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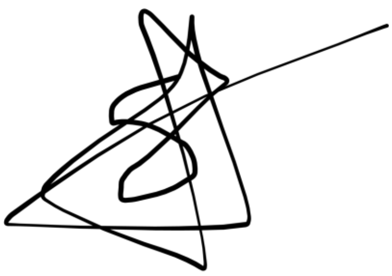

Abstract

Data collection has become a cornerstone of sustainability initiatives in smallholder coffee farming, yet the motives, methods, and power dynamics underlying these practices remain underexplored. This study employs Actor-Network Theory (ANT) to analyse how human and non-human actors, including farmers, NGOs, corporations, technologies, and regulatory frameworks, co-construct data networks in Sub-Saharan Africa. Through qualitative multi-method research, including document analysis and semi-structured interviews, the thesis examines some cases across Ethiopia, Uganda, and Kenya, focusing on the translation phases of problematization, interessement, enrolment, and mobilization.

The findings show that farmers mainly participate for money or because they feel pressured, while NGOs and corporations focus on following rules, tracking products, and ensuring sustainability. Non-human actors like certification programs and mobile technologies influence power dynamics, often making inequalities worse. Important issues arise around who owns data, who gets left out of digital access, and the lack of visibility for women, pointing out deep-rooted unfairness in agricultural management. The study questions the belief that collecting more data automatically helps small farmers, showing instead that data systems can continue harmful practices.

The thesis adds to discussions about agricultural digitalization by highlighting how data networks can be influenced by politics and how they can either maintain or change power differences. It suggests practical steps like changing who owns data, creating user-friendly tools for people with low literacy, and adjusting incentives to support farmers' control. By connecting Actor-Network Theory with studies on agriculture, this research provides a new way to think about fair and sustainable data practices in the global coffee industry.

Keywords: smallholder coffee farming, data collection, Actor-Network Theory, sustainability governance, power dynamics, Sub-Saharan Africa

1. Introduction

1.1 Context

Agriculture is essential for food systems around the world, helping billions of people earn a living (FAO, 2021). In developing countries, smallholder farmers are especially important because they grow a large part of the world's food and support local economies (Lowder et al., 2021). However, these farmers often face challenges like having small plots of land, using old farming methods, and not having enough resources, which makes it hard for them to be productive and sustainable (Tamburini et al., 2020). As the global population keeps increasing and climate change poses more risks to food security, it is vital to tackle these issues (IPCC, 2022).

Within the broader context of agriculture, coffee stands out as a vital crop due to its economic and social significance and stands for the duality of smallholder farmers. As one of the most heavily traded agricultural commodities, coffee sustains an estimated 30 million smallholder households (Olana Jawo et al., 2023), yet its value chains are increasingly mediated by sustainability certifications and digital traceability systems that prioritise transnational corporate interests over farmer autonomy (Quezada-Rodriguez et al., 2025). These systems rely on data extraction, yield metrics, GPS coordinates, carbon sequestration figures, yet rarely reconcile the divergent motives behind such collection, such as compliance versus resilience, or surveillance versus empowerment. However, the coffee sector is also facing the challenges faced by the wider agricultural world: environmental degradation, fluctuating market prices, and inequities in the global value chain. To address some of these issues, sustainability initiatives have emerged, emphasizing certifications, standards, and transparent supply chains. These certifications and standards notably rely on robust data collection to monitor compliance and drive meaningful improvements across the sector.

Effective data collection is increasingly recognised as a crucial tool in enhancing agricultural productivity, ensuring food security, and promoting sustainability (Carletto et al., 2019). Research shows that, for smallholder coffee farmers especially, data collection can support decision-making, improve access to markets, and improve resilience against climate-related risks (Bunn et al., 2019; Vermeulen et al., 2019).

1.2 Problem Statement

In this situation, smallholder farmers play two important roles: they help ensure global food security but are often overlooked in data-driven decision-making (Martinez, 2023). Giller et al. (2021) point out that organizations gather agricultural data for several reasons, such as improving farming techniques and productivity (like checking soil health and predicting crop yields) (Wolfert, 2022), tracking supply chains and meeting certification standards (like Fair Trade and organic labels) (Grabs & Ponte, 2023), adapting to climate change and reducing risks (like forecasting weather and monitoring pests/diseases) (Mbow, 2019), helping farmers access financial services and credit (like using farm performance data for credit scoring) (Aker, 2021), and shaping policies and providing agricultural support (like government subsidies and advice systems) (Klerkx et al., 2022).

However, this report does not provide an in-depth comparative analysis of these motives. Most existing research seems to focus on specific aspects of coffee farming, such as consumer preferences (Hernández-Aguilera, 2021), farmers' perception of collective action (Silvert et al., 2021), or value distribution in the coffee supply chain (Hafner et al., 2025). While these studies contribute valuable insights, they do not directly address the comparative analysis of data collection motives and methods that this thesis aims to explore. The research approach of synthesizing and comparing various motives for and methods of data collection within a single analysis of smallholder coffee production appears to be novel and could provide valuable insights for the field. This type of comprehensive study could be particularly useful for organisations looking to optimise their data collection strategies and for policymakers seeking to create more effective governance frameworks in the coffee sector.

1.3 Research Aim and Objectives

This thesis focuses on data collection of smallholder coffee farms and aims to map and understand the motives and methods of this phenomenon. It does so through two key informant interviews and document analysis, using Actor-Network Theory to map power relations and controversies. To achieve this goal, the following objectives are central to this study:

- To improve scientific knowledge regarding data collection in smallholder coffee farming. The findings will contribute to the broader academic discourse on agricultural sustainability, governance, and digitalisation by providing a structured understanding of how data flows, is governed, and influences decision-making in smallholder farming.
- To provide actionable insights for organisations involved in agricultural development, sustainability initiatives, and policy-making. By mapping out the different motives and methods behind data collection, stakeholders can better design data-driven strategies that align with smallholder farmers' needs while ensuring that data collection efforts are efficient and transparent. Understanding how data is gathered, used, and perceived by different actors can help improve the implementation of certification schemes, market access programs, and agricultural support initiatives.
- This study aims to highlight the critical role of data collection in fostering equitable, sustainable, and resilient smallholder coffee farming communities. Smallholder farmers often operate under precarious conditions, facing market volatility, climate change, and limited access to resources. Effective data collection can empower these farmers by providing them with better access to credit, improved market linkages, and more targeted agricultural support services. Additionally, by examining how data governance structures shape decision-making processes, this study sheds light on potential power imbalances within agricultural networks and offers insights into how data practices can be leveraged to promote social equity.

1.4 Research Questions

To achieve the aim and objectives of this thesis the following research question is central to this study: *why is data collection important in smallholder coffee farming, and how is it done?* This question seeks to explore the economic, environmental, and societal considerations regarding data collection within the context of smallholder coffee farms, and what practices are used to do so.

To guide the research the following three sub-questions were formulated:

SQ1. Who is collecting data in smallholder coffee farming and what are their motives?

The aim is to investigate the various actors involved in the network, highlighting their roles, interests, and power dynamics.

SQ2. How is data collected in smallholder coffee farming?

The aim is to delve into the methods, tools, and technologies used for data collection.

SQ3. What types of data are collected?

The aim is to focus on the content and purpose of data collection.

1.5 Thesis Outline

This thesis is structured into six chapters, each designed to systematically address the research questions and objectives outlined earlier. Below is an overview of the remaining chapters:

Chapter 2: Theoretical Foundation and Literature Review

This chapter sets up the main ideas for the study, concentrating on Actor-Network Theory (ANT) and how it relates to gathering data in smallholder coffee farming. It looks at previous research on agricultural data, the difficulties smallholder farmers face, and coffee production, pointing out the areas this thesis will address. Important topics include how data contributes to sustainability, the power relationships in farming networks, and the social and technical factors involved in collecting data.

Chapter 3: Methodology

This chapter explains how the research was conducted, including the design and methods used to answer the research questions. It describes a qualitative, multi-method approach based on Actor-Network Theory (ANT) and the selection of documents from Sub-Saharan Africa. The chapter outlines the main ways data was collected, which include reviewing documents and conducting semi-structured interviews, as well as the coding framework used for analyzing the data. It also talks about the study's limitations, like the size of the sample and difficulties in accessing data.

Chapter 4: Results

Presenting the findings from primary data collection, this chapter is organized around the ANT analytical framework. It examines the actors involved in data collection (e.g., farmers, NGOs, and corporations), their motives, and the methods they employ. The chapter also explores the translation phases (problematization, interest, enrollment, and mobilization) and identifies key controversies, such as data ownership and digital exclusion. Results are presented thematically to address each sub-question.

Chapter 5: Discussion

This chapter combines the findings from Chapter 4 with the ideas from Chapter 2. It talks about the differences in what motivates people, the successes and failures during translation phases, and the power imbalances shown by controversies. The discussion also examines how data can maintain inequalities and suggests ways to redesign data systems for more fairness and sustainability.

