y sus cooperativas en la gobernanza de la cadena de valor frente a los comerciantes internacionales de café, en la práctica han debilitado aún más su posición. Concluimos que el papel dominante de los compradores globales en la gobernanza de las cadenas de valor del café probablemente se mantendrá intacto y que los pequeños agricultores seguirán asumiendo gran parte de los costos de la adaptación y mitigación al cambio climático.

Introduction

The globalization of production has yielded new winners and losers within and across nations, spurring much debate on the different forms of inequality that it engenders. There has been a long standing interest in how the emergence and consolidation of global, regional and local value chains may exacerbate inequalities—and whether and how these inequalities can be mitigated. The dominant discourse argues for more widespread inclusion and upgrading towards higher value-added activities as the main pathways for addressing North-South inequalities (Barrientos et al. 2016a; Gereffi 1999; Gereffi and Lee 2014; Gibbon 2001; Humphrey and Schmitz 2004; Lang et al. 2022; Vicol et al. 2018). But despite massive participation in value chains, many Global South actors have often failed to significantly improve and/or retain the value added they create.

Governance dynamics in value chains have been shown to play a significant role in limiting the success of upgrading efforts and value chain-led development more broadly. This has been especially the case in the agro-food sector in Africa (Amanor 2019; Barrett et al. 2022; Barrientos et al. 2016b; Ponte and Ewert 2009; Tallontire et al. 2011; Tups and Dannenberg 2023), not only in relation to global but also regional value chains (Das Nair 2018; Das Nair et al. 2018; Ncube 2024). Therefore, scholars have been asking critical questions about the degree to which participation in agro-food value chains in Africa facilitates positive outcomes—such as improved competitiveness, value generation and capture, decent employment and sustainable livelihoods—and/or negative outcomes, like immiserating growth, decreasing margins, environmental degradation, and labour exploitation.

Yet, relatively little research so far has examined how the interaction of two key factors affect the governance of value chains: (1) climate change and related adjustments by farmers and other actors along value chains; and (2) domestic regulations in producing countries in the Global South that are explicitly designed (at least in theory) to tilt the balance of power in favour of smallholder farmers and other domestic actors, and against local subsidiaries of multinational corporations. This paper seeks to address this gap by focusing empirically on coffee originating from Tanzania—a country that produces both Arabica and Robusta coffee and thus is ideal to examine the possibly divergent trajectories of climate change and domestic regulation interactions (given that Robusta is thought of being less vulnerable to climate change).

We interrogate our empirical material to argue that: (1) climate change is slowly but surely altering the functioning of the coffee value chain in Tanzania, disproportionately affecting smallholder farmers; (2) this is compounded by reforms of the domestic regulatory system, which are inadvertently benefiting large estates by making it more difficult for coffee traders to buy specialty and sustainability-certified coffee from cooperatives and farmer groups. We find that while climate change initiatives and domestic market reforms could have led to a more significant role for smallholder farmers and their cooperatives in governing the value chain vis-a-vis international coffee traders, in reality they have further solidified the buyer-driven nature of the Tanzanian coffee value chain.

In the next section, we summarise our methodological approach. In section three, we frame our contribution in the context of current discussions on the changing features of the global coffee value chain. In section four, we focus on the case study of Tanzanian coffee. In the final section, we discuss what Tanzanian coffee tells us about the possible evolution of the coffee industry and the study of value chain governance more generally.

Methods

Our analysis is carried out in the context of a broader collaborative project between East African and European universities on 'climate-smart coffee' in Eastern Africa. For this article, it draws selectively from material based on a survey of 1,446 coffee farming households (see selected demographics in Appendix Table 1), 113 key informant interviews and 128 focus group discussions with coffee farmers in Tanzania.[1]

[1] Coffee farming communities in which surveys and focus group discussions took place were sampled in a two-stage procedure. We first identified the country's regions with the highest levels of smallholder coffee production and subsequently identified districts that would be representative of various agro-ecological zones. We selected the districts of Kyerwa (Kagera region – the main Robusta-growing region in Tanzania), Mbozi (Songwe region), Mbinga (Ruvuma region), and Rombo (Kilimanjaro region), and randomly sampled 32 villages with existing coffee farming areas based on a double stratification (high, middle, and

We coded our sources for anonymity (TZ##) throughout this paper (see Appendix Table 2 for details).[2] While the survey data is useful for capturing general trends, the qualitative narratives provide a more nuanced picture from key value chain actors about the changing climate and its impacts on production, the dynamics of domestic regulation, as well as perceptions on what these combined aspects mean locally. We also collected satellite-derived climatic data from Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) and from Climate Hazards Group InfraRed Temperature with Station data (CHIRTS), both with 5 km spatial resolution (for more details, see Appendix Table 3). All primary material was collected in 2022-23.

Data analysis took place in a two-step process: in a first step, we conducted a thematic analysis of qualitative data. We read all qualitative material through the lenses of four broad categories (climate change, regulatory reforms, strategic sourcing, and community involvement in coffee projects) and distinguished it by type of actor (smallholders and cooperatives, coffee estates, international traders and exporters, regulatory agencies, NGOs and donors; see Appendix Table 1 for details). Then, for triangulation, we interrogated the survey results and satellite data on selected aspects for which we had both perception and objective measurement data. All authors collaborated closely throughout the preparation of tools and the analytical process, jointly developing the coding framework, cross-checking interpretations and triangulating findings to align qualitative insights with quantitative trends. This collective engagement helped ensure analytical rigor and coherence across diverse data sources.

The Evolution of Governance in Coffee Value Chains

In value chain analysis, governance involves a range of relationships through which activities are organized that are not the arms-length market relationships widely assumed in microeconomic models (Gereffi et al. 2005). The very large literature on this topic emphasizes the influential role of particularly powerful firms—especially those that exercise significant 'buyer power' by placing large-scale orders along their value chains. The concept of governance is based on the premise that these processes are actively driven by the strategies and decisions of specific firms and involves an empirical focus on the concrete practices, power relations, and organizational forms

low elevation levels; and high, middle, and low changes in rainfall according to meteorological data). We conducted a digital survey (using the open-source tool KoboCollect) on climate change experiences, mitigation and adaptation measures, as well as livelihood strategies. Furthermore, we conducted 3–4 focus group discussions in every village, focusing on men, women, youth, and (where applicable) members of the local Agricultural Marketing Cooperative Society (AMCO) separately. Key informant interviews at the national level were conducted based on a comprehensive sector mapping, with the aim to cover the most relevant value chain actors, regulatory authorities, and civil society organizations. All key informant interviews followed a common semi-structured interview guide. Focus group discussions were audio-recorded and transcribed, while key informant interviews in Tanzania were captured with extensive notes. The key informant interviews lasted between 40 and 60 min, while the focus group discussions (FGDs) and surveys lasted between 60 and 90 min.

[2] Please note that this table lists only sources that have been directly used in this paper. A full list of sources is available from the authors.

that structure and define a value chain (Ponte and Sturgeon 2014). Much of this literature has also unpacked how different governance dynamics have varied implications on weaker players in the Global South (Bair 2009; Gibbon and Ponte 2005). For the purpose of our analysis, we use a definition of governance as 'the actions, institutions and norms that shape the conditions for inclusion, exclusion and mode of participation in a value chain, which in turn determine the terms and location of value addition, distribution and capture' (Dallas et al. 2019, p. 667).

In relation to the global coffee value chain, Grabs and Ponte (2019) identified three historical phases during the post-WWII period. First, in the 'ICA phase' (1962–1989), international trade coffee was governed by the International Coffee Agreement. Grabs and Ponte (2019) characterise governance in this period as having a low level of 'drivenness', with increasing concentration in roasting and trading segments that raised entry barriers—but with roasters neither in the position to dictate the terms of the trade to traders nor to set inclusion/exclusion thresholds (see Fig. 1 for a general depiction of the structure of coffee value chains). Second, in the post-ICA 'liberalization phase' (1989–2007), the formal regulatory infrastructure was abolished and market-driven differentiation slowly arose—along with increasingly differentiated quality and sustainability demands. Grabs and Ponte (2019) characterise governance in this period as 'buyer-driven' (specifically, 'roaster-driven')—accompanied by further consolidation in roasting, coffee oversupply, and vertical integration by traders made easier by market liberalization in producing countries.

Third, a 'diversification and reconsolidation phase' (2008-) saw a portfolio-based reconsolidation of large roasters, along with the increasing use of traceability tools for supply chain management, the related decline of sustainability premiums, and a further rise of quality expectations. Grabs and Ponte (2019) consider governance in this period still 'buyer-driven' with roasters as the strongest actors (in some consumption countries, along with retailers). This is the result of re-consolidation among roasters after a period of diversification, the application of more stringent financing

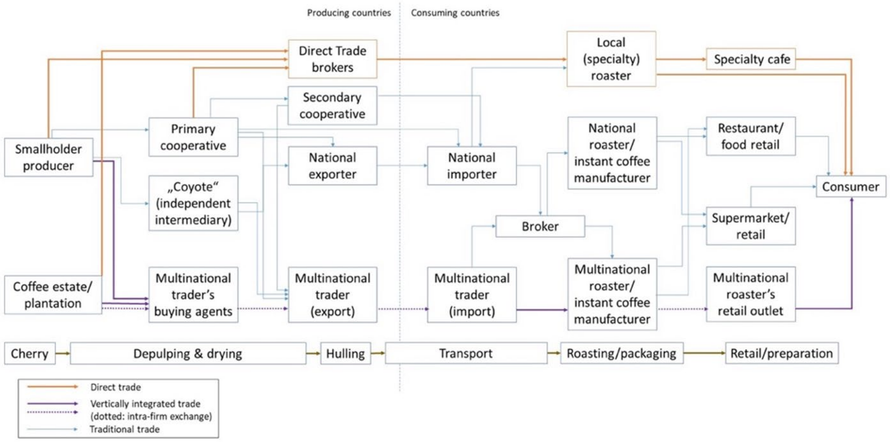

Fig. 1 General structure of coffee value chains. Source: Adapted from Carodenuto and Grabs (2021) and Grabs (2020)

terms by roasters to international traders, and the power of determining the choice of sustainability standards. At the same time, they indicate a growing influence of small specialty roasters that focus mainly on quality.

