SCHOOL OF
ECONOMICS AND
MANAGEMENT

LUND UNIVERSITY

Master's programme in Innovation and Global Sustainable Development

Innovation for Climate Change Adaptation in Costa Rican Coffee Production

A comparative analysis of cooperatives in the coffee regions Guanacaste & Tarrazú

By

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Abstract

Latin America is predicted to experience losses of almost 90% of land suitable for coffee production due to climate change by 2050. Simultaneously, worldwide coffee demand is increasing steadily and is expected to grow continuously due to new emerging niche markets. This highlights the urgency of and the need for innovations for climate adaptation in coffee production. This thesis examines the role of coffee cooperative innovations in two regions of Costa Rica and how they contribute to climate change adaptation. Using the MLP and transformative adaptation framework, this thesis explores whether climate change is inducing or accelerating cooperative innovations in Guanacaste and Tarrazú. The findings suggest that climate change acts as an innovation accelerator and not as an innovation inducer. Surprisingly, the Russia-Ukraine conflict is seen as the main driver of certain cooperative innovations such as organic fertilizers. In terms of value-added products and process innovations, climate change can be viewed as an indirect driving force. In sum, coffee cooperatives in Costa Rica display different innovative potentials depending on the region, but they are greatly contributing to the sustainability transition of the coffee sector in Costa Rica.

Keywords: Costa Rica, coffee, sustainability transitions, climate change adaptation, cooperatives & innovations

Programme Code: EKHS35
Master's Thesis (15 credits ECTS)
May 2022
Supervisor: Cristina Chaminade
Examiner: Prince Young Aboagye
Word Count: 17661

Acknowledgements

I would like to dedicate this thesis to my maternal grandfather, Jorge Beltran. I have a feeling I inherited my passion for coffee from him and my Colombian roots. Abuelito, I wish could have shared my experiences with you.

This thesis is the outcome of one of the best experiences of my life. Getting to live in Costa Rica and do research in collaboration with Universidad Nacional de Costa Rica (UNA) for almost four months was a dream. Therefore, I would like to thank Lund University first and foremost for this opportunity, the master's degree and the last two unforgettable years.

To my lovely supervisor, Professor Cristina Chaminade, thank you for your endless support and for making the thesis writing process fun and inspiring.

To all the kind professors at Centro Internacional de Política Económica para el Desarrollo Sostenible (CINPE), thank you for your incredible hospitality, for making us feel at home and all your support. A special thank you goes out to Rafael Diaz, Jeffrey Orozco, Keynor Ruiz, Marco Otoya, Olman Segura and Fernando Sáenz.

To my friend and travel companion Marta Hergueta, thank you for the late-night chats, the productive brainstorming sessions, and all the unforgettable travel memories. Couldn't have done it without you.

To my lovely family, thank you for believing in me and for always supporting me along the way, through good and bad. Could not have done it without you either.

Lastly, I would like to thank all the wonderful interview participants, from cooperatives to industry experts and institutional actors. Thank you for making me feel welcome and for showing me your kindness and interest in my thesis topic. You all contributed to a very smooth and unique data collection experience. This thesis was made possible because of you.

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List of Abbreviations and Glossary

UNA	Universidad Nacional de Costa Rica
CINPE	Centro Internacional de Politica Economica para el Desarollo Sostenible
MAG	Ministerio de Ganadería y Agricultura (Ministry of Livestock and Agriculture)
NAMA	Nationally Appropriate Mitigation Action
ICAFE	Instituto del Café de Costa Rica (Costa Rican Coffee Institute)
WRI	World Resource Institute
SINAC	Sistema Nacional de Áreas de Conservación Costa Rica (National System of Conservation Areas of Costa Rica)
MLP	Multi-level Perspective
EbA	Ecosystem-based Adaptation
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
BPA's	Buenas Practicas Agricolas (Best Practice Principles)
Beneficios	Costa Rican Spanish word for central coffee processing mills

1. Introduction

Coffee is the second most traded commodity globally, second only to petroleum (Aguilar & Klocker, 2000; Pham et al., 2019). Recent studies express growing concern for coffee, an agricultural crop highly sensitive to local climate, that is grown in more than sixty countries across the tropics by over 25 million mostly smallholder farmers (Läderach et al., 2017; Pham et al., 2019). Globally, Pham et al. (2019) illustrate that there will be an overall loss of 50% of suitable land for both Arabica and Robusta coffee production by 2050. In addition, the most vulnerable region to climate change in terms of coffee production, which will experience the greatest losses is Latin America, as forecasts predict heavy losses of approximately 88% by 2050 (Pham et al., 2019). These realities exist parallel to the fact that worldwide demand for coffee is increasing steadily annually and is expected to continue growing due to the emergence of new niche markets around the world (Birkenberg & Birner, 2018). Similarly, Eakin et al. (2014) portray that coffee farmers will eventually choose economic risks and pursue other crops rather than face climate threats. As climate changes pose concerning threats to coffee production and its viability in several regions around the world, Central America is particularly at risk since predictions suggest that this particular region will suffer disproportionally in terms of agricultural and ecological aspects from climate change impacts (Hannah, Donatti, Harvey, Alfaro, Rodriguez, Bouroncle, Fung, Hidalgo, Imbach, Läderach, Landrum & Solano, 2017; Powlison Belković, 2020; Rahn, Läderarch, Baca, Cressy, Schrot, Malin, Rikxoort & Shriver, 2014; Viguera, Alpizar, Harvey, Martinez-Rodriguez & Saborio-Rodriguez, 2019; Vignola, Harvey, Bautista-Solis, Avelino, Rapidel, Donatti, & Martinez, 2015).

Coffee is the most diffused perennial crop grown in Costa Rica, however, that might change in the near future due to its high susceptibility to local climate changes, particularly related to rising in temperatures and variations in precipitation patterns (Pham et al., 2019; Viguera et al., 2019). According to a study conducted by Viguera et al. (2019), current climate change models are predicting significant rises in temperature and increases in severity linked to extreme climate events in Central America generally. Consequently, these phenomena will have great direct and indirect implications in the Costa Rican context. One direct example is the reduction of suitable land and conditions for coffee growing and an indirect effect would be the impact on smallholder farms. Therefore, this poses a vital need to understand how climate change is affecting small coffee growers in Costa Rica to formulate measures allowing them to adapt and cope with the current and future challenges (Viguera et al., 2019). Certain challenges linked to increased temperatures and rainfall unpredictability are already being

perceived by farmers in certain regions (Viguera et al., 2019). Therefore, the development of national and local adaptation measures is urgent to reduce potential impacts (Hannah et al., 2017).

Several authors argue that adaptation solutions should be tailored specifically to local climate conditions, but also considering Costa Rica's smallholder coffee grower's limited financial capacity (Hannah et al., 2017; Pham et al., 2019).

Cooperatives may play a key role in this process thanks to their innovative capabilities mainly due to their strong "organizational capacity for communication, training, and education" (Gertler, 2001). Since smallholder coffee farmers have limited adaptive capacity due to limited access to much capital and resources, being part of cooperatives facilitates knowledge and resource sharing, skill building and credit access, which in turn stimulates innovations and potential adaptation strategies (Hannah et al., 2017; Läderach et al., 2017; Rahn et al., 2014).