Chapter 6: Conclusion

The last chapter wraps up the answers to the research questions by looking back at the results from previous chapters. It goes over the main question, which is why data collection matters in smallholder coffee farming and how it is done, and brings together the conclusions for each smaller question. It also gives practical advice for people involved, like policymakers, NGOs, and farmers, and offers ideas for future research to tackle unanswered questions or broaden the study. The chapter ends by considering what the findings mean for sustainable agricultural development.

This setup helps connect theory to real-life situations, allowing for a thorough look at why and how data is collected in smallholder coffee farming, all while staying focused on the study's goals.

2. Theoretical Foundation and Analytical Framework

2.1 Agricultural Data

The collection and utilization of data in the context of smallholder farming are critical for informing agricultural policies, improving productivity, and addressing challenges such as climate change and food security. Empirical studies conducted in Sub-Saharan Africa (SSA) have demonstrated that agricultural growth has a disproportionately positive impact on poverty alleviation, reducing poverty rates at a magnitude 11 times greater than non-agricultural economic growth among the poorest populations ((Giller et al., 2021); (John & Arul Leena Rose, 2024)). This underscores the necessity of high-quality data to support interventions targeted at improving agricultural outcomes for smallholder farmers. Given the increasing pressures of climate change and other socio-economic factors, policymakers and practitioners require detailed, context-specific information to understand how smallholder farmers are being affected and to develop appropriate adaptation strategies ((Martinez, NA); (Carletto et al., 2021); (Frelat et al., 2016); (Carletto, 2021); (Bayih et al., 2023); (Ndung'u et al., 2022); (Zaks & Kucharik, 2011)).

Data, broadly defined as the raw numbers, values, and textual information obtained through research, surveys, interviews, observations, and experiments (Viswanatha, 2023), serves as the foundational input for evidence-based decision-making. In recent years, innovations in data systems have facilitated the generation of real-time, disaggregated, and interoperable agricultural data, enhancing the ability of researchers, policymakers, and practitioners to analyse trends and design responsive strategies ((Carletto et al., 2021); (Giller et al., 2021); (Ebitu et al., 2021); (Zaks & Kucharik, 2011); (Moore et al., 2021)). However, despite advancements in data collection and management, significant challenges persist. Many agricultural databases remain incomplete, with missing values and a lack of metadata, introducing uncertainty into data analysis and limiting the reliability of research findings ((Fleischmann et al., 2023); (Carletto et al., 2021); (Taherdoost, 2021); (John & Arul Leena Rose, 2024); (Hafner et al., 2025); (Bright-Ponte, 2020)). These data limitations hinder the capacity to draw precise conclusions and develop targeted policy interventions that can effectively support smallholder farmers.

2.2 Low-income Countries

The challenges associated with data collection and utilization in smallholder farming systems are further exacerbated in low-income countries, where socio-economic factors severely limit the availability of data infrastructure. Many of these nations lack the necessary financial and institutional resources to establish and maintain robust data collection systems, leading to significant gaps in agricultural data availability and quality ((Fleischmann et al., 2023); (Carletto et al., 2021) ; (Carletto, 2021) ; (Kpienbaareh et al., 2024); (Sekajugo et al., 2022); (Nyariki, 2017)). The limitations in data availability are particularly concerning given the stark disparities in agricultural productivity between Sub-Saharan Africa (SSA) and other regions of the world. Research highlights that agricultural productivity in SSA has increased at a significantly slower rate compared to global trends, limiting the region's ability to leverage agricultural growth as a driver of poverty reduction and economic development ((Giller et al., 2021); (Chivenge et al., 2022); (Frelat et al., 2016); (Ndung'u et al., 2022); (Lanyasunya et al., 2006)). When coupled with the previously discussed issues of missing values, incomplete databases, and insufficient metadata, the absence of reliable measurement infrastructure in low-income countries further amplifies uncertainty in agricultural data analysis. This, in turn, hampers the development of policies that could enhance smallholder resilience and improve productivity. Given that agricultural growth has been shown to be particularly effective in alleviating poverty in SSA ((Giller et al., 2021); (John & Arul Leena Rose, 2024)), the lack of precise, high-quality data represents a major obstacle to realizing the full potential of agricultural development in these regions.

2.3 Smallholder Farming

Smallholder farmers play a critical role in global food systems, particularly in the developing world, yet they face numerous structural and environmental challenges that hinder their productivity and resilience. These farmers typically cultivate small plots of land, often located in marginal areas with limited soil fertility and inadequate access to irrigation. As their agricultural activities are largely dependent on rain-fed systems, they are highly vulnerable to climate variability and extreme weather events, further exacerbating food insecurity and economic instability ((Martinez, NA); (Giller et al., 2021); (Silvert et al., 2021); (John & Arul Leena Rose, 2024)). In addition to environmental constraints, smallholder farmers frequently lack access to credit, agricultural extension services, and technical support, which limits their ability to adopt improved farming practices or invest in productivity-enhancing technologies. Despite these challenges, smallholder agriculture remains the backbone of food production in developing countries. Researchers indicate that 80% of the food consumed in the developing world originates from smallholder farms, highlighting their central role in ensuring food security at local, national, and global scales ((Zheleva et al., 2017); (Frelat et al., 2016); (Lanyasunya et al., 2006); (John & Arul Leena Rose, 2024); (Olana Jawo et al., 2023); (Zaks & Kucharik, 2011)). However, the lack of reliable and comprehensive agricultural data, as previously discussed, poses a significant obstacle to developing policies that could support smallholder farmers in overcoming these barriers. The vulnerability of smallholder farmers is further heightened by broader transformations in agricultural and environmental systems. The agricultural sector as a whole is undergoing profound shifts due to climate change, economic fluctuations, and evolving market demands, with smallholder farmers—particularly the estimated 500 million family farms—being disproportionately affected by these changes ((Carletto, 2021); (Bayih et al., 2023); (Gray & Gibson, 2013); (Carletto et al., 2021)). Addressing data gaps and improving access to measurement infrastructure are essential for designing targeted interventions that enhance smallholder resilience and long-term sustainability.

2.4 Coffee Production

Coffee production is a cornerstone of rural livelihoods in many developing regions, particularly in East Africa, where an estimated 30 million people in smallholder households rely directly on coffee cultivation for their income and sustenance ((Olana Jawo et al., 2023); (Silvert et al., 2021). Smallholder coffee farmers typically cultivate coffee on plots of less than two hectares, often in remote, marginal areas where infrastructure, market access, and agricultural services are limited. Much like other smallholder farmers, coffee producers in these regions depend primarily on rain-fed agriculture, making them highly susceptible to climatic variations and extreme weather events that threaten yield stability and quality. Moreover, access to credit, technical assistance, and improved agricultural inputs such as disease-resistant coffee varieties and organic fertilizers remains inadequate, further constraining their productivity and income potential ((Martinez, NA); (Giller et al., 2021); (Silvert et al., 2021). Despite these challenges, smallholder coffee farms play a vital role in global coffee supply chains. Coffee is one of the most valuable agricultural commodities in the world, and its production follows a complex set of practices that influence both yield and quality. Coffee cultivation involves several key stages, beginning with seedling propagation in nurseries, followed by transplantation to the field, where trees typically take three to four years to reach full productivity. Farmers must carefully manage shade, soil health, and pest control to ensure high-quality beans. Traditional agroforestry systems, in which coffee is grown under the canopy of taller trees, are common in SSA and provide ecological benefits such as biodiversity conservation, soil moisture retention, and carbon sequestration ((Zaks & Kucharik, 2011); (Lanyasunya et al., 2006)). However, despite the environmental advantages of such systems, smallholder coffee farmers often struggle to achieve consistent yields due to aging trees, inadequate replanting strategies, and limited knowledge of modern agronomic techniques ((Frelat et al., 2016); (Ndung'u et al., 2022)). The challenges facing smallholder coffee farmers are further compounded by global market fluctuations and price volatility. Since coffee is primarily traded as a cash crop, price instability can have severe consequences for smallholder households, whose incomes depend on securing fair prices in international markets ((Carletto et al., 2021); (Bayih et al., 2023); (Gray & Gibson, 2013); (Carletto et al., 2021)). Certification schemes such as Fair Trade and Rainforest Alliance have sought to mitigate some of these issues by offering farmers premium prices for sustainably grown coffee, yet participation in these programs remains limited due to the high costs and administrative barriers involved ((John & Arul Leena Rose, 2024); (Silvert et al., 2021)). Certification schemes function as obligatory passage points (Callon, 1986), where farmers must accept standardised data practices to access premium prices. These non-human actors redefine power relations, while NGOs frame certifications as empowering, farmers reveal how audit protocols can displace traditional knowledge systems. Furthermore, the lack of comprehensive and reliable data on coffee production exacerbates these issues, as policymakers and development organizations struggle to design effective interventions without accurate information on yields, production constraints, and market conditions ((Fleischmann et al., 2023); (Carletto et al., 2021) ; (Kpienbaareh et al., 2024)). Given the significant role of smallholder coffee farming in rural livelihoods and economic development, addressing these challenges requires targeted investments in agricultural research, extension services, and digital data systems. As previously highlighted, improved data collection mechanisms are essential to overcoming uncertainties in agricultural analysis, particularly in low-income countries where measurement infrastructure remains inadequate ((Fleischmann et al., 2023); (Carletto et al., 2021); (Sekajugo et al., 2022); (Nyariki, 2017)). By integrating real-time, interoperable data systems into smallholder coffee farming, stakeholders can gain deeper insights into production trends, climate risks, and value chain dynamics, ultimately enabling more informed policy decisions and sustainable development initiatives. Ensuring that smallholder coffee farmers have access to credit, climate-smart agricultural practices, and stable market opportunities is crucial for securing both their livelihoods and the long-term resilience of global coffee production. While these structural challenges are well-documented, conventional analyses often treat data gaps as technical problems solvable through better tools or training. Such approaches risk overlooking how data collection emerges from networks of human and non-human actors. Actor-Network Theory (ANT) provides a framework to trace these socio-technical formations, revealing how power operates through seemingly neutral elements like missing metadata or app interfaces.