In this article, we suggest that this overall picture may be currently evolving because: (1) climate change-related concerns are becoming more important in the coffee industry; and (2) regulatory attempts at the domestic level are seeking to tilt the balance of power in favour of (smallholder) farmers. These two factors may have individual but also combined key effects on the governance of coffee value chains.

Climate Change

Climate change has received surprisingly little attention in GVC analysis in general—and this is particularly surprising when it comes to the agro-food sector. There is plenty of research on the climate change impacts on agricultural production, including in Africa, and on coffee production in particular (see below)—but much less on how climate change is transforming the governance of value chains. This is also the case for coffee, where the literature has mainly focused on production and productivity when assessing climate change vulnerability. Studies in the Tanzanian context have highlighted declining Arabica coffee yield (Craparo et al. 2015), changes in ripening patterns (Craparo et al. 2021), and projected climatic change that will intensify such negative impacts (Kasongi et al. 2024).

Coffee-producing communities' perceptions of—and responses to—climate change has been another focus of work to date (Bacon et al. 2017; Call et al. 2019; Guido et al. 2020a; Guido, Knudson and Rhine; Guido et al. 2020b; Mbwambo et al. 2021; Rahn et al. 2014; Temba et al. 2020). This scholarship shows that coffee smallholders have an acute understanding of the ways changing weather patterns are affecting their production and resulting livelihoods (Mbwambo et al. 2021). Adaptation measures include shifting production from lower to higher altitudes (which creates additional land use pressure and may spark conflict) (Ovalle-Rivera et al. 2015) and adapting in place—for instance via the use of new cultivars or production practices aimed at preserving water, establishing shade, and increasing soil health (Bracken et al. 2023; Rahn et al. 2014; Temba et al. 2020). On-farm adaptation may also include diversification, intercropping, or shifting entirely to different and less climate-vulnerable crops, while off-farm livelihood strategies include seeking wage labour or moving into small business ownership (Call et al. 2019). The literature furthermore highlights the need for organizations to support such adaptation strategies and build relevant capacities (Bracken et al. 2023; Gomes et al. 2020; Jaramillo et al. 2011; Läderach et al. 2017; Pham et al. 2019; Van der Vossen et al. 2015).

These are all important insights but they are not linked to how adaptation practices may (re)shape the governance of the coffee value chain. The same occurs in relation to mitigation processes.Though coffee farming is a relatively minor contributor to carbon dioxide emissions at a global level, some work has investigated how to quantify (Killian et al. 2013; Nab and Maslin 2020) and reduce net emissions in coffee production (Van Rikxoort et al. 2014), for instance via the (re)introduction of shaded coffee systems (Andrade and Zapata 2019; Rahn et al. 2014). Recent work aiming to link climate action and corporate sustainability strategies highlights the limited engagement by coffee traders and roasters (Bager and Lambin 2020; Bianco 2020; Bradley and Botchway 2018). Research also highlights the potential of partnerships, supply chain collaborations, and improved buyer-supplier relations to contribute toward farm-level climate resilience and farmer entrepreneurialism (Bezares et al. 2021; Dentoni et al. 2021; Hochachka 2023; Kangogo et al. 2020; Rosenstock et al. 2020; Manyise and Dentoni 2021). Still, such collaborations may also contribute to reinforcing asymmetric power dynamics, including via disproportionate benefits for companies as compared to smallholder farmers (Richey and Ponte 2021), the reinforcement of local elite structures (Vicol et al. 2018), and the biasing of market access away from smallholders toward large estates (Quiroga et al. 2020).

In sum, very little is known about the impact of climate change on the governance of coffee value chains. Elsewhere, we have suggested that climate change adaptation and mitigation initiatives in coffee value chains are strongly donor-driven or are seen mainly as a performative issue to manage reputation (Grabs et al. 2022). Although some international coffee traders and roasters are starting to map risks, and they recognize that on a larger scale there might be future climate-related risks from concentrating their procurement on fewer origins, they are not (yet) seeing major supply risk happening—with the exception of some quality niches. In light of market developments at the time or writing (with international coffee prices spiking due to climate change-related production challenges in Brazil and Vietnam),[3] this lack of concern seems even more problematic.

Because adaptation is seen mainly as a corporate reputation management measure, mitigation measures are actually receiving much more attention among international traders and roasters globally. In anticipation of what could become a large market, some international traders are seeking to specialize on carbon in-setting—i.e., the reduction of carbon emissions within a company's own value chain. They ideally seek win-win situations where they can reduce their own emissions while also making money from reducing the emissions of downstream buyers (Grabs et al. 2022). In a way, these dynamics may also be signs of some readjustment of the power balance between roasters and international traders, as net-zero commitments can potentially lock roasters into specific sourcing agreements with traders and into specific coffee producing areas—in order to demonstrate that they are achieving carbon reductions.

Domestic Regulation

Given the importance of coffee in many tropical nations—in terms of its contribution to GDP, purveyor of foreign exchange, and driver of rural development—it is perhaps not surprising that governments have aimed to intervene in domestic coffee markets and pursue 'coffee statecraft' (Fridell 2014). Such interventions have different goals, including increasing state earnings from coffee, protecting the interests of coffee companies and plantation owners, and increasing smallholder producer incomes. One major area of domestic regulatory reform concerns who is allowed to buy, sell, trade, and export coffee. From 1962 to 1989, global coffee markets were governed by

[3] See https://www.nytimes.com/2025/02/22/business/coffee-prices-climate-change.html and https://www.nbcnews.com/business/consumer/coffee-costs-climate-change-consumer-prices-rcna191158.

the International Commodity Agreement (ICA) and participating producing countries held and managed export quotas (Gilbert 1996; Talbot 2004). During this period, many producing countries, including Tanzania, used parastatal coffee marketing boards to establish a monopoly on exports (Baffes 2005, 2006; Behuria 2020; Birthwright 2021; Lukanima & Swaray 2014). After the ICA lapsed, liberalization ensued but proceeded at a different pace across coffee origins (Lukanima & Swaray 2014). Some countries (e.g. Uganda, El Salvador, Honduras) opted for fully open markets, with no restrictions on who could purchase cherry coffee, own processing plants, and export coffee (Córdoba et al. 2023). In such cases, domestic and international trading houses and processors coexisted and competed. Some countries (e.g. Ethiopia) only allowed domestic firms to export coffee in an effort to maintain foreign exchange control and spur local industry (Ponte 2002). Others regulated the sales of coffee cherries. For instance, in 2016 the Rwandan government passed a zoning policy that requires coffee farmers within specific zones to sell to specific washing stations (Behuria 2020; Gerard et al. 2022). In rare cases, such as Costa Rica, export contracts are subject to governmental approval and laws govern exporters' profit margins above costs to increase the producers' share of total price (Grabs 2020).

To maintain price transparency and competition, some countries (e.g. Ethiopia, Kenya, as well as Tanzania) continued to operate national coffee auctions (also called exchanges) where buyers would have to bid on each shipment (Ponte 2002). However, this practice was frequently criticized for undermining traceability, segregation, and relationship building along supply chains (Cramer & Sender 2019). The extent to which coffee trade today is managed via private contracting alone, auctions, or the intermediation by state-owned enterprises is different from country to country; many countries with auctions also have loosened the requirements and made these voluntary rather than mandatory.

Governments also intervene in other ways to strengthen their coffee sectors, e.g. by supporting producer cooperatives, promoting local consumption, and subsidizing R&D of new cultivars and supporting replanting campaigns (e.g. Colombia or Brazil) (Cramer & Sender 2019). One interesting avenue of state intervention is the support of product upgrading via entering specialty markets. Many producing countries have encouraged growers to improve coffee quality, e.g. through restrictions on growing only Arabica coffee (e.g. Colombia, Costa Rica, Ethiopia), exporting only high-quality coffee (e.g. Ethiopia), instituting quality grading schemes and certifications, investing in domestic processing capacity (e.g. Rwanda), supporting segmentation and differentiation, and supporting good agricultural practices in the field (Behuria 2020; Birthwright 2021; Samoggia & Fantini 2023). These efforts to establish high-quality, country-level reputations is reflected in country-level price differentials at the international market. Countries such as Colombia and Rwanda have tried to valorize these reputations further via Geographical Indications, i.e. certifications of a specific national or regional origin of the product (Barjolle et al. 2017). Finally, some countries have also built out their reputation for sustainability in an effort to capture differentiation premiums, both via supporting third-party certification efforts but also by creating their own, local efforts (Grabs 2021). For instance, the regional government of Minas Gerais in Brazil introduced the 'Certifica Minas Café' certificate and established equivalence with the third-party UTZ certification (Glasbergen 2016), while Colombia initiated a program of 'Colombia 100/100' intending to make 100% of Colombian coffee sustainable by 2027, including by developing an internal code of conduct (Grabs 2021). While these insights have been linked to reflections on governance in the global coffee value chain (Grabs and Ponte 2019), domestic regulatory efforts can no longer be analysed independently from climate change interventions. Therefore, in the next section, we start building a picture from below (in Tanzania) on whether the dynamics of governance in coffee value chains may be changing due to a combination of climate change and domestic regulatory reforms.