Coffee production is context-specific, so this study compares two strategic regions: Guanacaste and Tarrazú. Most researchers focus on Tarrazú, a famous land for producing high-quality altitude coffee. On the other hand, the literature based on Guanacaste associates this region with low-altitude coffee, and as being one of the most vulnerable regions, displaying very low levels of productivity. What remains understudied is how climate change affects these regions differently. Díaz Porras & Delgado Ballestero (2012) compared climate change perceptions on smallholder farm level in Nicoya, Guanacaste and León Cortéz, Tarrazú, but no study has made broader comparisons. Furthermore, as cooperatives play vital roles in both regions, this study aims to identify how these institutions' innovative potential differs and how these regions could learn from each other. There is no study so far specifically comparing cooperatives, innovation, and adaptive responses to climate change.

The coffee regions of Guanacaste and Tarrazú were chosen because even though coffee is grown on the hilly parts of Guanacaste, it is the most vulnerable coffee region in Costa Rica mostly affected by drought. Additionally, the coffee produced here is low-altitude coffee. On the contrary, Tarrazú is famous for its high-quality altitude coffee and perfect climate conditions. As such, it would be interesting to understand if and how climate change affects these regions differently, how the innovative potential of the cooperatives present differs and potentially how they can learn from each other. A couple of studies comparing climate change perceptions on smallholder farm level in Guanacaste and Nicoya exist, but no study so far specifically compare cooperatives and their adaptive responses to climate change (Díaz Porras & Delgado Ballestero, 2012).

Likewise, there seems to be an extensive focus on mitigation actions in the Costa Rican coffee sector. Pham et al. (2019) state that, "more research specifically on its impacts and on adaptation solutions should be considered" supporting the topic of this thesis on cooperative innovations for climate change adaptation in Costa Rican coffee production. On April 25th, 2022 the National Costa Rican Adaptation Strategy was published, which clearly states that the agricultural sector is one of the most vulnerable sectors in terms of climate change impacts, thus strengthening the need for research on possible innovations as solutions (SINAC, 2022).

1.1. Research questions

The overarching research question in focus is:

Is climate change inducing or accelerating innovations in Costa Rican coffee cooperatives?

In order to answer and support the main research question, five sub-questions were formulated to make the results more tangible.

a) What climate change challenges are being perceived by cooperatives in the respective regions?
b) What types of adaptation strategies are evident in the coffee regions Guanacaste and Tarrazú?
c) What innovations are being developed by coffee cooperatives in Guanacaste and Tarrazú in relation to the identified adaptation strategies?
d) What are the main drivers of these innovations?
e) What are examples of innovation barriers and how does the innovative capability differ among cooperatives in the regions examined?

1.2. Thesis Outline

The thesis is structured as follows. Chapter 2 will examine the theory. Chapter 3 will thoroughly describe the methodology and chapter 4 will present the results and discuss the findings. Finally, chapter 5 is the conclusion. References and appendices can be found at the end of the thesis.

2. Theory

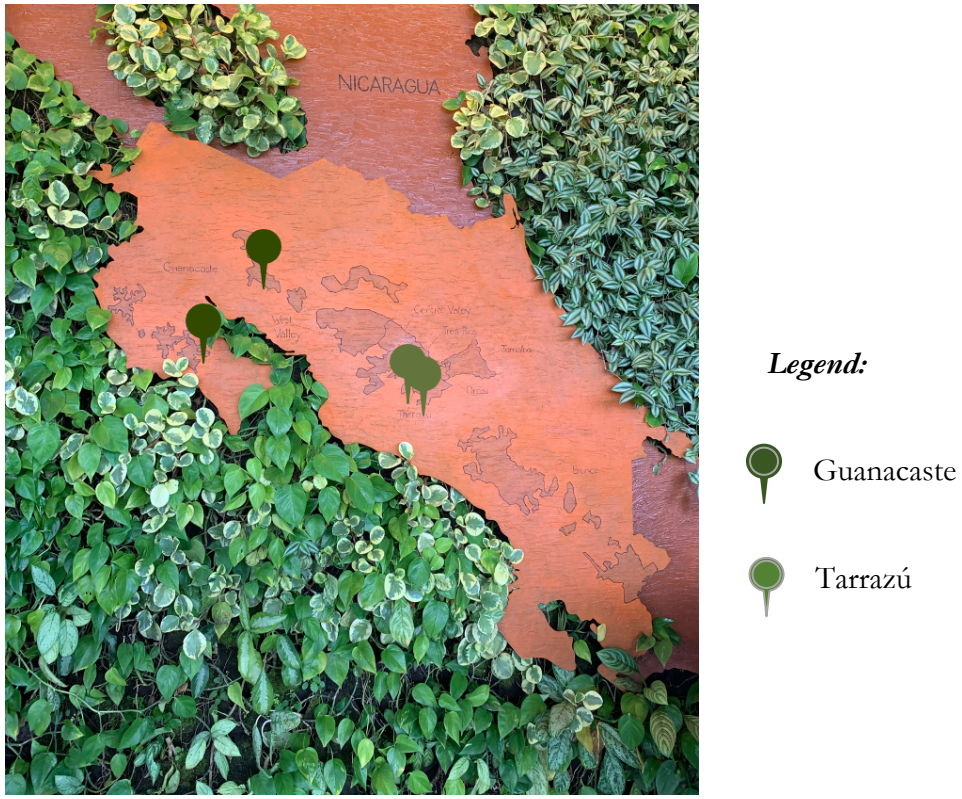
2.1. The Costa Rican coffee sector

Existing literature on the topic of coffee production, current climate change-related challenges, adaptation strategies and innovation opportunities, will be shed light on in this chapter.

2.1.1. Evolution of the Costa Rican coffee sector and its actors

Costa Rica is a small country in Central America, covering a land area of approximately 50,660 km^2 (Gu, Adeoti, Castro, Orozco & Diaz, 2012) and presenting a population of just over five million people according to the World Bank (2019). There are eight adequate coffee regions in Costa Rica, namely Valle Occidental, Tres Rios, Turrialba, Brunca, Orosi, Tarrazú, Valle Central and Guanacaste (see figure 1 below). The coffee regions of Costa Rica are characterized either by low altitude conditions, which are less than 1000 meters above sea level or high-altitude conditions of volcanic origin, more than 1000 meters above sea level. This research will compare Tarrazú (high-altitude) and Guanacaste (low altitude).