2.5 Actor-Network Theory (ANT) and Analytical Framework

Actor-Network Theory (ANT) provides a valuable theoretical framework for analysing the intricate relationships and interdependencies that shape agricultural systems, particularly within smallholder farming and coffee production. ANT is defined as a set of tools or approaches designed to examine the complexities and tensions that emerge in cross-institutional partnerships, where actors from different organizational backgrounds and roles must coordinate their efforts to achieve shared goals ((Rohstock, 2024); (Cooke et al., 2024)). Given the multifaceted nature of agricultural development—where smallholder farmers interact with government agencies, NGOs, private sector actors, and international markets—ANT offers a robust lens for understanding how these networks function, adapt, and evolve over time. By tracing the interactions between actors within the agricultural sector, ANT can help illuminate the socio-technical challenges of data-driven policy design and implementation. More broadly, ANT has been widely recognised as one of the dominant frameworks for explaining the dynamics of sustainability-oriented innovation, including the complex socio-technical challenges associated with its implementation ((Aka, 2025); (Gray & Gibson, 2013)). This is particularly relevant in the context of smallholder agriculture, where sustainability efforts such as climate-smart farming, agroforestry in coffee production, and fair-trade certification require coordinated action among diverse stakeholders. Applying ANT facilitates a comprehensive analysis of the interdependent relationships between individuals, institutions, and technological systems, allowing researchers to better understand how different forces interact to influence agricultural productivity and resilience ((Xu et al., 2022); (Castella et al., 2022); (Tang et al., 2018); (Fisher et al., 2024); (Wynn & Garwood-Cross, 2024); (Fu-ren & Szu-yun, 2014)). The increasing use of big data and AI in agricultural research further highlights the relevance of ANT in studying emerging digital infrastructures and their implications for smallholder farming. Many social scientists over the past decade have been heavily influenced by Bruno Latour's work, particularly in examining how data collection, algorithmic decision-making, and AI-driven policy tools mediate human interactions within agricultural networks ((King, 2024); (Mifsud, 2024)). ANT has been influential in unpacking the complex, often contentious adoption of precision agriculture technologies, such as GPS-guide tractors, IoT sensors, and AI-driven analytics in farming systems. Carolan's (2023) study on ANT showed it helped reveal how these technologies do not simply "diffuse" into passive environments, but actively reshape power dynamics, labor practices, and ecological management through their entanglement with human and non-human actors.

Despite its utility, ANT has faced several critics. First, the principle of generalised symmetry, which treats human and non-human actors as equal participants in networks. Critics argue that it risks obscuring structural power imbalances. Another critique relates to the lack of normative engagement, often avoiding evaluating whether networks are just or sustainable. Critics like Sismondo (2009) argue that ANT's descriptive neutrality avoids ethical questions, such as "who bears the risks of algorithmic errors?". These critiques do not negate ANT's value but highlight its complementary role in agrarian studies.

ANT provides the theoretical lens for analysing how data collection in smallholder coffee farming is shaped by interactions between human and non-human actors. It treats all entities—people, policies, technologies, and economic forces—as actors that co-construct the data collection network. This allows for an in-depth examination of how different stakeholders influence, negotiate, and adapt data practices. The four actor groups (NGOs, the public sector, the private sector, and smallholder farmers) serve as key human actors, while technologies, regulations, and economic drivers act as non-human actors shaping data collection. ANT enables a comparative analysis of how these actors interact across different organizational contexts. While building on qualitative approaches, this research applies ANT's framework to treat humans and non-humans as equally constitutive of data networks. The ANT lens, drawing on Latour (2005) and Callon (1986) is used through three main stages: actant symmetry, translation phases, and controversy mapping. Actant symmetry is made up of an explicit analysis of how technologies, regulations, and ecological factors exercise agency alongside human actors. The translation phases allow systematic tracking of how problems are defined (problematisation), interests aligned (interessement), roles assigned (enrolment), and outcomes stabilised (mobilisation). Lastly, controversy mapping identifies where network stabilisation fails.

This study applies Actor-Network Theory (ANT) to conceptualise agricultural data collection as a contested socio-technical network. Actor-Network Theory provides the central theoretical framework for this study, shaping both the research approach and methods. ANT's emphasis on the interplay between human and non-human actors enables a detailed examination of how motivations, tools, policies, and practices collectively shape data collection among smallholder farms. In the context of coffee sustainability, the key network is the global coffee value chain, and the actors include smallholder farmers, NGOs, Public Sector actors, and Private Sector actors. By mapping out these actors and their interactions within the broader network, ANT allows a deeper understanding of the motives, challenges, and opportunities involved in data collection.

Table 1

Analytical Framework for Data Collection

ANT Concept	Definition/Key questions	Application to thesis
Actants	Human and non-human actors shaping data collection.	Identify: - **Human**: Farmers, NGOs, corporations, governments. - **Non-human**: Apps, certifications, policies.
Translation Phases	How actors align interests (e.g. farmers enroll in certification schemes for market access). How networks form and stabilize (Callon, 1986).	Analyze: 1. **Problematization**: How is data collection framed as a solution? 2. **Interessement**: How are actors recruited (e.g., incentives)? 3. **Enrollment**: Who is assigned roles (e.g., data providers)? 4. **Mobilization**: Does the network stabilize or collapse?
Controversies	Conflicts over data ownership (e.g. farmers lack access to their own yield data). Points of conflict or breakdown in the network.	Examine: - **Data ownership**: Who controls data? - **Exclusion**: Who is left out? - **Motives**: Do actors' goals align or clash?
Outcomes	Stabilized practices or unresolved tensions.	Assess: - Which data practices become entrenched? - Where do power imbalances persist?

3. Methodology

3.1 Research Approach and Design

An extensive literature review to gain insights into the main topics and themes of this study was first conducted. This included academic literature on smallholder farming, coffee production, data collection practices, and Actor-Network Theory (ANT). Google Scholar was used to search the following keywords: "smallholder farming"; "smallholder coffee"; "data collection"; "data collection practices"; "ANT"; "Sub-Saharan Africa".

To answer the research questions, a qualitative, multi-method research approach has been applied grounded in actor-network theory (ANT). Based on ANT, an analytical framework has been developed to analyze how data collection in smallholder coffee farming is shaped by interactions between human and non-human actors. The four actor groups—NGOs, the public sector, the private sector, and smallholder farmers—serve as key human actors, while technologies, regulations, and economic drivers act as non-human actors.

3.2 Case Studies

This research examined a few cases from each human actor group. The cases focus on smallholder coffee farming in Sub-Saharan Africa, specifically Ethiopia, Uganda, and Kenya, which are major coffee-producing countries with distinct governance structures and sustainability initiatives. Selection criteria included the actor's role in data collection, ensuring that cases actively gather and utilise data for sustainability monitoring, market access, or agronomic improvements. Accessibility was also a key factor, prioritising cases with publicly available reports or organizations open to participating in interviews. Additionally, the selected cases must provide diverse perspectives on data collection, including digital monitoring, certification schemes, and farmer-led initiatives. Furthermore, cases must demonstrate both human and non-human actors in data collection.