Learning from the Case Study of Tanzanian Coffee

Overview of Production and Exports

Tanzania produces both Arabica and Robusta coffee. Robusta production is mainly concentrated in the country's northwest region, particularly in Kagera. Over the past two decades, Arabica coffee production has remained relatively stagnant, fluctuating between 30,000 and 35,000 metric tonnes. In contrast, Robusta production has shown an upward trend (Fig. 2). This disparity has been attributed to the differing sensitivity of the two coffee varieties to climate change, with Arabica being more susceptible

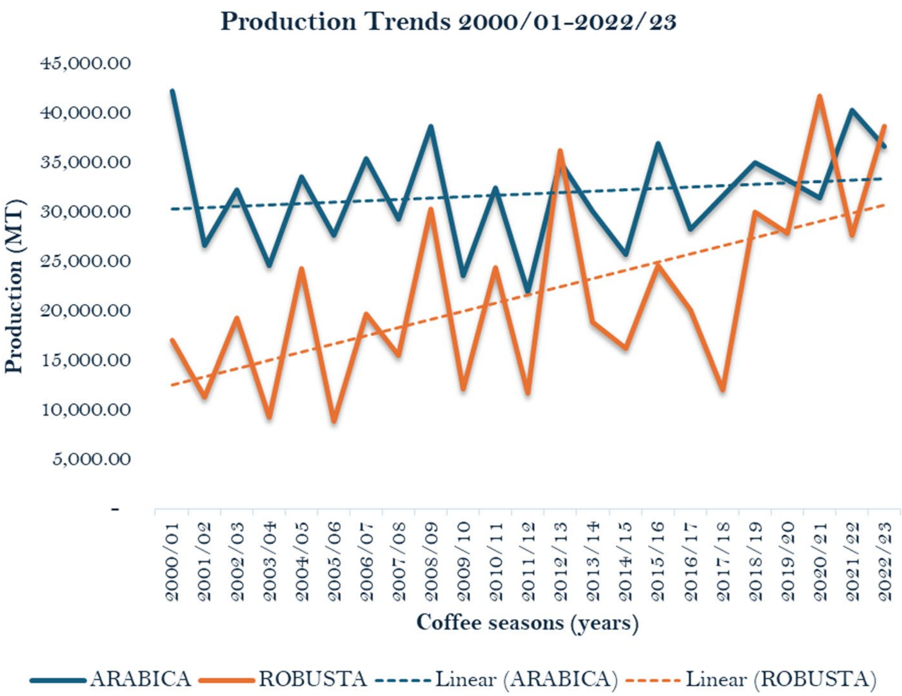

Fig. 2 Tanzanian coffee production trends (2001–2023) (metric tons). Source: elaborated from Tanzania Coffee Board (TCB) data

than Robusta (Bunn et al. 2015), but more recent findings dispute this picture (Kath et al. 2020).

Within the country, there have been substantial changes in the regional composition of production which are relevant for our discussion of climate change, given their different agro-ecological conditions. There has been substantial expansion of production in the Southern Highlands and in Western Tanzania, due to better land availability, less competition from other agricultural products and non-farm activities, and a less marked incidence of changes in rainfall patterns (Fig. 3) (Chang'a et al. 2021). In contrast, in the Northern Region, the traditional home of coffee, there has been a major decline in coffee cultivation, due to lower and more erratic rainfall, higher temperatures (Chang'a et al. 2021; Hamisi 2013; Wagner et al. 2021) (see also below), and less water available for traditional furrow irrigation. It is also an area with smaller and decreasing plot sizes and higher levels of competition from other, more profitable crops (banana, avocados, tomatoes, vegetables, fruit) and dairy. 'Many of us have switched from cultivating coffee to bananas and avocados due to favourable market prices and less production costs. Coffee is no longer a primary source of income in our region' (TZ1). There is also higher competition from other economic activities, especially for young (and educated) people who may not be interested in coffee farming. Essentially, many traditional areas of coffee cultivation in Kilimanjaro and Arusha have become peri-urban areas (TZ8).

Coffee exports have been generally increasing in volume since the early 2000s (see Fig. 4), driven by expansion of production in the Southern Highlands for Arabica and in Western Tanzania for Robusta. In the last decade, Japan has been the leading destination for Tanzania's coffee (measured by volume), followed by Italy and Germany (Fig. 5). Historically, auctioning was the primary channel for exporting

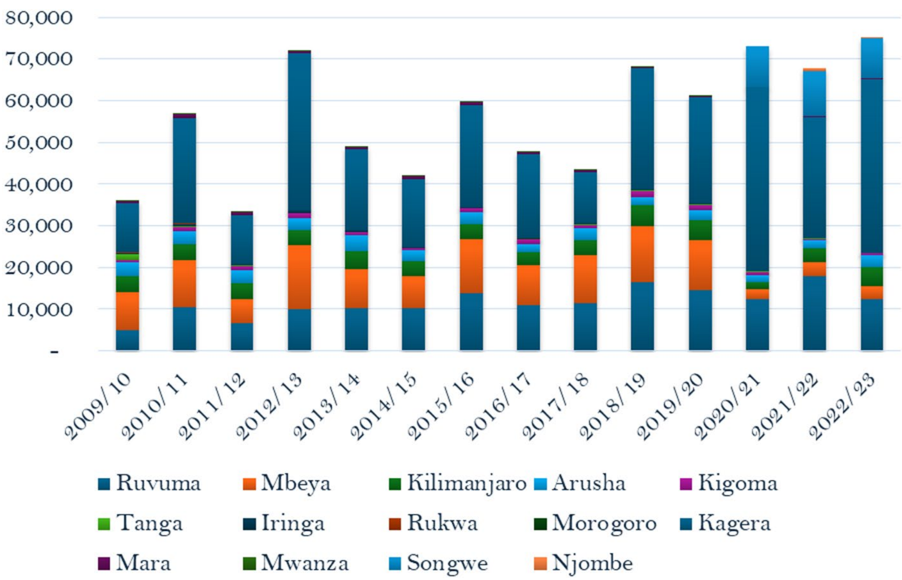

Fig. 3 Tanzanian coffee production by region (metric tons). Source: Elaboration from TCB data

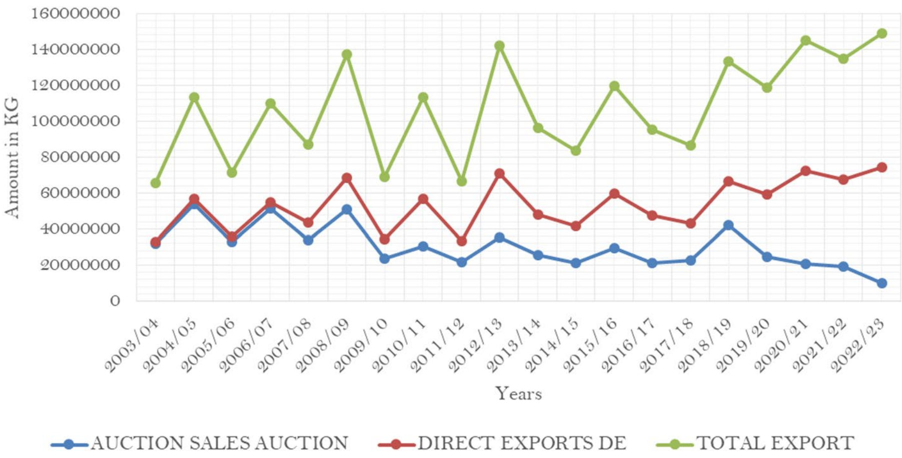

Fig. 4 Tanzanian coffee exports (2004–2023). Source: elaborated from TCB data

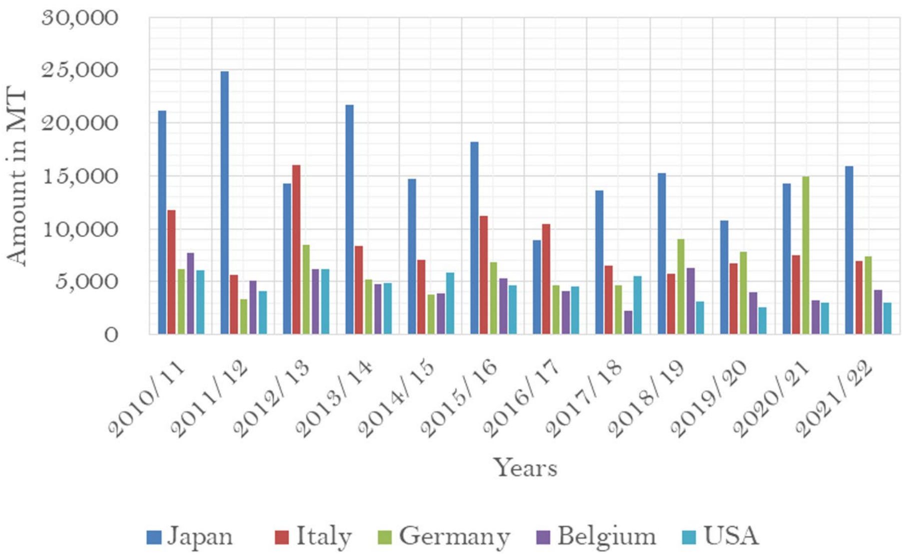

Fig. 5 Main export destinations of Tanzanian coffee (2010/2022). Source: elaborated from TCB data

Tanzania's coffee. However, in the early 2000s Tanzania Coffee Board (TCB) started allowing direct sales, while still retaining a key regulatory role. A significant proportion of Tanzania's coffee is now sold through direct exports rather than at the auction (Fig. 3). The distribution of exports between the two channels went from 50%–50% in the early 2000s, to roughly 70% of coffee sold via direct exports and 30% through the auction in the 2022/2023 season.