Figure 1 - Map of Costa Rica highlighting the coffee regions of Guanacaste and Tarrazú



Source: Own photograh taken at Hacienda Alsacia, Alajuela

High-quality coffee production has always played a key role in Costa Rica's history and economy, because coffee is handpicked by tradition, consequently representing a central part of Costa Rica's national identity (Birkenberg & Birner, 2018). Costa Rica distinguishes itself by exclusively producing Arabica coffee after the Robusta variety was banned (Vogt, 2019). This results in recognized high-quality coffee beans that are often referred to as Grano *de Oro*, meaning golden beans (Birkenberg & Birner, 2018). The introduction of coffee in Costa Rica dates back to the early 19th century when Costa Rica was still a Spanish colony. After gaining independence in 1821, coffee soon became Costa Rica's largest source of foreign revenue, thus representing economic stability as a result of European exports (Gu et al., 2012). Later on, coffee has also been integral to the country's development process, successfully linking Costa Rica to the global market since it represented the number one cash crop until the late 20th century (Aguilar & Klocker, 2000; Gu et al., 2012; Vogt, 2019). Likewise, on the topic of development and modern catch-up strategies, Gu et al. (2012) reflect that "the agricultural sector has played important 'catalyst' roles for sustainable development" (Gu et al., 2012, p. 194).

Several public policies encouraged coffee farming, such as the National Assembly decision of 1831, stating that any farmer cultivating coffee on land for five consecutive years was entitled to claim the land. Furthermore, coffee was also exempt from certain taxes. As a result, coffee farmers formed special communities and Costa Rica became the first Central American country to establish a coffee industry (Gu et al., 2012).

The coffee industry of Costa Rica is composed of several actors. Firstly, most coffee producers in the country are smallholders, entering the sector in great numbers but on a small scale. Smallholder farms in Costa Rica typically manage about five hectares (ha) of land or less (Eakin, Tucker, Castellanos & Diaz-Porras, 2014). Processors are also crucial in the coffee industry since they oversee the processing or milling part of the coffee production. Central processing plants are known as *beneficios* in Costa Rican Spanish. Wet and dry milling processes exist, but the most commonly diffused in Costa Rica is the wet milling process (Gu et al., 2012). Moreover, traders are the actors in charge of linking coffee growers with export opportunities, making it a strong export economy from the start. Another interesting actor is the republican government which has played a significant role indirectly supporting coffee growers by investing and improving infrastructures as well as incentivizing coffee production over the years. This could be a result of the benefits related to coffee production during the coffee boom decades in the 19th century. Specifically, the boom is associated with coffee revenues being used to pay off the federal debt, establishing the postal service, founding several hospitals and constructing the National Theater in San José, among others (Gu et al., 2012). Therefore, the Costa Rican coffee industry set out on a successful high-quality trajectory from the very beginning, partially due to the perfect climate and territories, volcanic rich soils, and sufficient rainfall supporting the creation of a strong social, cultural, economic, and political country. Thus the coffee sector represents an integral part of the Costa Rican culture, compared to other export industries such as bananas, which are seen mostly as an enclave (Gu et al., 2012).

Institutional actors are also worth mentioning. In 1933, the Institute for Costa Rican Coffee, IDECAFE (later known as the ICAFE) was created with the purpose of increasing regulations because of rising conflicts between coffee farmers, process plant owners and exporters. The Institute of Coffee (ICAFE from here onwards) was formed as a successor of the IDECAFE and included the Costa Rica Coffee Research Centre as of 1977 (CICAFE) as well. Since the 1970's, these entities combined represent highly specialized knowledge, research and development centers for coffee (Gu et al., 2012). Evidence suggests that this research institute was highly successful because Costa Rica displayed the highest coffee yields per hectare globally (Aguilar & Klocker, 2000; Gudmundson, 2014).

Furthermore, the 1960's symbolize important changes in the organizational structure of sectoral systems in Costa Rica with the rise of Cooperatives which will be examined shortly (Gudmundson, 2014). The next section will explore the theoretical framework guiding this research, namely sustainability transitions literature, particularly in the agri-food industry.

2.2. Food practices in transition

One of the main goals linked to current sustainability food transitions is making food production and consumption more sustainable. However, the globalization of such food production and consumption is challenging actors and relations in local communities. There are several definitions surrounding sustainability transitions. One way of defining transitions is as a long-term, multi-dimensional "set of processes that lead to a fundamental shift in socio-technical systems" (Markard, Raven & Truffer, 2012, P. 956). Likewise, Spaargaren, Oosterveer and Loeber (2012) define transitions as, "structural changes resulting in the emergence of new modes of production and consumption… a change in the routine behaviors and opinions of all actors involved: the regulating authorities, the farmers, the managers and the workers" (P. 4). Lastly, Rotmans, Kemp and van Asselt (2001) state that, "transitions are transformation processes in which society changes in a fundamental way over a generation or more". As such, transitions are complex and require changes on technological, material, institutional, political, socio-economic, and cultural levels. The results of such transitions are shifts in the regime involving the development of new products, new processes and modified business models (Markard, Raven & Truffer, 2012).

This thesis will focus on the notion of socio-technical transitions since they involve both technological and non-technological innovations but also include a social, cultural, and regulatory component which can be linked to the coffee cooperatives and the coffee sector in focus. The specific connection to coffee cooperatives is clear as socio-technical systems do not exist independently but depend on actors forming the human component. That is, "human actors are embedded in social groups which share certain characteristics" (Geels, 2004).

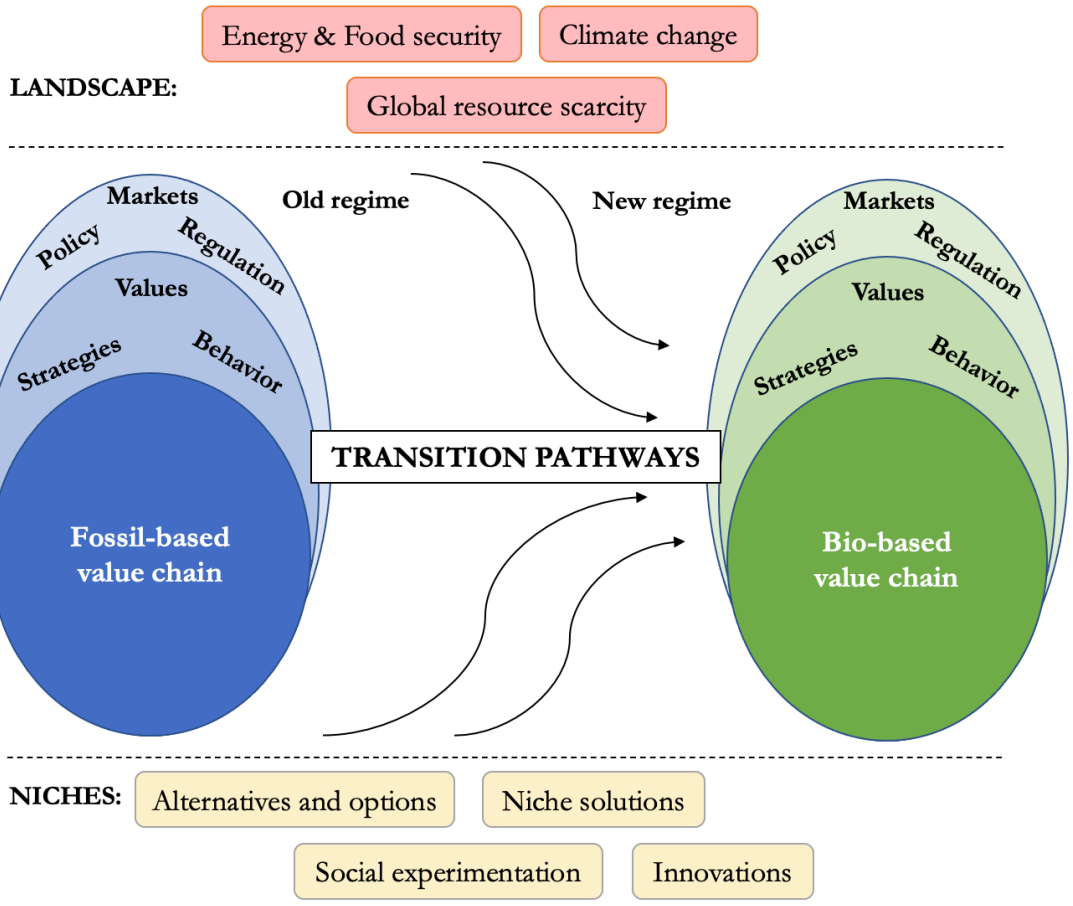
The concept of socio-technical systems stems from the multi-level perspective (MLP from now on), and the idea that to combat grand environmental challenges like climate change, sectors like the agri-food sector, need to undergo alterations to the overall configuration of the system (Geels, 2011). The MLP perspective views sustainability transitions as non-linear processes resulting from developments happening on three specific analytical levels (see figure 2 below). The superior level is