To identify suitable cases, a desk study was conducted using academic literature, industry reports (e.g., from Fairtrade, Rainforest Alliance, and World Coffee Research), and government/NGO publications. Reports from key institutions such as the Ethiopian Coffee and Tea Authority, Uganda Coffee Development Authority, and Kenya Coffee Research Institute were reviewed, along with sustainability programs from major companies such as Nespresso, Olam, and Starbucks. From this research, a shortlist of five potential cases per actor group was created:

- TechnoServe's Coffee Initiative (Ethiopia), Solidaridad's Blockchain Traceability Program (Uganda), and Enveritas AI-driven assessments (Kenya) for NGOs;
- Public sector initiatives such as Ethiopia's farmer registry, Uganda's digital mapping project, and Kenya's research-based extension programs;

- Nespresso’s AAA Sustainable Quality Program, Olam’s AtSource system, and Starbucks’ C.A.F.E. Practices for private-sector initiatives;
- Cooperatives like Yirgacheffe Coffee Farmers Union (Ethiopia), Bukonzo Organic Farmers Cooperative (Uganda), and Nyeri Coffee Farmers Cooperative (Kenya).

Following this shortlist, key representatives from each potential case were contacted to assess feasibility. This included NGO project managers, government officials, sustainability leads, and cooperative leaders. Stakeholders were identified via LinkedIn, academic networks, and industry events, and an email outreach strategy was implemented to request interviews and relevant reports. The selection was refined based on willingness to participate and the availability of supporting documents, ensuring that all cases offer sufficient depth for analysis.

Unfortunately, the shortlist was cut down due to resource and time constraints. The final list included TechnoServe’s Coffee Initiative, Enveritas, Ethiopia’s farmer registry, Uganda’s digital mapping project, Nespresso’s AAA Sustainable Quality Program, and the Bukonzo Organic Farmers Cooperative.

3.3 Methods for Data-collection

The selected cases were analysed through document review and semi-structured interviews, providing insight into how different actors collect, manage, and utilise data in smallholder coffee farming. Information was found by scouring google through the keywords related to each case study, such as “Ethiopia Coffee Industry” or “Data Collection Methods”. A list of over 50 documents were analysed and coded.

Interviews were recorded, written down, and organized. The interview guide is based on ANT’s four translation phases and modified from Gray (2013) and Castella’s (2022) actor-intervention matrices, making sure the questions address both personal choices and network limitations. This approach shows how data collection networks are put together, which is a new use of ANT in agricultural research. In total, only two interviews were done. Each interview lasted about 1 hour, was recorded with consent forms, and was written down by hand.

3.4 Methods for data-analysis

Data from interviews and documents were analysed using the ANT framework (Table 1). Coding followed three steps:

1. Actant identification: tags marked human/non-human actors.
2. The translation phases involve sorting thematic codes into four categories: problematisation, interessement, enrolment, and mobilisation.
3. Controversy mapping: conflicts were flagged to identify network breakdowns.

NVivo coding steps:

1. Node creation (see Table 2 for ANT codes).
    a. Parent nodes mirrored ANT components.
    b. Child nodes housed specific codes. Aligned with ANT's focus on actor interactions.
2. Deductive vs. inductive coding.
    a. Deductive: transcripts were first coded using ANT-derived categories.
    b. Inductive: emergent themes were added.

Table 2

Codes for Nvivo coding

Phase	Code	Definition
Actants	Farmer – Motive	Farmer's stated reason for data participation.
	NGO – Motive	NGO's justification for data collection.
	Corporation – Compliance	Corporate actor's regulatory data demands.
	Technology – Agency	How tools and apps influence behaviour.
	Policy – Enforcement	Government regulations shaping data flows.
Translation	Problematisation - Yield Gap	Framing low yields as a problem.
	Problematisaion – Climate Risk	Framing climate change as a problem.
	Interest – Premium	Using price premiums to recruit farmers.
	Interest – Penalty	Penalties for non-compliance.
	Enroll – Training	Training farmers to use tools.
	Enroll – Contract	Contracts binding farmers to data sharing.
	Mobilisation – Data flow	Successful data circulation.
	Mobilisation – Resistance	Network breakdowns.
Controversies and power	Conflict – Ownership	Disputes over who owns or controls data.
	Conflict – Access	Barriers to data access.

	Exclusion – Digital	Marginalisation of non-tech savvy actors.
	Exclusion – Gender	Gender-based data gaps.
	Power – Surveillance	Data used for monitoring vs. empowerment.
	Power – Bargaining	Negotiations over data terms.
Outcomes	Outcome – Adoption	Stable data practices.
	Outcome – Rejection	Rejected data systems.
	Outcome – Hybrid	Mixed adoption.

The coding framework was developed by integrating Actor-Network Theory (ANT) with empirical insights from agricultural data governance. Drawing on ANT's core principles (Latour, 2005; Callon, 1986), the categories were adapted to reflect documented conflicts in smallholder data collection (Giller et al., 2021), ensuring the analysis bridged theoretical and field-based perspectives. The coding structure operationalized ANT's key concepts to dissect how human and non-human actors negotiate, resist, or stabilize data collection practices. For actant symmetry (Latour, 2005), codes such as [Tech-Agency] and [Policy-Enforcement] reflected ANT's principle that non-human actors (e.g., digital tools, certification standards) actively shape networks alongside human participants. This aligns with Latour's assertion that technologies prescribe actions (Reassembling the Social), evident in how farm management apps dictate data-entry protocols for smallholders. For translation phases (Callon, 1986), the coding captured Callon's four moments: [Prob-YieldGap] (problematization, e.g., framing low yields as a "data deficiency"), [Interest-Premium] (interessement, e.g., financial incentives to adopt data-sharing contracts), [Enroll-Contract] (enrolment, e.g., compliance with certification requirements), and [Mobil-Resistance] (mobilization, e.g., collective pushback against unfair data terms). These phases were inspired by Callon's study of scallop fisheries (Mapping the Dynamics of Science and Technology), where network stability hinged on negotiated roles. Controversy mapping (Venturini, 2010) employed codes like [Conflict-Ownership] and [Dispute-Access] to identify tensions where networks faltered, such as clashes over data ownership between farmers and agribusinesses. This approach drew on Venturini's "cartography of controversies" to reveal fault lines in socio-technical systems. Empirical grounding came from peer-reviewed agricultural studies. For instance, [Power-Surveillance] reflected corporate surveillance in precision agriculture (Giller et al., 2021, Food

Security), while [Exclusion-Digital] captured how tech-centric systems marginalize resource-poor farmers (Zaks & Kucharik, 2011, Environmental Research Letters). Codes like [Corp-Compliance] stemmed from research on certification schemes as tools of control (Hansen, 2024, Sustainability). Methodologically, the coding adhered to qualitative best practices. Thematic coding (Braun & Clarke, 2006) generated inductive tags like [Farmer-Motive] from interview narratives, while deductive coding (Gibbs, 2007) applied ANT's predefined categories (e.g., [Mobil-Resistance]). Triangulation (Denzin, 1978) cross-checked discrepancies, such as NGO claims versus farmer experiences. The codes were further tailored to the coffee-farming context. Actor-specific motives distinguished [NGO-Motive] (sustainability targets) from [Farmer-Motive] (livelihood security). [Tech-Agency] highlighted apps' dual role in coercing or enabling farmers, and [Enroll-Contract] mirrored real-world dynamics (e.g., Nespresso's AAA program).

3.5 Reflections on Data Gathering

While this study provides valuable insights into data collection practices in smallholder coffee farming, several methodological limitations must be acknowledged to contextualize the findings and guide future research. The study relied on a limited number of interviews (two) and a focused selection of cases, which may not fully capture the diversity of data collection practices across Sub-Saharan Africa. The small sample size restricts the generalizability of the results, as regional variations in governance structures, farmer demographics, and technological adoption are not comprehensively represented.

The exclusion of certain actors (e.g., non-certified farmers, smaller NGOs) due to accessibility constraints may introduce bias, as the findings disproportionately reflect the perspectives of well-resourced organizations and compliant farmers.

While document analysis provided breadth, it is inherently limited by the quality, transparency, and intended audience of the sources. Reports from NGOs and corporations may emphasize success stories or align with organizational agendas, potentially overlooking systemic challenges or farmer dissent.

The study's reliance on publicly available documents also means that proprietary or sensitive data (e.g., internal corporate metrics) were inaccessible, limiting the analysis of power dynamics in closed networks.

The two interviews, though insightful, were insufficient to triangulate all actor perspectives. For instance, the absence of interviews with private-sector representatives or non-cooperative farmers left gaps in understanding coercive pressures or resistance strategies.

Time and logistical barriers prevented follow-up interviews, which could have clarified ambiguities (e.g., data ownership disputes) or explored emergent themes (e.g., gendered exclusion) in greater depth.

Practical limitations (e.g., funding, fieldwork access) necessitated reliance on secondary data and a narrowed case selection. This curbed opportunities for participatory methods (e.g., farmer diaries, ethnographic observation) that could have enriched the study with ground-level perspectives.