Climate Change

The Effects of Climate Change on Coffee Production

Our survey data, focus group discussions and key informant interviews highlight that two main aspects of climate change are affecting the volume, quality and location of coffee production: changing rainfall patterns and rising temperatures. In relation to *rainfall*, a large proportion of respondents reported decreasing amounts and intensity (see Fig. 6) in all four districts we carried out our research. A substantial proportion also reported delayed and/or unpredictable onset. In focus groups, many also highlighted that the short rains season are often failing (affecting the flowering of coffee trees). Robusta coffee farmers noticed a similar pattern in rainfall timing, with many growers reporting more unpredictability. Unlike in the past, when rains typically occurred in June or July to support flowering, now the rain might not arrive until August or September (TZ 41, 42, 43). When rain fails, it also makes the application of chemical fertilizer more difficult and less effective. As reported in one focus group, 'we received rainfall about two weeks ago, in some areas people started to apply fertilizers, but since that time, there has been no subsequent rain to facilitate the absorption and distribution of the nutrients by the plants' (TZ3). Dry spells also affect the availability of leafy vegetation for mulching and the quality of wet processing. Irrigation is the main adaptation practice that could help solve some of these issues, but it makes leaf rust attacks more likely because the moisture is applied from below instead of from above with rainfall. Also, irrigating during drought attracts leaf miners, which are drawn by moisture and do not have other alternative crops to feed upon. Additionally, in many areas, irrigation infrastructure is not available, and

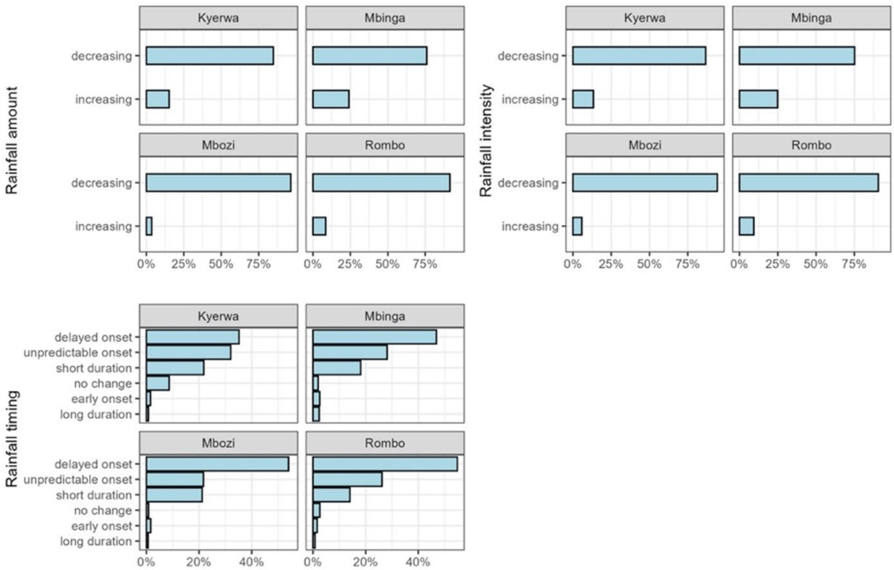

Fig. 6 Perceptions on changes in rainfall. Source: own survey

where there is some, conflicts over water rights are increasing. The perception data on decreasing rainfall are confirmed by meteorological data in three districts (although statistically insignificant), while in Kyerwa (Tanzania's Robusta growing area) the trend is one of a statistically significant rainfall increase (see Fig. 7). Meteorological data also indicates increasing inter-annual rainfall variability across the study sites, particularly from 2010 onwards (Fig. 8).

More than 70% of respondents to our survey also claim to have observed increasing *temperatures* over the past few decades (see Fig. 9), a trend that is confirmed to be statistically significant in the analysis of meteorological data (see Fig. 10). This is leading to new pest and disease attacks (such as fruit flies), a higher incidence of existing attacks, and—for those who can afford it—too much agro-chemical use, which itself affects biodiversity and increases the costs of production. A shorter cold season and higher temperatures before harvesting entail quicker and earlier ripening of cherries, which also tend to ripen all at the same time (TZ14). This leads to thinner coffee that lacks body in the cup and makes the management of harvesting harder as more labour is needed for a shorter time period.

In relation to the *location* of coffee cultivation, Bunn et al. (2015) suggest that Tanzanian coffee could be moving up in altitude due climate change. Insights from

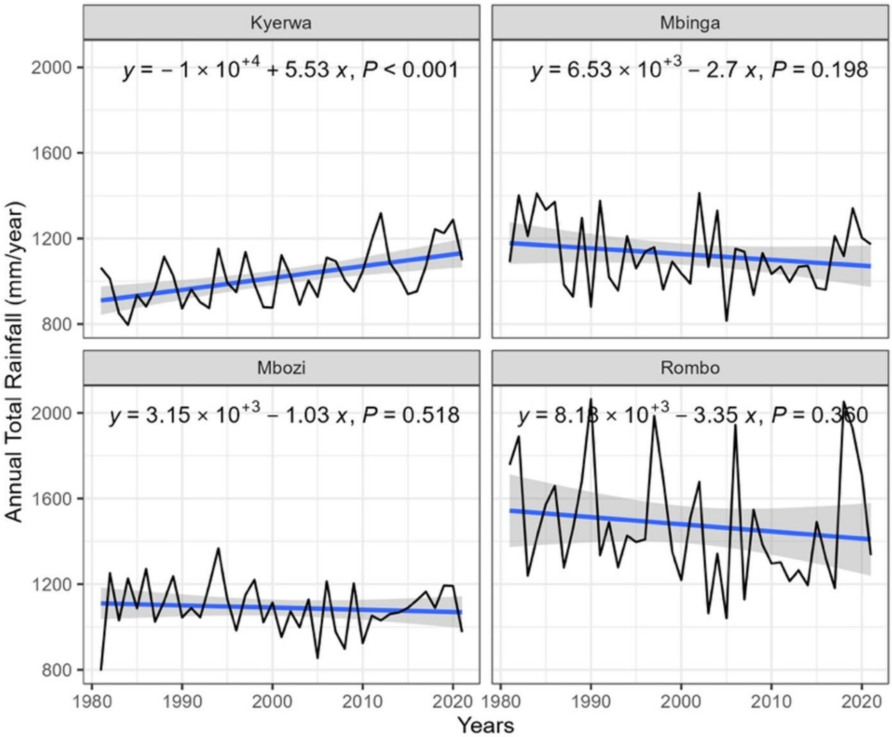

Fig. 7 Meteorological records of average annual rainfall in four districts, Tanzania (1980–2020). Source: Satellite-derived climatic data from Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) with 5 km spatial resolution

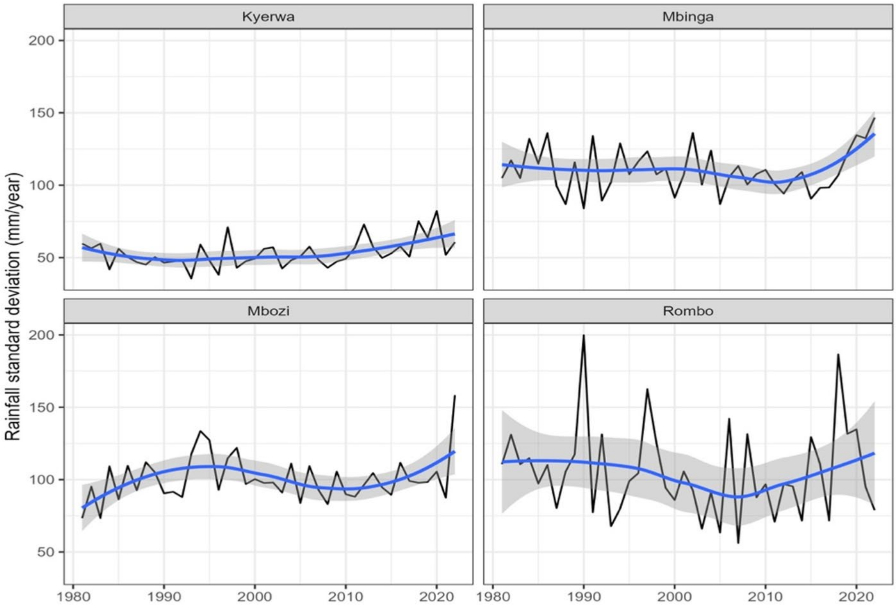

Fig. 8 Inter-annual rainfall variability. Source: Satellite-derived climatic data from Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS) with 5 km spatial resolution

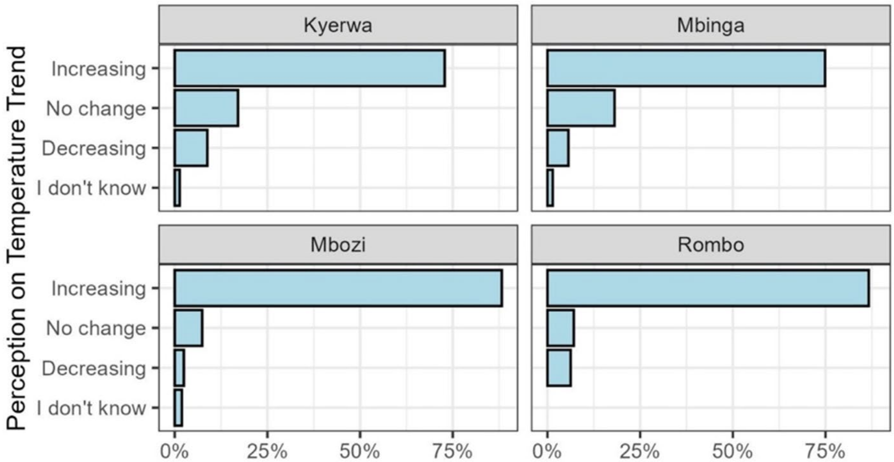

Fig. 9 Perceptions on temperature trends. Source: own survey

our focus group discussions indicate that coffee farming may be intensifying in the midlands and highlands (except in the Northern region), while coffee cultivation in the lowlands may be decreasing in intensity, becoming more difficult and/or being abandoned (especially but not only in the Northern region). The lowlands are generally becoming drier and face increasing human settlement (TZ37). In the lower