represented by an exogenous socio-technical landscape representing the regulations, political and social values of society. Landscapes change very slowly. The regime is made up of current established practices and norms that maintain a stable system and are usually associated with incremental innovations (Chilvers et al., 2017). Lastly, the niche level is known as the "locus for radical innovations" and represents a protected space for research and development (Geels, 2011, P. 26). This level is constantly challenging the regime and maturing innovations to eventually break through and alter the existing regime. As such, the regime is particularly interesting since transitions are defined as regime shifts. In relation to this thesis, the regime can be portrayed as the existing state of coffee production with the coffee cooperatives as the main actors on the niche level, constantly developing and perfecting innovations, waiting for the exact mature moment when eventually an innovation will be "ripe" enough to break through and create a regime shift.

It is important to note that current socio-technical regimes are regularly challenged by new ideas, innovations, and knowledge thus potentially spurring system transformation. Therefore, system transitions rely on innovations. Thus, the role of innovations is key in the functioning and transformation of existing systems (Geels, 2004) strengthening the importance of this research.

Path dependencies and lock-in effects describe existing socio-technical systems and their stability, making it very challenging to disrupt current regimes since they tend to be highly institutionalized. Conversely, transition studies suggest that new actors have the potential of disrupting regimes due to their increased innovative capabilities (Vermunt et al., 2020). However, critiques to the MLP framework state that it is not optimally applicable to the agri-food sector since it overlooks geographical, ecological, and biophysical elements.

Figure 2 - Elements of the multi-level perspective framework



Source: Author's elaboration based on Chilvers et al. (2017)

The landscape in this case is given by challenges related to climate change, scarcity of water and the need to secure future coffee production. The ICAFE could be seen as a crucial institutional actor in the landscape since they play a crucial role in regulation. They contribute to innovations to some extent by facilitating research and development of new coffee varieties but furthermore add external pressure on the regime and niche levels due to the strict regulation. As figure 2 suggests, the regime represents the mainstream system functioning (Kuokkanen et al., 2018). The old regime is therefore what the coffee industry has looked like for many years, relying heavily on chemical fertilizers, depending on carbon-intensive equipment for processing and in general, being environmentally unsustainable. The existing regime is usually difficult to change due to existing

habits, behaviors and rules affecting its actors. The new regime suggests the possible outcome a successful sustainability transition could have in the coffee sector if niche innovations can disrupt the old regime. Regimes face pressure from both the landscape and also from the niches. Niches operate independently of the regime and follow less structured rules. As such, they have more freedom in trying to address the specific landscape challenges with the goal of destabilizing the regime (Kuokkanen et al., 2018). On the niche level, the actors that are focused on are the cooperatives which represent understudied innovative potential. One interesting aspect pointed out by Kuokkanen et al. (2018) is that transitions literature tends to neglect the role of agency, arguing that it is "partially due to the view of landscapes as external environments on which regimes cannot exert influence" (Kuokkanen et al., 2018, P. 1514). The authors convey that it is crucial to recognize agency as the network that influences ongoing regime destabilization and transitions, the actors' internal identity and capabilities and not only look at agency as the ability to adapt to external changes. Given that niche actors work on radical innovation, the notion of transformative adaptation becomes key.

The Intergovernmental Panel on Climate Change (IPCC) defines transformative adaptation as, "transformational adaptation seeks to change the fundamental attributes of systems in response to actual or expected climate and its effects, often at a scale and ambition greater than incremental activities" (Ferdinand et al., 2020). Likewise, the World Resource Institute defines transformative adaptation in agriculture as "intentional alterations in response to climate change-related risks that accomplish one or more of the following three goals". The three goals can be seen in table 1. These goals and the concept of transformative adaptation are also linked to the concept of innovation development. Due to the increasing concerns and uncertainty related to climate change, incremental changes are no longer enough:

> Transformative pathways are meant to build long-term resilience such that systems shift as the climate changes. Without such transformative pathways, incremental adaptation efforts that are meant to maintain current system states may result in decreasing resilience, or maladaptation, over time (Ferdinand et al., 2020).

As a result, radical innovations and system changes are needed as intensifying climate change impacts are pushing systems into new states and the need for long-term sustainability transitions increases.

Table 1 - Goals related to transformative adaptation

Goal	Description
1	Significantly shift the geographical locations where specific types of crops and livestock and the systems that support their production, processing, marketing, and distribution take place.
2	Fundamentally alter the agricultural landscape as a result of changes to many aspects of food production and marketing systems (e.g., from sedentary, crop-based agriculture to pastoralism, or from smallholder farming to large commercial agriculture)
3	Apply at a broad geographical scale significantly new methodologies and technologies that change the types of agricultural products produced in a particular region or production system (e.g., improved agro-processing to prevent increased spoilage due to climate-related higher temperatures, which enables production of new, value-added products).

Source: Own creation based on a study by Carter, Ferdinand and Chan (2018)

Actors of a transition are the objects of study who are carrying out certain systemic changes by blocking or enhancing the transition pathway to align with their interests (Spaargaren, Oosterveer & Loeber, 2012). Eventually, the new behavior will prevail among actors and the transition process becomes institutionalized thus fundamentally altering the previous set of governing rules in the regime. In a study by El Bilali (2019), the author points out that in agri-food sustainability transitions, the role of social movements and the "role of firms and industries in transitions and modelling transitions remain largely underserved" (El Bilali, 2019). This ties back to the research gap of this thesis and emphasizes the importance of analyzing actors such as coffee cooperatives in the coffee sustainability transition of Costa Rica.

2.3. Agency in food transitions: The role of cooperatives

Cooperatives are fairly common in natural resource-based industries with sustainability issues as core concerns since they play a vital role in sustainable development (Gertler, 2001). The formal definition of cooperatives is given as "an autonomous association of persons united voluntarily to meet their common economic, social, and cultural needs and aspirations through a joint-owned and democratically controlled enterprise" (Gertner, 2001, P. 18). Such cooperatives are governed by specific guidelines reflecting the cooperative values. According to the research by Gertner (2001), there are seven key principles that cooperatives follow (see table 2 below).