4. Results

The list of all documents analysed can be found in Appendix 1. The # referred to throughout the results are the # of each document. Interview 1 refers to the interview with an expert in the coffee industry. Interviews 2 refers to the interview with the Boku Organic Farmers Cooperative.

4.1 Actants in Data Networks

4.1.1 Farmer-Motive

The coded extracts highlight several key motivations driving farmers to adopt new practices and engage in data collection. These include practical training leading to improved yields, market access and compliance, and economic and operational benefits.

The interviews highlighted that farmers participate in data collection as it helps their cooperative "inform them on their areas of improvement" [1]. Furthermore, farmers' participation is "oftentimes a market access issue or a requirement for certification." [2]. The prospect of gaining "access to a better price" for their coffee would be a compelling reason for farmers to share data.

In terms of the practical training, #10 states how "[a] Long time ago, the agronomy government official used to come and just tell us to do this and that but TechnoServe came all the way to the field and showed us how to actually do it. Now we know how to use NPK, we know how and when to pick our berries from the coffee tree and now we get more yields from the same tree." In addition to this, #31 states that with improved trainings and data collection, "Knowing the data definitely translates into improving their techniques and correcting things that went wrong".

For the compliance motives, #23 indicates that "We have to show that there's something we are doing to comply with EUDR requirements […] Roasters in the EU want Uganda to be compliant with [deforestation and address climate change crisis the world is facing."

Lastly, for the economic and operational benefits, both #42 and 43 stated that one of the motives to collect data is that it "helps us a lot to know expenses and costs, as with the financial information and the data on every activity of the farm, we can calculate the costs by bag, by hectare, by year, the effective and total operational costs".

4.1.2 NGO-Motive

The coded extracts show the main reasons and goals of NGOs, which are: checking the impact and confirming programs, ensuring sustainability for everyone, coordinating with stakeholders, promoting decent work, and aligning sustainability with business practices.

In regard to the impact assessment and program verification, #10 stated that it aimed to "(i) test and check the robustness of current impact estimates; (ii) to provide new insights on yield impact and best practice adoption; and (iii) to independently verify data collection methods and identify inherent biases". #21 also mentions that they aim to help companies "make truthful, independently-verified sustainability claims about products they purchase.".

In terms of stakeholder coordination and decent work advocacy, #26 states that increased data collection in Uganda aims to "understand the current landscape of projects and interventions working to achieve decent work in coffee-growing areas and identify potential synergies and opportunities for collaboration with key actors".

Lastly, harmonising sustainability and practices is mentioned in both #42 and #43, in which the Rainforest Alliance's sustainable agriculture certification program is claimed to be a means of "creating a world where people and nature live in harmony" and making "responsible business the new normal". #21 also mentions that Enveritas' purpose is to "set requirements and best practices for producers verified by Enveritas.".

4.1.3 Corporation-Compliance

The coded extracts demonstrate how corporations and industry authorities engage with compliance requirements. The key aspects are certification and private standards, sustainability claim verifications, regulatory traceability systems, and labor compliance programs.

The organic farmers cooperative of Boku collect data primarily to ensure farmers are "compliant to the standards" [2] such as organic regulations and fair trade standards. For companies further up the supply chain, data collection serves as a "value add" for traceability and to position themselves as managing a "fully transparent, sustainable supply chain.".

In terms of certification and private standards, #17 states that "companies have also developed their own private verification codes… although each of these codes is defined by the company concerned and therefore, they are all different, they also address social and environmental issues of coffee production".

#21 Enveritas also require companies to substantiate sustainability claims, which "contain relevant summary information about the size and nature of the supply chain or sourcing region, compliance levels for the applicable sustainability criteria, and the data collection methods used."

Regarding traceability systems, #35 states that the Ethiopian Coffee and Tea Authority is leading efforts to "develop a traceability system to comply with EUDR standards". The text also states that "achieving EUDR compliance could strengthen Ethiopia's position in sustainable coffee production, while non-compliance risks unintended negative consequences.

Lastly, labour compliance programs are mentioned within the Nespresso AAA program, #42 and #43, where farms receive "recordkeeping assistance to better understand the economics of their workforce, as well as to ensure compliance with labour regulations”. Nespresso also monitors practices through “internal and external inspections” to promote workers’ rights and ensure compliance.

4.1.4 Technology-Agency

The coded extracts highlight how digital tools and technological solutions are actively shaping coffee farming practices and decision-making processes. Comprehensive farm management systems, remote sensing for crop health, geospatial risk assessment, and mobile workforce management are the key components.

The Boku farmer cooperative previously had a mobile app that “didn’t work out”[2] and was abandoned. They are currently looking to develop a new app for field data collection, acknowledging the shift towards digitisation.

Farm management systems are mentioned in #11, stating that TechnoServe is “always on the lookout for digital tools that will help farmers improve their incomes and build a better future”. Tools which directly support and influence farming processes and data management are named as “farm and farmer management, crop management, harvest and procurement, quality control, QR code integration, network integration”.

In addition to this, #25 details some technology for remote sensing of crop health, “depending on their overall health, plants reflect different amounts of visible green and near-infrared light. These variations can be captured from imagery and analysed.”. #32 also mentions “geospatial analysis” to develop customised “risk maps” targeting major reforestation risk locations of certified farms and protected areas.

Lastly, mobile apps are mentioned in #42 and #43 as being able to “assign daily tasks to each worker. The app also collects data on the work done and facilitates the counting of hours worked and to be paid.”

4.1.5 Policy-Enforcement

The coded extracts illustrate how regulatory policies directly shape coffee production, trade, and data management practices: trade and taxation policies, and EU Deforestation Regulation (EUDR) Compliance.

The Boku farmer cooperative complies with “national laws and the international laws regarding human rights” [2].

A specific tax is mentioned in #17, the “German Coffee Tax”, which is a direct government regulation impacting the coffee value chain. This tax is a significant cost component, amounting to 2.19€/kg of the total retail value of coffee products.

The EU Regulation on Deforestation-free Products is mentioned in many documents, notably in #23 who state that “each farmer will have a unique code”, and that over “60% of Uganda’s coffee exports go to the EU market”, making compliance crucial. Furthermore, #35 is developing a traceability system to comply with EUDR standards, which will “integrate coffee traceability records, geospatial data on coffee plots, forest management zones for forest-grown coffee, deforestation data, and environmental assessments for larger plantations”.

4.2. Translation Phases

4.2.1 Problematisation-Yield gap

The coded extracts identify yield gaps as a key challenge in coffee farming, namely due to suboptimal farming practices and variability in coffee production.

Low yield estimates are a primary concern for Boku, as it directly impacts their “production capacity” [2], ability to project business, borrow money, and plan sales. The cooperative collects data to assess if farmers are implementing good agricultural practices to “increase production”.

#10 aimed to provide “new insights on yield impact and best practice adoption.”. This framing suggests that a problem existed where farmers were not achieving optimal yields, which the program aims to resolve. The study also stated that it aimed to estimate “the impact of the program on average yield levels”.

#29 aims to improve understanding of "large differences in coffee quality between farms and between villages within a district".

4.2.2 Problematisation-Climate risk

The coded extracts consistently frame climate change as a critical challenge for coffee production, emphasizing its disruptive effects on yields, quality, and farming systems. More precisely, they highlight the direct impact on production stability, threats to quality and profitability, deforestation and ecosystem stress, as well as policy and intervention drivers.

#17 acknowledges that "climate change is making it difficult for farmers to produce reliable yields". #29 also states that "the impact of climate change and the absence of shade systems in many farms is something that needs to be reviewed seriously. It has become clear from the dataset that both temperature and shade cover have an impact on coffee quality.". Furthermore, #31 indicates that farmers' inherited methods of coffee production are becoming inadequate because "climate change is making it clear that different approaches are sorely needed".

In response to climate risks, #23 states that the EUDR addresses the "deforestation and climate change crisis the world is facing.".

Lastly, #42 and #43 state that coffee farms are "reliant on irrigation systems that are vulnerable to the impacts of climate change". Nespresso also launched a reforestation project promoting agroforestry as a means of "protecting biodiversity and vulnerable bodies of water located in the region".

4.2.3 Interest-premium

The coded extracts show that higher prices encourage coffee farmers to use better quality and sustainable methods, mainly through bonuses for certifications or direct market rewards.

Boku holds Fair Trade certification, and states that data collection on coffee quality and traceability is particularly relevant for "higher end speciality coffee segments" [2].

#29 states that "to obtain a premium price for high quality coffee, smallholders mostly need to be organised in groups that have acquired certification status and/or have a good and consistent trade link with a registered buyer.". #42 and #43 state that the Nespresso AAA program offers "generous market incentives paid to farmers" and that farmers gain "access to premiums that often exceed market prices".

4.2.4 Interest-penalty

The coded extracts illustrate how penalties and enforcement mechanisms affect farmers' behavior and compliance in coffee production, either through financial coercion or by excluding them from programs if they do not comply.