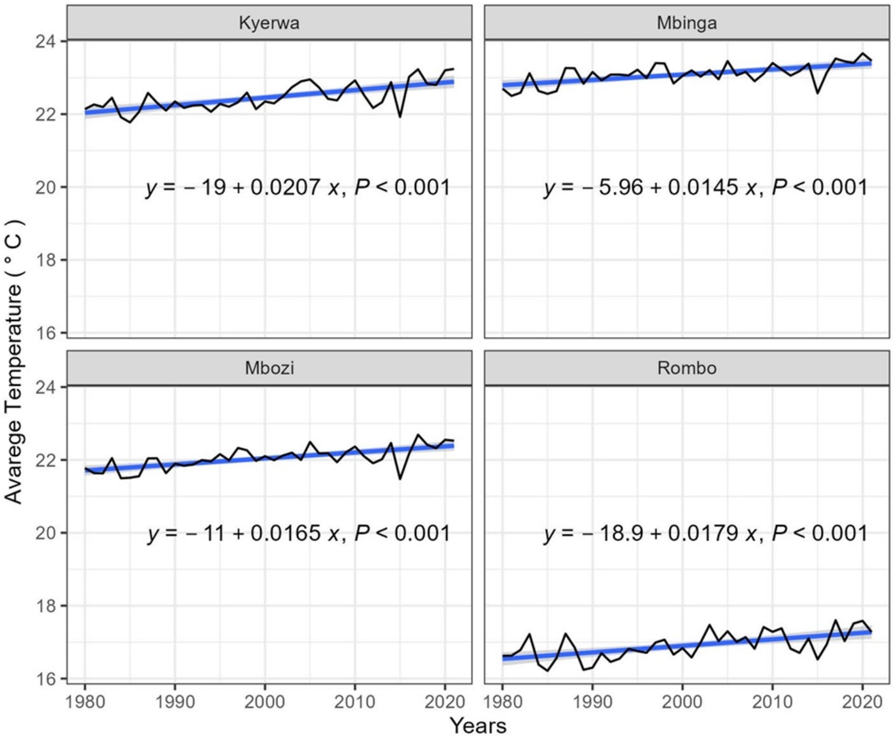

Fig. 10 Meteorological records of annual average temperatures in four districts, Tanzania (1980–2020). Source: Satellite-derived climatic data from Climate Hazards Group InfraRed Temperature with Station data (CHIRTS) with 5 km spatial resolution

altitude areas of the Southern Highlands, the participants of a focus group stated that 'currently, production has also decreased due to delayed rainfall. Those with capital who practice irrigation farming are the ones who still produce coffee' (TZ38).

While the volume of coffee *production* overall is increasing (see Fig. 2), this is mostly due to increases in Robusta production (rainfall is increasing in the Robusta producing region of Kagera). Arabica production is actually stagnant—and growers perceive changing rainfall patterns and increasing temperatures as key limiting factors. 'In the past, adequate rainfall and moderate temperatures supported abundant coffee yields. However, ongoing drought has substantially reduced production levels, making it increasingly difficult to predict future harvests' (TZ 44). These observations are supported by Wagner et al. (2021) and Craparo et al. (2015), who highlighted that drought, caused by a delayed onset of the main rainy season and rising temperatures, contributes to lowering coffee yields. But coffee production is not only shaped by climate change considerations (as we will discuss in Sect. "Changing Domestic Regulation").

Climate-induced decreases in coffee *productivity* are countered by efforts to develop new varieties that are not only more resilient but also have higher yields than traditional varieties. The development, propagation and distribution of varieties resistant to selected diseases (no drought resistant varieties are available in Tanzania at scale) has been a major focus of government and donor/NGO projects, with the Tanzanian Coffee Research Institute (TACRI) at the centre of these productivity enhancing efforts. According to TACRI researchers (TZ15), these varieties are more compact (therefore allowing an increase of planting density) and more productive than traditional varieties, thus potentially improving coffee profitability. They are resistant to the two main diseases for Arabica: coffee berry disease (CBD, relevant especially at higher altitudes) and coffee leaf rust (CLF, at lower altitudes). TACRI is also developing Robusta varieties that are resistant to coffee wilt disease (CWD). TACRI researchers state that many farmers are reluctant to replace traditional varieties with the new ones (TZ16). Some farmers told us that compact varieties require more water/irrigation, and this is a problem if they do not have access to water sources or irrigation equipment: ‘The new coffee seedlings are suited for those with financial means. Low-income farmers may struggle to cultivate them due to their high requirement for water and fertilizers. One needs to invest in a water pump and labour for irrigation’ (TZ5). They also perceived that new seedlings do not appear to be compatible with their environmental conditions (TZ6). In some cases, the improved varieties are grafted on stumps of traditional varieties, which are more drought resistant (TZ19).

Climate change impacts the *quality* of coffee as well. Drought affects the average size of coffee beans—the proportion of highly priced AA beans appears to be decreasing, and coffee beans manifest more irregular sizes. Finally, beans manifest lighter density and this lowers their quality. As indicated by one participant in a focus group, ‘this year there has been a severe drought, with insufficient rainfall. The coffee beans are becoming much smaller and lighter due to prolonged drought, which negatively impacts the quality of the coffee’ (TZ4). ‘Aroma used to be good and long lasting, with good acidity and full body. Now coffee dries too quickly, it is lighter in body, acidity not as it used to be, and the coffee has a flatter, shortish aroma’ (TZ15).

Adaptation Practices

Figure 11 summarizes the top climate adaptation practices that were reported by *smallholder farmers* in our survey. While some of these can be broadly conceived of

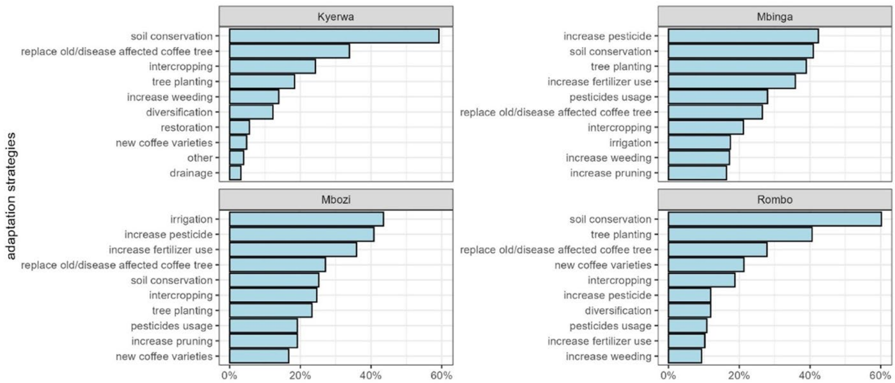

Fig. 11 Top smallholder coffee farmers’ adaptation strategies. Source: own survey

as good agronomic practices, they are also climate adaptation practices (Grados et al. 2024) because they help farmers to cope with the adverse effects of climate change. Noticeable is that even the most common practices (soil conservation, irrigation, increased pesticide use, planting of shade trees) have been adopted by only 20–40% of farmers—with the exception of soil conservation in Kyerwa and Rombo, which 55–60% of surveyed farmers report practicing. The adoption of new coffee varieties is not common in the Southern Highlands and the Western region, while it was reported by 20% of farmers in the Northern Region. In addition, Fig. 12 shows the number of climate adaptation strategies used by coffee farming households. While there is some variation between the study sites, the majority of households adopted only one to three strategies to cope with climate-induced challenges. A small proportion of households adopted more than five different strategies.

There is also a shared understanding of how climate change is impacting the Tanzanian coffee industry among *other value chain actors*. Cooperative unions and Agricultural Marketing Cooperative Societies (AMCOs) are well aware of the climate change impacts on coffee quality and yields but have little capacity to implement adaptation strategies on their own. Those involved in these efforts are part of larger development projects and/or exporter-led initiatives. An online search combined with fieldwork identified numerous recent value chain initiatives or interventions in Tanzania that use climate change related language (see Appendix Table 4 for a full overview). Yet, most of these development projects are still mainly related to 'classic'