Correspondingly, the strong links between producers, processing facilities and consumers in cooperatives facilitate sustainability transitions and transformations, due to the significant influence cooperatives have on production, through the small-scale farmer members. The result is the facilitation of innovations such as new products or process innovations. Consequently, "co-operatives can ensure that raw products meet quality requirements and production criteria" which in turn, generates high-quality premiums and increased return for members and more operating financial capital to invest in the cooperative development (Gertler, 2001).

Table 2- Cooperative principles

Principle	Description
1. Voluntary and open membership	Voluntary organizations, open to all members willing to accept cooperative responsibility, based on a nondiscriminatory nature.
2. Democratic member control	Organizations based on active decision making on behalf of cooperative members; voting rights exist.
3. Member economic participation	Members contribute equally to the capital of the cooperative. There are special rules for capital surplus and the destined uses within the cooperative.
4. Autonomy and independence	Autonomous organizations controlled by associated members.
5. Education, training and information	Education and training is provided for members, elected representatives, managers, and employees to ensure effective contribution of cooperative development. Benefits and nature of the organization are clearly communicated to the public.
6. Cooperation among cooperatives	Possibility of local, regional, national, and international collaborations.
7. Concern for community	Main goal is to work towards sustainable development of local communities through member approved policies.

Source: Own creation based on a study by Gertner (2001).

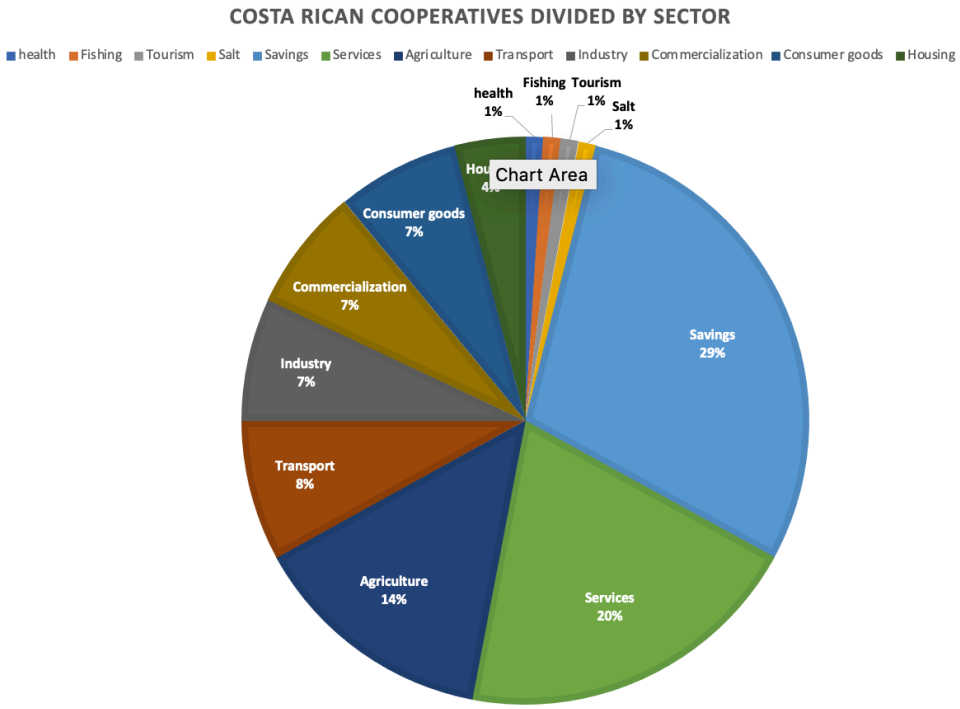
2.3.1. The rise of coffee cooperatives in Costa Rica

Agricultural cooperatives are often created as a defense mechanism for small-scale producers who seek protection from larger, more powerful competitors in the market (Gertler, 2001). In Costa Rica, coffee cooperatives were established as an opposition to the coffee elite oligarchy, providing marginal growers with several benefits including credit assistance and establishing local central processing plants, *beneficios,* for the farmers to take advantage of (Aguilar & Klocker, 2000; Gu et al.,

2012). The cooperative movement began with the *legislacion cooperativa Costaricense* of 1943 the legislative regulations governing the functioning and establishment of cooperatives in Costa Rica (Boza, 2018). In 1962, the cooperative initiative was reinforced by the founding of the Federation of Cooperatives of Coffee Growers (FEDECOOP), which provided additional technical assistance and commercialization guidance (Aguilar & Klocker, 2000). Supported by Aguilar and Klocker (2000), the cooperative idea flourished in Costa Rica since one-third of the coffee produced by the 1970's was processed in cooperative-owned beneficios.

Figure 3 below depicts the distribution of cooperatives between the economic sectors in Costa Rica. The agricultural sector, which is of interest for this research, translates into *sector agropecuario* and 14% of cooperatives in Costa Rica fall within this industry. The author illustrates that the one crop that stands out within the agricultural sector is without a doubt coffee (Lorenzo, 2006). Likewise, the coffee sector was responsible for 7,87% of employment in Costa Rica as a whole and approximately 23% of employment within the agricultural sector according to the 2006 study (Lorenzo, 2006). These numbers show not only the importance of cooperatives in Costa Rica as a whole but also how vital they are for the coffee industry.

Figure 3 - Costa Rican cooperatives illustrated by sector



Source: Own creation based on a study by Lorenzo (2006)

2.3.2. Current climate change challenges

Already in the year 2000, Aguilar and Klocker (2000) introduced early concerns for sustainability measures and environmental risks stemming from coffee growing and processing, stating that "the sustainability of coffee production is of great concern" (Aguilar & Klocker, 2000, p. 596). This supports the idea that researchers have long known that it is a crucial topic and action needs to be taken for future production.

Most authors seem to agree on the major negative impacts currently affecting coffee production. It is important to highlight that climate change can have both direct and indirect effects on coffee production. The major climate change threats outlined in studies are: reduced yield, increased occurrence of pests and diseases, which also diminishes overall yield and increases the production costs; soil and water management, biodiversity impacts and lastly, the loss of suitable coffee-growing terrain (Pham et al., 2019; Powlison Belković, 2020). The indirect effect climate change can display on the production of coffee is related to the socio-economic perspective, explained by Pham et al. (2019) as, "understanding the extent of climate-driven impacts on coffee production and the benefits of potential adaptation strategies will be of vital importance to maintaining and improving coffee productivity and profitability and sustaining the livelihoods of smallholder producers all over the world". These threats are mostly a result of increased temperatures and reduced and unpredictable rainfall (Harvey et al., 2018; Viguera et al., 2019).

One thing is clear, researchers believe that there is a strong need to focus research on adaptation strategies in agriculture and how to improve future coffee production (Pham et al., 2019; Viguera et al., 2019). According to Viguera et al. (2019), one to two adaptation practices are implemented on average per coffee grower. The possible measures will be examined in depth next.