#10 farmers describe the fear of loans from local authorities, "the way they do it is not ideal for farmers because if you don't make the payment in time they take your coffee by force so some farmers fear the loans, there is no payment installation scheme too."

In the case of Nespresso's program, #42 states that "a farm found to be noncompliant is then given time to take corrective action, but failure to correct these issues results in exclusion from the Nespresso Program.".

4.2.5 Enrolment-Training

The coded extracts show that training programs are the main way to get farmers to use better data collection methods. This is clear through practical, on-the-ground training, tracking how many farmers adopt these methods, filling in knowledge gaps, and including them in certification programs.

Boku trains its internal inspectors on how to use data collection tools (paper forms), interpret questions, and "probe the farmer in order to aggregate the relevant information." [2]. They also "train farmers' capacity on good agricultural practices, and compliance to organic standards."

In #4, a farmer from a cooperative noted that a company "came all the way to the field and showed us how to actually do it." Furthermore, #5 highlights that "after the training, 56% of participating farmers had adopted at least half of the improved agricultural techniques". #6 also talks about "the best training was on nutrition and the different types of composting, he had never seen such techniques" and learning techniques they "really did not have much knowledge about" before.

#31 states that certified farmers are supported by training to “better assess their output” and correct issues. The Nespresso program, #43, includes “farmer training, a sustainability standard, an assurance processes, and a consumer-facing label.”.

#10 also states that the training aims to provide “new insights on yield impact and best practice adoption”. It measures the “cumulative impact of training on average yields (kg/tree)”.

4.2.6 Enrolment-Contract

The coded extract highlights contractual agreements as a mechanism for structuring coffee production and market relationships.

The expert notes that farmers have “very limited say” [1] and are rarely asked for “explicit consent” due to “huge power and knowledge asymmetries” [1].

4.2.7 Mobilisation-Data flow

The coded extracts demonstrate how data collection, analysis, and sharing are actively mobilized to enhance transparency, traceability, and decision-making in coffee value chains; this is shown through digital tools for efficient data management, standardized compliance monitoring, and data-driven stakeholder engagement.

#11 mentions seeking “digital tools that will help farmers improve their incomes and build a better future.”. Furthermore, the document states that “easy data recording and access to information bring transparency to a food ecosystem. The managing of this data on paper is cumbersome and inaccurate.”

Nespresso’s AAA program, #43, states that “it is both interesting and challenging to have data on sustainability performance. Analysing and presenting the monitoring and evaluation data makes it easier to organise a constructive discussion with all our partners.”. The process for monitoring and evaluation involves “collecting data, analysing data, and communicating and adapting.”.

4.2.8 Mobilisation-challenges and resistance

The coded extracts reveal multiple forms of resistance that hinder effective data collection and adoption, including data collection biases and errors, farmer reluctance toward record-keeping, and resource constraints.

Boku experienced a “network breakdown” [2] with a previous mobile app that “didn’t work out” and was abandoned. The reliance on paperwork and manual analysis for 4100 farmers results in a “significant time burden”, representing a bottleneck in data processing.

#10 identifies “potential over-reporting by farmer trainers and enumerator bias”. While not systematic over-reporting for yield data, there were “inconsistencies in Farmer Trainer reporting”.

Farmers’ stated reasons in #28 for low adoption of record keeping include that they “don’t know exactly why they have been given these books, they don’t value it.” and some “are not able to read and write”. Some felt “the trainings on this were not sufficient”. In addition, #84 states that farmers did not understand why they should fill it, being “scared that this would be a way to be taxed”.

Furthermore, #45 states that farmers lack equipment, stating “everything has been good except that we don’t have equipment, if we could use scissors, pumps and other items, our harvest would increase and we could pay for these items back in a very short time”.

4.3. Controversies

4.3.1 Conflict-Access

The coded extracts highlight systemic barriers that restrict farmers' access to information, influence, and data transparency, specifically due to inequitable value distribution and a lack of clarity in trade and export data.

Boku asserts that “we manage our own data” [2], though they seek external analytical help for specific tasks like geo-location analysis. There’s ambiguity in data ownership within the industry; for certification data, it’s not “entirely clear” if the cooperative or exporter owns it, creating a “fuzzy space”.

#17 states that “generally, coffee farmers connected to certified supply chains generate a higher net income than those connected to non-certified supply chains.” However, it notes “the disconnect between end-product and farm production leaves farmers with limited, if any, points of leverage to capture a share of the-product.”

#44 states that estimating costs at the collection and export level is "challenging" because "data on this subject is virtually non-existent in the public domain". There are "no official statistical databases on exporter costs, taxes, and net profit margins, only isolated information in academic papers".

4.3.2 Exclusion-Digital

The coded extracts highlight that low literacy rates create barriers to participation in data-driven farming systems, even when using non-digital tools, such as the requirement of literacy for record-keeping and the absence of support systems.

A significant barrier is that "a lot more data is available than what is shared publicly" with organisations seeing data as a "competitive advantage" [1].

A stated reason in #8 for low adoption of record keeping is that "some of them are not able to read and write". Furthermore, #34 states that "because they can't read or write at all and no one was there to help them write in their record books.".

4.3.3 Exclusion-Gender

The coded extracts show detailed patterns in how different genders are represented in coffee farming data collection and program participation. Key issues include differences in sampling, conflicting trends in participation, and problems with visibility in the structure.

#10 states that the yield sample resulted in an "over-representation of cooperative members and fewer women".

4.3.4 Power-Surveillance

The coded extracts demonstrate how monitoring systems create asymmetric power dynamics in coffee value chains, including behavioral influences through monitoring, internalized compliance, dual-use surveillance systems, and operational discipline.

#7 and #22 indicate that "the regular monitoring of farmers in the yield sample led to a 12 to 15 percentage point increase on farmer attendance rates, a 7 percentage point increase in best practice adoption and a significant increase in fertiliser usage."

#7 also states that "frequent interaction between farmers and TechnoServe staff" has a "significant impact on how these farmers experience the training."

#32 states that certified farms and processing facilities are required to "set up internal oversight committees". #43 indicates that Nespresso and partners "monitor practices on participating farms through internal and external inspections" to promote workers' rights.

4.3.5 Power-bargaining

The coded extracts highlight structural imbalances in negotiation power within coffee supply chains, including farmers' disadvantaged positions, bargaining power implications, and the structural nature of inequality.

The expert states that accessing anonymised company data requires "some sort of an agreement", but these negotiations are "Not easy" [1], suggesting unequal bargaining positions.

#17 explicitly states that "there are inequalities in the coffee supply chain, with an important number of coffee farmers having limited insights, opportunities and control over the final form and destination of the coffee they produce/export. This puts most farmers in a disadvantaged bargaining position when it comes to getting value for their coffee."

5.1 Outcome

5.1.1 Outcome-Adoption

The coded extracts demonstrate measurable success in the adoption of improved agricultural practices among coffee farmers participating in training and certification programs: training-driven adoption and certification program compliance.

#5 indicates that "after the training, 56% of participating farmers had adopted at least half of the improved agricultural techniques". #10 states that the agronomy program has had a "substantial impact on both best practice adoption and the productivity of coffee trees".

5.1.2 Outcome—Rejection

The coded extracts highlight resistance to record-keeping despite training interventions, which is evidenced by a decline in adoption after training and the documented reasons for rejection.

#10 mentions that, for record keeping, the adoption of practices by farmers decreased after the training compared to before the intervention.

5.1.3 Outcome-Hybrid adoption

The coded extracts show that farmers use some practices but not others, which results in only a partial use of the best methods. Factors in their situation cause them to pick and choose which practices to adopt and make it hard for them to implement some.

5. Discussion

This thesis demonstrates how competing actor motivations, technological mediation, and power struggles shape data collection in smallholder coffee farms in sub-Saharan Africa. Using Actor-Network Theory (ANT), we show how people and things work together to create data networks, where the success or failure of these connections depends on shared interests, and disagreements highlight unfairness in the system. Three key themes emerge: asymmetries in actor motivations and agency, translation breakdowns and network fragility, and power imbalances and hidden inequalities.

First, the network of actors demonstrates profound asymmetries in how different stakeholders engage with data. Smallholder farmers, while numerically dominant in the sector, occupy a precarious position as data providers rather than data owners. Their participation is secured through a combination of economic incentives and coercive pressures, from the promise of better prices to the threat of market exclusion. This creates what might be termed data bargaining, where farmers exchange information for access, but rarely gain meaningful control over how that data is used or who benefits from it. The NGOs and corporations that design these systems position themselves as gatekeepers, using certifications and compliance requirements to define what counts as legitimate knowledge. Meanwhile, non-human actors like the EU Deforestation Regulation (EUDR) and mobile data collection apps actively reshape farming practices, often in ways that exacerbate existing inequalities. The failed mobile app mentioned by the Boku cooperative exemplifies how technologies can disrupt networks when they ignore local realities, a shocking reminder that tools are never neutral but always political.