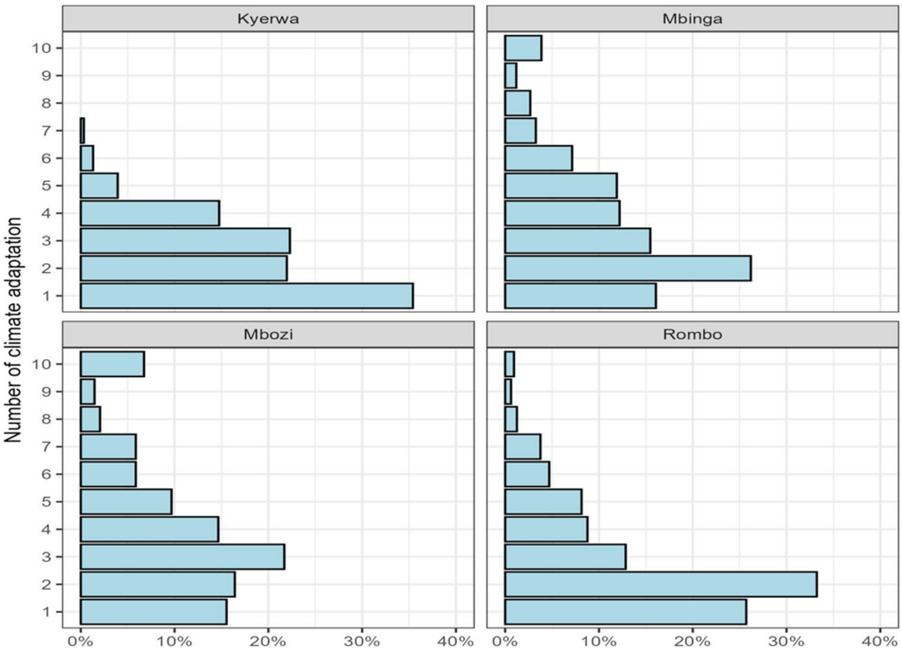

Fig. 12 Bundle of climate adaptations. Source: own survey

value chain interventions—addressing yields, productivity and quality—with climate change as add-on activity subservient to other objectives (Grabs et al. 2022).[4]

When climate change-related activities have been included in these projects, they are almost exclusively linked to climate adaptation, not mitigation—and include three main categories of practices: (1) Water/moisture management: building contours for rain trapping; digging of small wells/pools; mulching; using eco-pulpers to decrease water use in primary processing; using drip irrigation or manual watering; and digging of ditches within a coffee farm to store rainwater and help maintain soil moisture levels; (2) Intercropping, which is actually 'traditional' in the Northern coffee region, but is increasingly adopted in Southern region as well; (3) the adoption (or readoption) of agro-forestry/permaculture and soil management measures, eradication of alien species (especially eucalyptus, which depletes water availability for other species), and the planting of trees to shade coffee (TZ30 to TZ36) (for a full analysis, see Grabs et al. 2022).

However, the picture of climate change adaptation among *coffee estates* is quite different than that for smallholders. Estates are becoming increasingly important in Tanzania, especially in the specialty coffee sector. Like smallholders, they are also affected by climate change but generally have the capital and knowledge to more easily invest in irrigation (including drip irrigation technology) and water catchment systems. At lower altitudes, where adaptation is more difficult, some estates are diversifying into other crops -- especially avocado and macadamia. They are also better able to maintain or re-plant shade trees. To solve the problem of lack of water for wet primary processing, some estates are switching to eco-pulpers. However, they also report that eco-pulpers have a smaller throughput because they use less water, and this is a problem given that coffee, with higher temperatures, tends to mature all in a shorter period of time. Most estates hold sustainability certifications—and several mentioned that having Starbucks CAFÉ and/or Rainforest Alliance certification is a must (TZ17, TZ19 to 22). The more sophisticated estates monitor weather conditions as part of their risk minimization strategy, have their own (or hire) expertise in agronomy and weather modelling, are developing advanced water harvesting techniques, and are establishing nurseries for improved varieties. Some estates are experimenting with carbon footprint calculations and are considering selling credits in the carbon market—as coffee buyers have started asking to deliver contributions in meeting their net-zero commitments (TZ23).

Changing Domestic Regulation

Previous to 1993, buying coffee from farmers in Tanzania was only allowed by cooperative unions and/or marketing boards. All coffee procured domestically was sold to private exporters at the auction in Moshi. Farmers (through various forms of cooperative societies) owned the coffee up to the export point and bore the price fluctuation risk, but the payment system allowed a smoothing out of price variations

[4] A notable exception was a suite of climate change projects led by the HRNS foundation under its 'coffee and climate' program. The last such project operated in Mbeya and Songwe and uniquely positioned climate adaptation as its central objective but has now been phased out (TZ29).

within the marketing year. Farmers were paid the same price irrespective of when they had delivered coffee to the cooperative, and of when their particular coffee was sold, thus price stabilization was ensured within the marketing season. The system also provided quality incentives to cooperative societies and (less directly) to farmers, although payments to farmers were often delayed and resources were siphoned out of the system at various levels. Smaller, mostly Asian-Tanzania owned, export companies were able to compete with Kenya-based exporters and the subsidiaries of multi-national corporations—meaning that competitive bidding characterized the auction, especially for top-quality coffees (Baffes 2005; Ponte 2002; Winter-Nelson and Temu 2002).

The adoption of the 1993 Tanzania Crop Boards Act marked profound changes in this regulatory framework. Domestic trade was opened up to private traders and processors, although the Tanzania Coffee Board (TCB) kept numerous regulatory powers–including licensing powers, export quality control and running the coffee auction. The new system allowed registered domestic traders to buy coffee from farmers, but only at authorized buying posts—not at the farm gate. This new system yielded mixed results. On the one hand, farmers started being paid cash on delivery and received a higher proportion of the export price than in the pre-liberalization period (Temu et al. 2001; Winter-Nelson and Temu 2002). On the other hand, input-credit schemes collapsed, the volume of coffee exports flattened, and—at least in the first period after liberalization—coffee quality decreased as farmers were being paid one price for all coffee irrespectively of quality (Ponte 2002). Market liberalization led to the dramatic capturing of the domestic Tanzanian coffee market by foreign companies at all levels (domestic trade, processing and export). While in the mid-1990s, a number of independent local companies and cooperative unions were still operating in the domestic market, by the early 2000s their market position had been severely curtailed. And while 95 per cent of coffee was still produced by smallholders, foreign investors had started to dominate the estate production sector as well (Ponte 2002).

By the early 2000s, large exporters had vertically integrated into domestic trade, processing, and in some cases even estate production. Tanzania maintained a mandatory export auction, but most coffee was simply re-acquired at the auction by the same company that bought it domestically. Thus, there was little or no competitive bidding for this 'captive' coffee. Essentially, exporters built extensive networks of local agents and coffee buying posts competing with each other at the local level, along with independent local buyers that re-sold the coffee forward to other traders and agents. The potential price boosting effect of auctioning (and thus indirectly the bargaining power of farmers) was therefore dampened.

A series of new regulations and amendments from the Coffee Industry Act of 2001 onwards have attempted to address the dominance of multinationals in the domestic coffee trade, including the banning of holding multiple licenses (e.g. for trading, processing, exporting) by the same companies. Direct exports without going through the auction also started to be allowed, initially for specialty coffees and for coffees holding sustainability certifications, as long as the registered contract indicated a price that was above the current auction price for the same quality level. In time, however, these requirements were relaxed, to the point that by the early 2020s most exports were being sold outside the auction (Fig. 4). From 2022 onwards, any coffee has been allowed to be exported through direct sales, not only premium or certified coffee as it was the case previously (TZ9). Coffee now generally goes through the auction only when the seller has not yet identified a buyer. In other words, the regulatory system in practice is unable to tame the power of large exporters vis a vis smallholder coffee farmers and their cooperatives.

What could have made a partial difference in the governance of the Tanzanian coffee value chain are the provisions (applied from 2018/19 onwards) allowing only AMCOs to buy coffee from farmers—except for coffee estates (TZ10). These reforms were designed explicitly to tilt the balance of power in the domestic coffee value chain away from large traders and exporters (often local subsidiaries of multinational companies) and towards smallholders through their cooperatives. After a few hiccups, AMCOs have been able to obtain pre-financing to buy coffee from their farmers, normally from buyers rather than banks (TZ11). However, because they return a residual payment to farmers after the cooperative detracts costs for services, logistics and financing, the system does not provide appropriate incentives to operate efficiently. 'The objective should be to set a specific proportion of the realized FOB price paid to farmers to contain expenses … The current system relies on aggregation; it does not take care of quality properly' (TZ12). This is particularly affecting coffee procurement for the specialty market (coffee scoring at 85 points or above in the Specialty Coffee Association scale), which is now being increasingly sourced from coffee estates—mostly owned by foreign investors—rather than smallholders (TZ13).

These regulatory reforms also affected primary processing for Mild Arabica (turning coffee cherries into parchment coffee). Farmers operate two processing systems in Tanzania: wet hand-pulping of cherry coffee by individual farmers; and wet processing of cherry coffee at Central Pulping Units (CPUs). CPU processing, which had expanded significantly in 2000s, especially in the Southern Highlands, used to be run by private companies and sometimes by primary cooperative societies or smaller farmer groups. But now, because private companies are not allowed to buy cherry directly from farmers (TZ11), only AMCOs are allowed to operate CPUs (not even farmer groups can). But this is difficult to do for AMCOs because they need additional finance and expertise to carry out this function properly. Following the 2018 reform, 90% of CPUs in Mbinga and Mbozi (where expansion of this system had been most pronounced) have been reported to be not functioning—with deleterious impacts on overall coffee quality in the country (TZ28).[5]

These reforms have also affected the so-called 'project coffee' procurement system. Until recently, four of the main five coffee exporters in Tanzania were heavily involved in projects aimed at improving the loyalty of farmers to supply their coffee

[5] Secondary processing (to turn parchment coffee into green coffee ready for export) has not faced the same problems. For Robusta and Hard Arabica, processing for export is still mostly run by cooperative unions in Western Tanzania, along with some smaller private operations. For Mild Arabica, processing for export is mostly run by exporters (with a separate company name and licence) in the Northern region – while in the Southern Highlands cooperative curing plants (in Mbinga and Mbeya) are still significant, along with private ones run by exporters.

to AMCOs that were partnered with one or another exporter. This often involved special projects to improve quality or providing other kinds of support for local communities, including: social projects, including on gender issues; demonstration plots, training on farming as business, and the adoption of good agricultural practices; loans for AMCOs to purchase agrochemical inputs; supporting farmers with agronomic advice through the traders' own extension officers; and/or help in establishing nurseries for improved coffee varieties (TZ11, 18, 24 to 26).