2.3.3. Overview of implemented and potential innovative responses for climate change adaptation in Costa Rica's coffee industry

Costa Rica is often recognized as a global leader in adaptation and conservation efforts (Powlison Belković, 2020). Since the 1980's, governmental policies have been dedicated to environmental agendas, including significant reforestation initiatives, strict land regulation and a focus on the preservation of land and marine biodiversity (Powlison Belković, 2020). Moreover, Costa Rica was also the first country globally to implement a payment for environmental services (PES) program,

aimed at reforestation and conservation efforts. The author argues that this relates to the research because, "ideally, these kinds of policies will offer incentives and support for coffee farmers to adopt agronomic best practices on their farms, thus both increasing their resilience to climate risks and contributing to mitigation efforts" (Powlison Belković, 2020, P.17). This could be seen as an innovative response.

Adaptation practices are becoming more vital for the survival of coffee growing around the world. Eakin et al. (2014) describe adaptation as "a complex process requiring actors to perceive signals of change, attach importance to that perception and assign scarce resources and capacities to take action in response to the perceived threat" (Eakin et al., 2014, P. 5). The complexity component derives from the idea that the most vulnerable actors seem to be the ones that face multiple sources of change and stress simultaneously and also because numerous adaptation responses derive from unplanned actions (Eakin et al., 2014).

Existing studies discovered that more than 95% of coffee farmers in Costa Rica observed changes in their local climate, impacting their production. In addition, approximately 60% reported that they had altered the management methods to reduce the impacts (Harvey, Saborio-Rodriguez, Martinez-Rodriguez, Viguera, Chain-Guadarrama, Vignola & Alpizar, 2018; Viguera et al., 2019). As a result, diving into the challenges currently faced by local farmers and understanding what can be done as preventive measures will be examined next.

The most cited adaptation responses include Ecosystem-based Adaptation (EbA) methods. Vignola et al. (2015) define EbA in agriculture as a method that increases the adaptation ability of crops to climate changes. Examples include agricultural management methods which take advantage of existing biodiversity, ecosystems and ecological processes to increase crop resilience. The study by Viguera et al. (2019) observe four recurring adaptation strategies, including the EbA practices in addition to tree planting for shade-grown coffee, living fences and increased use of agrochemical products. Pham et al. (2019) continue the discourse by adding other adaptation methods to the list, incorporating agroforestry, intercropping, efficient water management, development of new cultivars resistant to both drought and heat stress and preferably also new pest and disease tolerant cultivars. Other, more risky responses indicated are the relocation of coffee plantations and switching from the sensitive Arabica coffee variety to Robusta, which is said to be of lower quality but more resilient (Pham et al., 2019). Similarly, there are a few adaptation responses less explored, including technological innovations, mostly linked to precipitation changes, along with the need for increased

education and awareness around the subject of climate change adaptation, lastly more institutional responses are needed (Viguera et al., 2019).

Addressing the current challenges one by one, it is possible to associate them with specific adaptation methods. The first challenge identified in the literature is the reduced yield. Coffee yield is determined significantly by climate conditions, especially during the initial phases of the plant; vegetation and reproduction (Pham et al., 2019). Likewise, growing coffee strengthens biodiversity, and conservation practices such as soil protection and finally it has carbon sequestration abilities. Similarly, authors agree that when the coffee yield decreases, it affects food security negatively and thereby also poverty alleviation leading to socio-economic challenges (Harvey et al., 2018; Viguera et al., 2019). Therefore, finding adaptation measures that prevent the reduction of coffee yield is urgent.

Another challenge identified in recent literature is the increased occurrence of pests and diseases. This is a direct result of increased temperatures in the coffee-growing regions. One of the adaptive responses associated with this problem is the planting of trees to promote shade-grown coffee and moreover, the development of more resistant coffee varieties (Aguilar & Klocker, 2000). However, the more frequent manifestation of new pests and diseases remains a deep worry of coffee farmers worldwide.

In terms of soil and water management, the main cause of drought is a combination of less annual precipitation and increasing temperatures. Soil conservation and increased agroforestry practices are being implemented because of climate change. This seems to be the only challenge partially addressed by technological innovations, which target the lack of rainfall and include innovations such as smarter irrigation systems (Viguera et al., 2019). Soil conservation initiatives could also be pursued by utilizing fewer chemical pesticides (Eakin et al., 2014).

Finally, one of the greatest concerns is the loss of suitable land for coffee production, since climatic effects will limit where coffee can be grown (Eakin et al., 2014). Eakin et al. (2014) hypothesize that coffee growers will eventually leave their production, finding alternative crops due to climate change. This demonstrates that most smallholder farmers would choose economic market risk over climate change threats. Powlison Belković (2020) seem to agree, as the author reflects "there is concern that as temperatures warm, coffee production will move to higher altitudes, possibly into areas of virgin forest, as currently suitable land for coffee production becomes less suitable". However, this could possibly bring new concerns, if virgin forests would become land for coffee production, potentially affecting existing areas of conservation and biodiversity.

Although recent literature and past studies show increased attention to the risks and consequences related to climate stress experienced by Costa Rican coffee growers, it is a surprisingly small number of farmers taking action to limit the effects and mediate their collective vulnerability to climate stress (Eakin et al., 2014). The results indicated by Eakin et al. (2019) state that respondents replied, "there's nothing we can do". Therefore, the next section will challenge that by examining present regional comparisons and the different approaches to climate change risks.

2.3.4. Regional comparison of climate change perceptions

Existing regional comparative analysis of coffee production in Costa Rica highlight that climate change risks affect regions differently (Eakin et al., 2014). In broad terms, studies show that coffee plants in Los Santos are more productive, producing an average of 113 fanegas[1], compared with coffee cultivars in Guanacaste, which produce an average of 46 fanegas, that is equivalent to approximately 37 fanegas per hectare in Los Santos versus 17 fanegas per hectare in Nicoya (Díaz Porras & Delgado Ballestero, 2012).

The case study by Eakin et al. (2019) compares climate change perceptions and consequent adaptation responses in Central America but includes a relevant comparison in Costa Rica, namely between Nicoya (Guanacaste) and León Cortéz in Los Santos (Tarrazú). The study suggests that Nicoya is mostly affected by the lack of rainfall, thus suffering extensively from drought. On the contrary, León Cortéz appears more struck by unpredictable torrential rainfall in recent years. Similarly, other studies confirm these facts emphasizing that approximately 96% of farmers in Los Santos experience challenges related to increased temperature and about 94% of farmers blame these significant changes on heavy rainfall (Harvey et al., 2018; Viguera et al., 2019).

A similar comparative study was conducted by Díaz Porras & Delgado Ballestero (2012) between coffee produced on the Nicoya peninsula and in León Cortéz, Tarrazú. Even though the analyses are comparable, the results are somewhat different. Their investigation shows that there is less coffee produced in Guanacaste with respect to Nicoya. One potential reason for this could be climate change and fewer adaptation possibilities on the peninsula (Díaz Porras & Delgado Ballestero, 2012). This next section will further explore why.

[1] Fanega is the unit of volume used by processing plants, *beneficios*, when receiving coffee from producers. One fanega equals approximately 558 lbs (Aguilar & Klocker, 2000).