The translation phases of this network reveal why certain data practices take hold while others fail. Problematization, the initial framing of issues, varies dramatically depending on one's position in the network. Where NGOs see yield gaps as measurement challenges requiring better data systems, farmers experience them as practical problems needing hands-on solutions. This disconnect explains why training programs that demonstrate techniques in the field succeed where abstract data demands fail. Enrolment strategies further highlight these tensions: farmers embrace practices like improved agronomy when they see direct benefits but resist intrusive record-keeping that feels extractive. The mobilization of data flows shows how networks stabilize when interests align, as in Nespresso's AAA program, but fracture when actants are forced into roles that don't serve them. These translation breakdowns are not technical failures but political ones, revealing whose knowledge and needs are prioritized in sustainability governance.

Most revealing are the controversies that emerge where translation fails. The struggle over data ownership epitomizes this issue, as farmers assert control over their information, while certification systems quietly transfer that authority to corporations under the guise of compliance. This creates what ANT scholars call a "black box," where power relations are concealed within technical protocols. Similarly, digital exclusion controversies show how technologies designed for literate users systematically marginalize those they claim to serve. Perhaps most insidious is the gendered erasure in data systems, where women's labour disappears from datasets not by accident but through sampling choices that privilege male-dominated cooperatives. These controversies demonstrate that data networks don't merely describe reality, they actively create it, determining whose work is visible and whose knowledge counts.

The implications extend far beyond sub-Saharan Africa’s coffee sector. These findings challenge the dominant narrative that more data automatically leads to better sustainability outcomes. Instead, they show how data systems reproduce and amplify existing power structures, a phenomenon we might call "data colonialism" in agricultural governance. The results suggest that truly equitable systems would need to fundamentally reconfigure network relations: giving farmers real ownership over data, designing tools around their capabilities rather than corporate needs, and making visible the currently erased labor of women and marginalized producers.

Ultimately, this study demonstrates that sustainability certifications and data systems are not just technical solutions to agronomic problems but sites of intense political struggle. The ANT framework helps us see these systems for what they are: contested networks where the power to define, measure, and govern is constantly negotiated. For practitioners, this means moving beyond a narrow focus on data quantity to ask more critical questions: Who benefits from these systems? Whose knowledge is excluded? And how might we build networks that don't just extract information from farmers, but truly serve their needs? The answers will determine whether agricultural data systems become tools of liberation or new vectors of exploitation in the global coffee trade.

This analysis bridges theoretical sophistication with practical relevance, using ANT not just as an analytical tool but as a way to imagine more just alternatives. By taking seriously both human and non-human actors, from farmers to apps to regulations, we gain a fuller picture of how power operates in modern agri-food systems and where opportunities for meaningful change might lie. The task ahead is not just better data collection, but the democratic reorganization of the networks that govern coffee's future.

6. Conclusion

This thesis has explored the motives and methods of data collection in smallholder coffee farming, employing Actor-Network Theory (ANT) to analyze the complex interactions between human and non-human actors. The study reveals that data collection is not merely a technical process but a contested socio-technical network shaped by power dynamics, competing interests, and technological mediation. By addressing the central research question, Why is data collection important in smallholder coffee farming, and how is it done?, the findings highlight the dual role of data as both a tool for empowerment and a mechanism of control. Below, the conclusions are structured around the research sub questions, followed by implications for practice and future research.

SQ1: Who is collecting data, and what are their motives?

The study identified four primary actor groups involved in data collection: NGOs, the private sector, public institutions, and smallholder farmers. Each group operates with distinct motives. NGOs frame data collection to verify sustainability claims, assess program impacts, and advocate for decent work conditions. Private sector actors, such as corporations and certification bodies, prioritize compliance with standards (e.g., Fair Trade, EUDR) and supply chain transparency to meet market demands. Public institutions focus on policy enforcement and traceability systems to align with international regulations. Smallholder farmers participate primarily for economic incentives (e.g., premium prices) or due to coercive pressures (e.g., market exclusion). These motives often clash, creating tensions over data ownership and usage. For instance, while corporations leverage data for compliance, farmers rarely retain control over their information, reinforcing asymmetrical power relations.

SQ2: How is data collected?

Data collection methods range from traditional paper-based surveys to digital tools like mobile apps, remote sensing, and blockchain. However, the translation of these methods into practice is uneven. Successful enrolment occurs when tools align with farmers' needs, such as field-based training that demonstrates tangible benefits (e.g., yield improvements). Resistance or failure arises when technologies ignore local realities, such as low literacy rates or inadequate infrastructure. The abandonment of Boku Cooperative's mobile app exemplifies this disconnect.

The study also highlights the role of non-human actors (e.g., EUDR, certification protocols) in enforcing data practices, often prioritizing corporate interests over farmer autonomy.

SQ3: What types of data are collected?

Data focuses on agronomic metrics (yields, soil health), economic indicators (prices, costs), and compliance-related parameters (deforestation risks, labor conditions). Critical gaps persist, however; omissions, qualitative knowledge (e.g., traditional farming practices) and gendered labor contributions are often excluded from datasets. Surveillance and data systems frequently prioritize monitoring over empowerment, as seen in Nespresso's AAA program, where farm inspections ensure compliance but offer limited farmer agency.

Theoretical Contributions

By applying ANT, this study challenges conventional narratives that equate more data with better outcomes. Instead, it demonstrates how data networks reproduce inequalities by privileging certain actors (e.g., corporations, NGOs) while marginalizing others (e.g., farmers, women). Key ANT concepts, actant symmetry, translation phases, and controversies, reveal the politicized nature of data systems, where tools like certifications and apps act as "obligatory passage points" (Callon, 1986) that reshape power dynamics.

Practical Recommendations

For practitioners, the findings underscore the need to reconfigure data ownership. Farmers should have meaningful access to and control over their data. Initiatives like farmer-led cooperatives or decentralized data platforms could mitigate extraction. In addition, design inclusive tools such that technologies must accommodate low-literacy users and offline contexts. Participatory design processes involving farmers are critical. Lastly, align incentives through programs that should prioritize mutual benefit over compliance, such as linking data sharing to direct financial rewards or agronomic support.

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Appendix 1

Table of documents analysed

#	Name	Link
1	Technoserve Coffee Initiative	https://www.technoserve.org/fight-poverty/projects/coffee-initiative/
2	Technoserve Improving Smallholder Farmer Livelihoods	https://www.technoserve.org/fight-poverty/projects/improving-smallholder-farmer-livelihoods-in-majang/
3	Technoserve enhancing market efficiency	https://www.technoserve.org/fight-poverty/projects/enhancing-market-efficiency-and-resilience-for-growing-ethiopias-new-coffee-economy/
4	Technoserve Nespresso AAA	https://www.technoserve.org/fight-poverty/projects/nespresso-aaa-sustainable-quality-program-in-ethiopia-and-kenya/
5	Technoserve Coffe Initiative Final Report	https://www.technoserve.org/wp-content/uploads/2016/08/Coffee-Initiative-Final-Report.pdf
6	Technoserve triple line evaluation	https://www.technoserve.org/wp-content/uploads/2017/04/triple-line-evaluation-of-the-coffee-initiative.pdf
7	Technoserve small-farmers	https://www.technoserve.org/fight-poverty/who-we-serve/small-farmers/coffee/
8	Technoserve coffee-farm college	https://www.technoserve.org/fight-poverty/projects/coffee-farm-college/
9	Coffee wet mill	https://www.technoserve.org/resources/technoserves-coffee-wet-mill-processing-guide/
10	Laterite independent assessment	https://www.laterite.com/wp-content/uploads/2020/07/Laterite_TNS_independent-assessment_2013.pdf
11	TracexTech coffe traceability	https://tracextech.com/coffee-traceability-story-berry-to-brew/
12	Peets technoserve	https://www.peets.com/blogs/peets/partner-spotlight-technoserve
13	Reviging high quality coffee	https://panorama.solutions/en/solution/reviving-high-quality-coffee-stimulate-climate-adaptation-smallholder-farming-communities
14	Nespresso investing	https://nestle-nespresso.com/nespresso-will-invest-20-million-usd-in-drc
15	Technoserve Comprehensive Ethiopian Coffee Strategy	https://www.technoserve.org/wp-content/uploads/2022/06/Comprehensive-Ethiopian-Coffee-Strategy.pdf
16	Solidaridad	https://www.solidaridadnetwork.org/commodity/coffee/
17	Solidaridad grounds for sharing	https://www.solidaridadnetwork.org/wp-content/uploads/2024/08/The-Grounds-for-Sharing-A-study-of-value-distribution-in-the-coffee-industry-6Aug2024-FINAL.pdf
18	Solidaridad Colombia	https://assets.ctfassets.net/9vhdnop8eg9t/5WD0UFg3xtCByLXwG84LNs/482fe5cb64002e146a053e01f906fc27/Colombia_Solidaridad_ADD.pdf