Exporters also saw these activities as part of their head offices' preparation plans in view of delivering climate mitigation measures in the future. The key motivation of 'project coffee' was essentially to secure the supply base, control quality, and maintain sustainability certifications (TZ11, 27) (see also Richey and Ponte 2021). 'Project coffee' was thus not only a CSR-type initiatives but also as a way of building social capital 'because competition among buyers is tough on the ground' (TZ11). The expenses incurred in these projects, however, were detracted from the quality premium that farmers could have received themselves. Because community projects impact thousands of community members, they also provide a broader legitimation base for supporting these relationships. While exporters' sourcing models in the past focused strongly on quality and sustainability criteria that were needed to enter leading companies' supply chains, in the 'project coffee' period companies turned to signalling that producer loyalty and long-term supply chain relations were an important factor that smallholder farmers could benefit from.

This system is now being abandoned due to the reform of domestic coffee procurement rules. As the representative of a large exporter stated: 'If you are working with the same farmer group year by year, you built a relationship and a dialogue regarding sustainability and environmental reflections … But now these projects do not work because AMCOs can switch supplier at a whim. There was more confidence in the old system to support farmers, and sustainability certification was the glue' (TZ19). At the same time, the system also created informal local monopsonies: 'We had an informal division of labour among exporters. We carved out geographic areas where we did project coffee, while other companies did it in other areas' (TZ18). Even during these times, exporters saw these as investments in relationships but were also aware of the risks involved. If the supplier AMCOs ended up selling coffee to other buyers—the trader engaged in the relationship risked losing not only access to coffee but also struggle to get repaid for the inputs or services provided. With the formal empowerment of AMCOs, this risk now appears to be too high for the 'project coffee' system to continue.

Conclusion

In this paper, we have shown that it is important to consider how the underlying governance dynamics of value chains are evolving with the rise of climate change concerns—combined with domestic market reforms where these have taken place.

The climate change literature on African agriculture has provided important insights on impacts and adaptations, but these have been rarely leveraged in terms of how climate change may (re)shape value chain governance. Analyses of domestic market reforms have included reflections on how they are attempting to help smallholder farmers to tilt value chain functioning to their benefit, but they ignore how these dynamics interact with climate change adaptation and mitigation initiatives.

Our research shows that the governance of the Tanzanian coffee value chain, as in many other coffee origins, has been buyer-driven (by roasters via international traders) since the deregulation of domestic coffee procurement in the 1990s. Climate change is making coffee production more challenging. Discourses around the importance of climate change as a threat to coffee, the necessity for adaptation, and the potential benefits of mitigation measures are increasingly mentioned in the language of development projects in Tanzania, even if activities to date continue to mainly focus on traditional value addition interventions (Grabs et al 2022). Yet, exporters' risk considerations related to climate change in Tanzania were not featuring prominently at the time of fieldwork (2022/23). Because the country is not a key origin in the global coffee market, the risk of supply failure did not enter international traders' strategic considerations. For example, one of the top exporters of coffee from Tanzania stated to us: 'Tanzania has a small market share globally, so big players are not seeing it as a risk factor in relation to climate change. It's too small … Tanzania comes at the bottom of the layers of global demand, except for the Japanese market. Not many clients say that you need to have Tanzanian coffee in your blend' (TZ24) c Climate change is making large international traders less interested in propping up Tanzanian coffee in comparison to other, more important origins at the global level.

Adaptation efforts in smallholder production areas also appear to be dampened by recent domestic procurement reforms, which make it harder for multinational companies to source consistently from the same farmers. These reforms were intended to (re)empower cooperative societies by giving them exclusive rights to buy coffee from farmers. But many cooperatives remain ineffective because of a lack of extant capacities, such as financing or technical knowledge to properly run primary coffee processing plants. In Tanzania, under the new regulatory system, cooperatives can switch more easily between different coffee buyers year after year, in theory allowing them more bargaining power. But higher uncertainty is also leading international coffee traders to decrease or abandon established partnerships with local cooperatives and farmer groups (in what are known as 'project coffee' procurement systems), which usually entail providing agronomic support, quality control and social or health services to local communities. As a result, international traders—at least in Tanzania—are gradually switching from buying specialty and sustainability-certified coffee from cooperatives/farmer groups to buying it from large estates. The combination of these factors, together with the hollowing out of the Tanzanian coffee auction to allow direct exports, ends up working against coffee smallholders and makes it even more difficult for them to tackle the very real challenges they are facing from climate change.

These reflections suggest that a restructuring of the global coffee value chain could soon be played around adaptation and mitigation to climate change and the type of sourcing strategies that will be enacted by international coffee traders and roasters to manage supply risk—in the context of changing domestic regulatory environments. But our insights from Tanzania suggest that the dominant role of global buyers in governing coffee value chains is likely to remain relatively intact and that smallholder farmers are likely to be bearing the costs of adaptation and mitigation. They also suggest that the analysis of governance in global value chains needs to be informed by climate change considerations and domestic regulatory reforms more centrally.

Appendix

See Tables 1, 2, 3 and 4.

Table 1 Selected demographics from the survey

Variable	Study site	Min	Mean	Max	SD
Age	Kyerwa	20	50.1	99	13.5
	Mbinga	20	49.6	96	13.5
	Mbozi	22	47.3	90	13.1
	Rombo	22	64.6	100	13
Coffee farming experience	Kyerwa	2	27.1	61	14.3
	Mbinga	1	28.2	72	14.5
	Mbozi	2	24.6	69	13.7
	Rombo	1	35.3	84	17.2
Household size	Kyerwa	1	6.6	62	4.7
	Mbinga	1	5.6	16	2.4
	Mbozi	1	6.8	22	3.3
	Rombo	1	5	47	3.7
Coffee farm size	Kyerwa	0.3	4.4	30	4.3
	Mbinga	1	6.4	53	6.1
	Mbozi	0.5	6.9	80	6.3
	Rombo	0.2	2.2	32	2.9

Table 2 Sources quoted in this Article

Code	Type of data	Date	Source	Location	
TZ1	FGD	13-04-2023	women FGD	Rombo District	
TZ2	FGD	15-04-2023	women FGD	Rombo District	
TZ3	FGD	03-02-2023	men FGD	Mbozi District	
TZ4	FGD	02-05-2023	men FGD	Rombo District	
TZ5	KII	01-02-2023	village leader	Mbozi District	
TZ6	FGD	15-04-2023	men FGD	Rombo District	
TZ7	FGD	10-03-2023	men FGD	Mbinga District	
TZ8	FGD	28-04-2023	men/youth FGD	Rombo District	
TZ9	KII	21-02-2022	regulatory agency	Moshi	
TZ11	KII	22-02-2022	exporter	Moshi	
TZ10	KII	21-02-2022	regulatory agency	Moshi	
TZ12	KII	12-04-2023	regulatory agency	Moshi	
TZ13	KII	12-04-2023	research institution	Moshi	
TZ14	KII	21-02-2022	regulatory agency	Moshi	
TZ15	KII	22-02-2022	research institute	Lyamungu	
TZ16	KII	14-04-2023	cooperative union	Moshi	
TZ17	KII	24-02-2022	coffee estate	Arusha	
TZ18	KII	14-04-2023	exporter	Moshi	
TZ19	KII	24-02-2022	coffee estate	Arusha	
TZ20	KII	14-04-2023	coffee estate	Moshi	
TZ21	KII	20-04-2023	coffee estate	Arusha	
TZ22	KII	20-04-2023	coffee estate	Arusha	
TZ23	KII	08-05-2023	coffee estate	online interview	
TZ24	KII	18-04-2023	exporter	phone interview	
TZ25	KII	19-04-2023	exporter	Moshi	
TZ26	KII	19-04-2023	exporter	phone interview	
TZ27	KII	13-04-2023	exporter	Moshi	
TZ28	KII	21-02-2022	industry association	Moshi	
TZ29	KII	28-02-2022	NGO	Usa River	
TZ30	KII	15-02-2022	NGO	phone interview	
TZ31	KII	16-02-2022	NGO	phone interview	
TZ32	KII	16-02-2022	NGO	phone interview	
TZ33	KII	18-02-2022	NGO	phone interview	
TZ34	KII	18-02-2022	NGO	Dar es Salaam	
TZ35	KII	18-02-2022	NGO	Dar es Salaam	
TZ36	KII	18-02-2022	NGO	phone interview	
TZ37	KII	22-04-2023	KII at AMCO	Rombo District	AMCOS KII at Mamsera Rombo
TZ38	FGD	28-01-2023	women FGD	Mbozi District	Nambizo, Mbozi (lowland area)).
TZ39	FGD	27-01-2023	youth FGD	Mbozi District	Nambizo, Mbozi (lowland)
TZ40	FGD	02-03-2023	youth FGD	Mbinga District	Ukata village, lowland
TZ41	FGD	31-05-2023	men FGD	Kyerwa district	TZ_KYR_Kamuli men FGD_0134

Table 2 (continued)

Code	Type of data	Date	Source	Location	
TZ42	FGD	06-06-2023	men FGD	Kyerwa district	TZ_KYR_Nyakatuntu men FGD_0139
TZ43	FGD	08-06-2023	AMCO FGD	Kyerwa district	TZ_KYR_Karukwanzi AMCOS members FGD_0147
TZ44	KII	25-01-2023	AMCO leader	Mbozi District	Igamba Mpya AMCOS,

Table 3 Methodological details on analysis of rainfall and temperature and climate perceptions