One major concern deriving from the study is that the land area dedicated to coffee production on the Nicoya Peninsula has decreased by 38% in recent years, compared to only 11% in Los Santos, stemming from environmental pressures (Díaz Porras & Delgado Ballestero, 2012). Similarly, the loss of land suitable for coffee production is of particular importance on the Nicoya peninsula. Therefore, an increased number of coffee growers are forced to switch crops. Another potential reason for crop substitution in Nicoya could be the lower altitude feature of Guanacaste. Even though coffee is grown in the hills of Guanacaste, there are not many options for relocating coffee plantations "higher up", the only alternative would be to substitute the crops. The region of Tarrazu, famous for high altitude, thus the option of moving plantations up the mountain is potentially available.

In terms of coffee plant pests, the research reveals that 97% of farmers acted against diseases and saw positive outcomes. However, it is a bit paradoxical because 97% also reported increased use of chemical fertilizers (Díaz Porras & Delgado Ballestero, 2012). Thus, the net benefit environmentally speaking is questionable for long-run adaptation purposes.

Finally, another interesting outcome is the percentage of smallholder coffee growers belonging to a cooperative or association. According to the case study in focus, 89% of coffee producers from the Nicoya peninsula are part of an association or cooperative, compared to 73% in Los Santos (Díaz Porras & Delgado Ballestero, 2012). It is vital to further understand the role of cooperatives and how they potentially can help smallholder coffee growers deal with the current environmental challenges and promote adaptation responses. Cooperatives and their role in the Costa Rican coffee transition will be examined next, together with supporting sustainability transition frameworks.

2.3.5. Cooperatives as a driver for sustainable development

Sustainable development is a social process, with human communities as core elements of sustainable ecosystems, that calls for modification of human activities to work towards the common goal of protecting natural systems, increasing biodiversity and working in harmony with natural processes (Gertler, 2001). Sustainable development is therefore based on organizational and institutional arrangements that support sustainable production and consumption initiatives, promote the development of sustainable communities, and protect the local ecosystems. The concept of community is vital because individuals acting alone have little to no power to implement sustainable practices and thus preserve natural resources.

Cooperatives are usually established by small scale producers in search of collective efforts to protect themselves from powerful players on the existing market. An important feature of cooperatives is that they can promote cultural, organizational and technological change, significant for sustainable development purposes. Likewise, cooperatives foster cooperation and collective action and address social and environmental topics. This is a key difference and contribution since capitalist market economies often fail to make minority voices heard, therefore, cooperatives contribute to social issues such as the reduction of social inequalities. As Gertler (2001) illustrates, "co-operatives can promote economic democracy and the empowerment of marginalized groups—a hallmark of sustainable development and a precondition for shared responsibility", it is evident that cooperatives also help stabilize regional economies and provide incentives for investments.

Another key concept is that "sustainable practices promote 'co-operative identity' and identification with the co-operative". An empirical example of this feature is the fact that coffee was the first agricultural product to receive the Nationally Appropriate Mitigation Action (NAMA) in Costa Rica. The NAMA is a governmental promise to become carbon neutral by 2021, specifically targeted at the coffee and livestock industry as of now.

In sum, the previous literature review confirms that food systems are currently under landscape pressure from climate change. This is particularly evident in the case of the coffee industry, which is the second most traded good in the world. The literature review emphasizes the potential of cooperatives, as the key agents in the coffee system, and how they can develop innovations to tackle the current climate change challenges thus destabilizing the current regime and facilitating a successful sustainable transition. Therefore, the aim is to further understand what niche innovations are currently being developed by the cooperatives and evaluate the state of the sustainability transition. The next section will describe the methodology used to collect the data for this thesis.

3. Methodology & Data

3.1. Research Design

This thesis research is based on primary data collection through, specifically in-depth individual interviews. The thesis uses a comparative case study, which "captures data at one point in time and selects sufficient cases according to those background characteristics that are then used to detect relationships and associations" (May, 2011, P. 98). Qualitative case studies allow for a comprehensive exploration of a specific topic and context (Rashid et al., 2019). The case study design choice seems fitting for the purpose of this thesis because case studies lead to a holistic understanding of complex phenomena. This is due to the data collection from multiple perspectives on the same research issue (Richie & Lewis, 2003). Similarly, an explanatory approach will be used to examine the research questions, since this approach allows the study of associations between existing phenomena, in this case, the link between innovations and climate change adaptation (Richie & Lewis, 2003). This qualitative research design is suitable for the study since it enables the collection of data from different and specific participants selected based on relevance, behaviors, values, and opinions at a specific point in time.

There are various philosophical points of view from which researchers can develop interviews. For this thesis, the "traveler" perspective, a constructivism approach where knowledge is created through the interview taking a partial view on reality, is used. Data collected through interviews will be triangulated with visual data and participant observations, to ensure validity and reliability of the fieldwork and to compensate for any unforeseeable challenges.

3.2. Caste study: The coffee cooperatives in Tarrazú and Guanacaste

The case study focuses on four cooperatives located in Guanacaste and Tarrazú respectively. The cooperatives included in the analysis are: CoopeTarrazú and CoopeDota in Tarrazú and CoopePilangosta and CoopelDos in Guanacaste. These will be briefly introduced subsequently.

CoopeTarrazú is located in San Marcos de Tarrazú, part of Los Santos and was founded on the 13th of October, 1960 with 228 associated members and an initial financial capital equal to approximately $6000. The primary reason for its establishment was market injustice for coffee

producers and unheard voices. After facing several obstacles, CoopeTarrazú has become the largest coffee cooperative in Costa Rica, since it is home to the largest *beneficio* and the most associated members, which equaled more than 5000 in 2022 (Impacto social del cafe en Costa Rica - Cooperativa de Tarrazú, 2022).

CoopeDota, as mentioned earlier, is a pioneer in carbon-neutral coffee. The cooperative was established on October 14th, 1960, initially with 96 small scale coffee producers, a collective sum of 29 thousand colones and a shared dream (Coopedota, 2022). CoopeDota is located in Santa Maria Dota in the Dota county and within the Tarrazú coffee region. Today, CoopeDota is home to about 900 cooperative members (Coopedota, 2022). Together, CoopeTarrazú and CoopeDota represent 10% of coffee producers in Costa Rica.

Moving on with the cooperatives in Guanacaste, the first one looked upon is CoopePilangosta, located in the Hojancha county of Costa Rica. Hojancha is part of the Nicoya Peninsula which constitutes one of the Blue Zones worldwide[2]. As a result, CoopePilangosta is unique because it is the only coffee in the world from a Blue Zone denomination, along with coffee from CoopeCerroAzul in Nandayure[3]. The cooperative has 192 members as of today (COOPEPILANGOSTA R.L, 2021). The cooperative was founded on March 27th, 1962, originally with 23 associates and a financial capital of about 8000 thousand colones (COOPEPILANGOSTA R.L, 2021). Initially only dedicated to coffee production, CoopePilangosta has throughout the last couple of years differentiated and now include few associate members dedicated to orange growing. However, coffee still remains the most important crop.