19	Enveritas	https://www.enveritas.org/approach/
20	Enveritas standards coffee	https://www.enveritas.org/library/standards/static/data/printable/EnveritasStandards-Coffee-English.pdf
21	Enveritas claims framework	https://www.enveritas.org/static/documents/Enveritas_Claims_Framework.pdf
22	Enveritas sustainable investor	https://www.enveritas.org/progress/?ref=thesustainableinvestor.org.uk
23	Uganda wrestles with EUDR	https://www.agroberichtenbuitenland.nl/actueel/nieuws/2024/09/24/as11-uganda-wrestles-with-eudr-compliance-amidst-coffee-trade-challenges
24	Drone mapping coffee uganda	https://www.pix4d.com/blog/drone-mapping-coffee-uganda/
25	ESRI uganda flying labs	https://www.esri.com/en-us/lg/industry/natural-resources/stories/uganda-flying-labs-case-study
26	ILO Uganda coffee value chain	https://www.ilo.org/sites/default/files/2024-07/Uganda_Coffee_Value_Chain_Mapping.pdf
27	Uganda coffee	https://ugandacoffee.go.ug/node/1030
28	Uganda scenario	https://storymaps.arcgis.com/stories/007a56633afd4115871670e840ac9617
29	Technical report coffee	
30	Ethiopia single farmer project	https://www.cafeimports.com/europe/blog/2024/07/31/ethiopia-single-farmer-project/
31	Rainforest alliance	https://www.rainforest-alliance.org/in-the-field/championing-ethiopias-coffee-farmers-in-the-birthplace-of-arabica/
32	Rainforest alliance	https://www.rainforest-alliance.org/insights/advances-for-people-and-nature-in-our-certification-program/
33	UNDP Ethiopia	https://www.undp.org/ethiopia/news/forests-and-ethiopias-coffee
34	Funds projects ethiopia	https://www.sustainable-supply-chains.org/funds-projects/initiative-for-climate-smart-supply-chains/ensuring-the-sustainability-of-climate-smart-and-fair-coffee-value-chains-in-ethiopia/
35	SNRD forest friendly coffee	https://www.snrd-africa.net/forest-friendly-coffee-and-eudr-ethiopias-sustainable-coffee-pathway/
36	Bunkonzo Organics	https://bukonzoorganics.com/
37	Bunzonco organics	https://fairtradeafrica.net/wp-content/uploads/2022/01/Bukonzo-Organic-Compressed.pdf
38	Bukonzo organic farmers cooperative	https://www.tdc-enabel.be/en/projecten/bocu-bukonzo-organic-farmers-cooperative-union-3/
39	Bukonzo farmers	https://www.shared-interest.com/en/impact/bukonzo-farmers
40	Nespresso AAA	https://www.sustainability.nespresso.com/communities/aaa-sustainable-quality-program
41	Nespresso AAA sustainable	https://nespresso.fi/en/aaa-sustainable-quality-program
42	AAA nespresso	https://www.rainforest-alliance.org/resource-item/lessons-learned-nespresso-aaa-sustainable-quality-program/
43	Greener future coffee nespresso	https://www.rainforest-alliance.org/wp-content/uploads/2021/07/greener-future-coffee-farmers-nespresso-report.pdf

44	Nespresso AAA	https://www.gcrmag.com/nespressos-aaa-sustainable-quality-program-turns-20/
45	OLAM	https://www.olamgroup.com/news/all-news/press-release/olam-atsource-wins-2020-reuters-responsible-supply-chain-award.html
46	Atsource	https://www.ofi.com/sustainability/sustainability-with-atsource.html
47	Olam s	https://satelligence.com/case-study/olam/
48	Starbucks	https://about.starbucks.com/stories/2023/digital-traceability-tool-connects-baristas-in-stores-all-the-way-back-to-the-farmers-like-virginie-from-rwanda/

Appendix 2

Sustainable Development Goals (SDG) Statement

Name	Sebastian Fortineau
ID	i6344382
Supervisor	Ron Corvers
Date	20/06/2025
SDG	Codes 8, 9, 13

Explanation

Through the research conducted for this master's thesis, I seek to contribute to one or more of the 17 SDG(s) set forth by the United Nations (https://www.undp.org/sustainable-development-goals). Specifically 8 (Decent work and economic growth), 9 (Industry, innovation and infrastructure), and 13 (climate action). Agriculture is the backbone of our society, but even more so in developing countries such as those located in Sub-Saharan Africa. Coffee production employs a large percentage of the population in those countries, and is therefore a key player in the economic growth of the countries. Furthermore, this growth has to be sustainable and 'decent' for those employed. This also relates to SDG 9, about having a sustainable industry. The innovations mentioned in this thesis highlight the importance of sustainable growth across varied sectors, and the synergies that can be created when we work together. With more data, more data infrastructure will also be needed. And lastly, climate action is important since the effects of climate change are felt worldwide, but even more so on specific countries and workforces such as coffee producers who have specific growing conditions. Ensuring that the climate does not affect their livelihoods and wellbeing is therefore very important.

Appendix 3

Statement on the use of Generative AI (GenAI) in the master thesis

I hereby certify that I adhered to the SBE guidelines on the use of GenAI tools such as ChatGPT in the master thesis. In the box below, I document how and for what purposes I used GenAI.

During the preparation of this work, I used GenAI for the following purposes:

- Search engine: [List tool(s); provide explanation]
- Ideation helper: ChatGPT to help with initial ideation and framework scheming.
- Text summarizer: [List tool(s); provide explanation]
- Explanation provider: [List tool(s); provide explanation]
- Language assistant: Grammarly to help with grammar and spell check
- Table editor: [List tool(s); provide explanation]
- Translator: [List tool(s); provide explanation]
- Other: [List purpose; list tool(s); provide explanation]

After using any tool, I reviewed, quality-checked, and edited the content as needed and take full responsibility for the content of the thesis.

By signing this statement, I explicitly declare that I am aware of the fraud sanctions as stated in the Education and Examination Regulations (EERs) of the SBE.

Place:	Maastricht, The Netherlands
Date:	20/06/2025
First and last name:	Sebastian Fortineau
Study programme:	Sustainability Sciences, Policy and Society
Course/skill:	Master Thesis
ID number:	i6344382
Signature:	

Appendix 4 – Interview Guide

All text in Italic is used as a guide and expected answers. These statements or questions will only be used if the interviewee asks for more clarification.

Introduction

- Purpose: explain the study's focus on data collection for sustainability.
- Confidentiality: assure anonymity and voluntary participation.
- Consent: obtain written consent through the consent form.

Background

- What is your role in smallholder coffee farming/data collection?
- How long have you worked with smallholder coffee farmers?

RQ1: Who collects data and why?
(related to actors, motives, power dynamics – ANT problematisation, identify human/non-human actants and their problem definitions)

- Which organisations or tools are involved in collecting data from smallholder coffee farmers in your context?
    - *NGOs, government, private companies, farmers themselves, farmer cooperatives, others?*
- What are the primary reasons your organisation collects this data?
    - *Is it for certification, yield improvement, policy compliance, or market access?*
- How do different actors influence what data is prioritised?
    - *Do buyers demand specific metrics (e.g. carbon footprint)? Do farmers resist?*
- Are there conflicts over who owns or controls the data?
    - *Case where farmers cannot access their own data.*

RQ2: How is data collected?
(related to methods, tools, enrolment strategies – ANT translation, trace how tools (non-human) enroll actors into networks).

- What methods or technologies are used to collect data?
    - *Mobile apps, paper surveys, sensors, satellite imagery ?*
- How were farmers or other actors convinced to adopt these methods?
    - *Training, incentives, penalties?*
- What challenges arise in data collection?
    - *Technology literacy, infrastructure gaps, farmer trust.*
- Do tools like blockchain or AI change power dynamics?
    - *Who controls the technology?*

RQ3: What data is collected?
(related to data types, omissions, controversies – ANT black boxing, examine what is excluded (e.g. qualitative knowledge) and why)

- What specific data points are collected?
    - *Agronomic (yields, soil), economic (prices), social (gender, labor)?*
- Are there data types you wish were collected but aren't?
    - *Hidden costs (e.g. unpaid female labor).*
- How is data verified or audited?
    - *Third-party audits vs. farmer self-reports.*

- Do global standards override local data needs?

ANT-specific questions

- Can you describe a situation where a technology or policy unexpectedly changed data practices?
    - *ANT's non-human agency.*
- How do farmers negotiate or resist data demands?
    - *ANT's controversies.*

Closing

- Is there anything else about data collection in coffee farming I should know?
- Can you share reports or tools your organisation uses?
- Thank you!