Analysis of trends of rainfall and temperature from satellite-derived data
We analyzed long-term historical trends in rainfall and temperature (1980–2020) at the four study sites (Kyerwa, Mbinga, Mbozi and Rombo) using time-series satellite-derived data (CHIRPS and CHIRTS, respectively). These climate datasets are freely available online: CHIRPS data can be accessed at http://chg.geog.ucsb.edu/data/CHIRPS/, and the CHIRTS dataset can be accessed at https://data.chc.ucsb.edu/experimental/CHIRTS-ERA5/. Both gridded d atasets are provided at a spatial resolution of 5 km. The analysis involved zonal statistics: the pixel values were averaged by district polygon, and this process was repeated for the time series of these datasets. Finally, we plotted the historical trends in rainfall and temperature using the ggplot2 package in R software, version 4.3.2 (R Core Team, 2024).
Analysis of rainfall variability
We also analyzed interannual rainfall variability across the study sites from 1980 to 2020. We computed the standard deviation of yearly rainfall based on the monthly averages at each site. Finally, using the ggplot2 package in R software, version 4.3.2 (R Core Team, 2024), we plotted the trend of rainfall standard deviation to show the inter-annual variability.
Analysis of climate perceptions
We analyzed perceptions of coffee farming in relation to historical trends and changes in rainfall and temperature in the area, using data gathered from a household survey. The main analysis was a descriptive analysis involving the computation of frequencies. The results were presented in the form of a bar graph using the ggplot2 package in R software version 4.3.2 (R Core Team, R., 2024. *R: A language and environment for statistical computing*).

Table 4 Coffee-related interventions in Tanzania (2006 to present). Sources: search engines, Tanzania fieldwork (2022)

Intervention	Start-End	Aim/Description	Targeted Geographical Area (s)	Lead Actor (s)	Funder (s)
Smallholder Coffee Development Project in Tanzania's Southern Highlands-CODE-P*	2020–2024	To contribute to better income and improve the nutrition of 24,000 smallholder farmers in southern Tanzania.	Songwe region- Mbozi & Ileje districts; Ruvuma region-Mbinga & Nyasa districts; Mbeya region-Mbeya district council & Rungwe	Vi-Agroforestry	European Union (EU) & SIDA
To Certification and Beyond*	2020–2024	Familiarizing farmers with certification schemes and voluntary sustainability to help them access better market opportunities.	Mbeya, Njombe, Ruvuma, and Songwe. Specific districts on coffee covered are Mbozi, Mbinga, & Nyasa.	Solidaridad	European Union (EU)
Passport to coffee export (PACE) project*	2020–2024	Training lead farmers of climate-smart practices.	Mbinga, Mbozi, & Mbeya Rural	Solidaridad	European Union (EU)
Sustainable Rejuvenation of Coffee Production in Western Tanzania*	2019–2024	To increase coffee production for improving the livelihoods of smallholder coffee farmers through training of extension officers on climate change and agroforestry, the establishment of coffee seedling nurseries and distribution, advocacy, and inclusion of women and youth.	Kagera region (all districts)	Café Africa	Jacob Douwe Egberts (JDE)
Kahawa ya Kesho program (literally means 'Future coffee')*	N/A	Focuses to motivate youth to engage in coffee farming.	Mbeya, and Songwe regions	Hanns R. Neumann Stiftung (HRNS)	N/A

Table 4 (continued)

Intervention	Start-End	Aim/Description	Targeted Geographical Area (s)	Lead Actor (s)	Funder (s)
Coffee and Climate Initiative (Phase 3)*	N/A	Supporting farmers and farmers' groups to adapt and mitigate climate change, access finance, facilitate extension services, and implement GAP.	Mbeya, and Songwe regions	Hanns R. Neumann Stiftung (HRNS)	N/A
Empowering smallholder families with a special focus on women and youth to increase their resilience to climate change through sustainable farming practices*	2020–2023	ICP targets to improve the livelihood of 4,000 smallholder households in Mbeya and Songwe in Tanzania.	Songwe, and Mbeya Regions	International Coffee Partners (ICP)	International Coffee Partners (ICP), Government of Sweden
Reducing GHG emissions and increasing yields from Robusta coffee production by 7,000 smallholder farmers and processors in Tanzania**	2021-N/A	Targets to reduce GHGs emissions from Robusta coffee production.	Kagera	Jacob Douwe Egberts (JDE)	Government of Germany, JDE Peet's, 4 C Services GmbH
Climate-smart coffee and cocoa: from theory to practice (CSCC)***	2017–2019	Develop climate-smart coffee/Cocoa initiatives for climate change adaptation and Mitigation.	Mt. Kilimanjaro & Mbeya (Tanzania), and Uganda (Mount Elgon region, the greater Luweero region)	International Institute of Tropical Agriculture (IITA)	N/A
Adaptation for Smallholders to Climate Change (AdapCC)***	2007–2010	To support coffee and tea farmers in developing strategies to cope with the risks and impact of climate change.	Peru, Mexico, Nicaragua, Kenya, Tanzania, and Uganda	Cafédirect and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)	N/A

Table 4 (continued)

Intervention	Start-End	Aim/Description	Targeted Geographical Area (s)	Lead Actor (s)	Funder (s)
Brewing up climate resilience in the coffee sector. Adaptation strategies for farmers, plantations, and producers**	N/A	Knowledge sharing brochure with the aim to inspire action through examples of successful intervention of the most pressing challenges.	Mexico, Honduras, Guatemala, Nicaragua, Costa Rica, Colombia, Peru, Brazil, Uganda, China, Ethiopia, Vietnam, Indonesia, Rwanda, Tanzania	Hanns R. Neuman Stiftung (HRNS)	N/A
Carbon Offsetting Systems in Coffee Regions**	N/A	Providing smallholder families with financial rewards for investing and maintaining agroforestry production systems is a first step towards resilient livelihoods.	Indonesia, Ethiopia, Tanzania, Uganda, Brazil, Honduras, and Guatemala	Hanns R. Neumann Stiftung (HRNS), International Coffee Partners (ICP)	N/A
Climate-smart Coffee Regions**	N/A	Aim to establish Coffee Smart Regions by promoting sustainable use of natural resources through providing training on climate-smart practices and implementing programs to protect forests and watershed areas within a specific coffee region.	Indonesia, Ethiopia, Tanzania, Uganda, Brazil, Honduras and Guatemala	Hanns R. Neumann Stiftung (HRNS), International Coffee Partners (ICP)	N/A
Coffee Farmer Alliances Tanzania (CFAT)***	2010–2015	Addressing mid to long-term threats on coffee by paying attention to families that grow it to improve their livelihoods.	Arusha, Kilimanjaro, and Mbeya	Hanns R. Neumann Stiftung (HRNS), International Coffee Partners (ICP)	N/A

Table 4 (continued)

Intervention	Start-End	Aim/Description	Targeted Geographical Area (s)	Lead Actor (s)	Funder (s)
Empowering Youth to become climate leaders**	N/A	To train youth on coffee and climate to become climate leaders in their communities.	Indonesia, Ethiopia, Tanzania, Uganda, Brazil, Honduras and Guatemala	Hanns R. Neumann Stiftung (HRNS), International Coffee Partners (ICP)	N/A
Gender Equality and climate action**	N/A	To introduce Climate Smart and time-saving techniques to address the time poverty of women.	Indonesia, Ethiopia, Tanzania, Uganda, Brazil, Honduras and Guatemala	Hanns R. Neumann Stiftung (HRNS), International Coffee Partners (ICP)	N/A
Fostering knowledge and exchange of learnings**	N/A	To exchange knowledge on known and innovative climate-smart Agriculture practices between farmers, extension officers, and World leading climate experts.	Indonesia, Ethiopia, Tanzania, Uganda, Brazil, Honduras, and Guatemala	Hanns R. Neumann Stiftung, ICP	N/A
Safe Use and Handling of Agrochemicals**	N/A	To support access to climate-smart practices and integrated pests and diseases management.	Indonesia, Ethiopia, Tanzania, Uganda, Brazil, Honduras, and Guatemala	Hanns R. Neumann Stiftung (HRNS), International Coffee Partners (ICP)	N/A

Table 4 (continued)

Intervention	Start-End	Aim/Description	Targeted Geographical Area (s)	Lead Actor (s)	Funder (s)
Tanzania Country Program**	N/A	The Country Program follows a holistic approach to improving the livelihoods of 25,000 smallholder coffee farmers and their families through marketing and service linkages, organization development, advocacy and policy influence, production and quality enhancement, climate-smart agriculture, and gender and youth.	Tanzania (Country program)	Hanns R. Neumann Stiftung (HRNS)	N/A
Tools for further development of smallholder production systems**	N/A	Works towards establishing coffee production systems of the future. These systems shall be not only more resilient to the impacts of climate change but also improve the overall livelihood situation of smallholder coffee farming families through increased food security and diversification.	Indonesia, Ethiopia, Tanzania, Uganda, Brazil, Honduras, and Guatemala	Hanns R. Neumann Stiftung (HRNS), International Coffee Partners (ICP)	N/A
Training for Coffee Agronomists**	2006- N/A	To invite and train agronomists on good agricultural practices, including also environmental, social, and climate change issues to improve yield and people's livelihoods.	Tanzania, Uganda, DRC	Cafe Africa	N/A

Table 4 (continued)

Intervention	Start-End	Aim/Description	Targeted Geographical Area (s)	Lead Actor (s)	Funder (s)
District Coffee Shows**	2006-N/A	To provide farmers with opportunities to taste coffee, learn about the market, see what is available for farm equipment and tools, fertilizer and inputs supplies, and how to cope with a changing climate.	Tanzania, Uganda, DRC	Cafe Africa	N/A

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Declarations

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