Finally, CoopelDos is also a Guanacaste based cooperative located further north near Tilarán. The cooperative has been processing premium coffee since 1971 and has approximately 350 associated members as of the time of this thesis writing (Coopeldos | Sembramos Progreso Desde 1971, 2022). Since most existing studies on the topic of climate change effects in coffee production focus primarily on mitigation measures and comparisons of small farmers in select coffee regions, the author decided to explore the climate change consequences and adaptation measures from a cooperative point of view.

[2] A Blue Zone is defined as a unique place with a high concentration of centenarians, and where people live healthier and longer than other places in the world. Currently, five Blue Zones have been identified worldwide (History of Blue Zones - Blue Zones, 2022).

[3] CoopeCerroAzul was contacted but without luck and is therefore not used in this research.

3.3. Verbal and Non-Verbal Data Collection

The verbal data component of this thesis is supported by semi-structured interviews, described by Flick (2009) as being open, theory-based interviews. Likewise, May (2011) states that "a semi-structured interview represents an opening up of the interview method to an understanding of how interviewees generate and deploy meaning in social life" (May, 2011, P.135). This method is used to collect primary data for the thesis because, "understanding motivations and decisions, or exploring impacts and outcomes, generally requires the detailed personal focus that in-depth interviews allow" (Richie & Lewis, 2003). Moreover, the comparability feature is also crucial, as it allows the interviewer to compare interview answers from different actors and explore similarities and differences thereof.

The verbal data collected during the interviews is complemented with visual data such as photographs which were collected at the site of every field visit and interview.

Visual data in the form of photographs represent the non-verbal data portion of this thesis. Richie and Lewis (2003) argue that "if context is such a fundamental aspect of the research phenomenon that observing or experiencing the research phenomenon in its natural context is critical to understanding, then naturally occurring data is likely to be preferred". This statement supports the idea that certain key aspects may be missed when conducting online interviews or just sitting in a closed office. The researcher of this thesis decided to include photographs because the visits to the cooperatives, offices, and farm locations where the face-to-face interviews were conducted, tell stories by themselves. It was an incredible experience to be fully emerged in the context and have the opportunity to document scenarios that words cannot express. As such, visual data strengthens claims, impressions and perspectives suggested by the verbal data.

Fieldwork research involves conscious and unconscious data collection. As a result, it is beneficial to make all data conscious to store it and use it for proof of claims later on. Therefore, the interview and visual data methodologies are also triangulated with observations. The researcher engaged in participant observations with the purpose of adding value to the research question answers. Observations are relevant in this research since they allow researchers to enter the lifeworld of the subjects being observed, thus enabling a thorough examination of how people act and behave in specific circumstances. Flick portrays, "the main features of the method are that you as a researcher dive headlong into the field. You will observe from a member's perspective but also influence what you observe due to your participation" (Flick, 2009). Consequently, the researcher of this thesis decided to include this method as it will give a different perspective in trying to answer the research

question and enable a comparison between the qualitative verbal and non-verbal data gathered. One major feature of observations is that they focus on situations, activities, and practices rather than individuals, thus providing a good compliment to interviews. The observations were collected in a fieldwork diary daily throughout the entire innovative practice.

3.4. Sampling

Qualitative research does not seek random samples nor aims at generalizing findings but rather study specific phenomena, relevant cases and their unique characteristics (Richie & Lewis, 2003). Therefore, this thesis employed purposive sampling, a non-probabilistic sampling method where each actor selected in the research represents a location or satisfies key criteria. Purposive sampling has two main objectives, "the first is to ensure that all the key constituencies of relevance to the subject matter are covered. The second is to ensure that, within each of the key criteria, some diversity is included so that the impact of the characteristic concerned can be explored" (Richie & Lewis, 2003). As these features reflect the purpose of this thesis, the author found them suitable for sampling selection.

Additionally, purposive sampling can be further classified into sub-strategies. For the purpose of this research, critical case sampling was preferred because "cases are chosen on the basis that they demonstrate a phenomenon or position 'dramatically' or are pivotal in the delivery of a process or operation. The logic is that these cases will be 'critical' to any understanding offered by the research" (Richie & Lewis, 2003). The critical cases are the cooperatives which represent the backbone of the comparative study. In qualitative research, sampling is usually not aimed at being representative. However, the researcher decided to include two cooperatives from each region to increase validity and reliability and furthermore, facilitate the comparison in the analysis chapter.

The first step in the sampling process was to identify the coffee cooperatives present in Tarrazú and Guanacaste. In Tarrazú, there are two major coffee cooperatives, CoopeTarrazú and CoopeDota as described above. These two were both contacted and later agreed to be interviewed. In Guanacaste, there are three coffee cooperatives, CoopePilangosta in Hojancha, CoopelDos in Tilarán and CoopeCerroAzul in Nandayure. The first two cooperatives are included in this research while the latter was unresponsive. Similarly, this comparative research also includes industry expert interviews and institutional actors. Therefore, several institutional actors and industry experts were contacted via email and phone calls, given recommendations from the CINPE professors, personal contacts and interviewees. The snowball sampling effect was also put into action as several

interviewees recommended colleagues or acquaintances who would be of great help for this research. In total, two participants are institutional actors, six interviewees are associated with cooperatives, and the final four are industry experts. All participants have been coded and classified as either cooperative (C), industry expert (IE) or institutional actor (IA). The interview details can be found below in table 3.

Table 3 – List of interviews

Code	Type of actor	Company	Role	Setting	Interview date
IE1	Industry expert	Britt Café	Agronomist	In person - Britt Café headquaters	9/2/22
IA1	Institutional actor	ICAFE	Project manager	In person - ICAFE headquaters	21/03/22
C1	Cooperative	CoopeDota	CSR director	In person - CoopeDota cafeteria and CoopeDota coffee field	23/03/22
C2	Cooperative	CoopeTarrazú	Bioprocesses engineer	In person - CoopeTarrazú research lab	23/03/22
C3	Cooperative	CoopeTarrazú	Coffee grower	In person - CoopeTarrazu research lab	23/03/22
C4	Cooperative	CoopeTarrazú	Innovation and R&D manager	In person - CoopeTarrazú offices	23/03/23
C5	Cooperative	CoopePilangosta	Cooperative director	In person - CoopePilangosta	28/03/22
IE2	Industry expert	Coffee Source	Sustainability project manager	Online - Zoom	29/03/22
IA2	Institutional actor	Ministry of Agriculture and Livestock (MAG)	Coffee program coordinater	Online - Zoom	31/03/22
IE3	Industry expert	Coffee Source R&D - Finca La Hilda	Agricultural engineer	Online - Zoom	31/03/22
IE4	Industry expert	Startbucks - Hacienda Alsacia	Head of R&D	In person - Hacienda Alsacia	5/4/22
C6	Cooperative	CoopeIDos	Agricultural engineer	Online - Zoom	7/4/22

Source: Own elaboration based on interviewee information and scheduling details

The sampling criteria used to select interviewees were based on the research questions. Examples of such criteria include: Institutional actors with key relevance on the topic, industry experts with diverse perspectives and relevant positions in the sector currently, industry experts with hands-on knowledge of coffee production, industry experts with many years of expertise in the field, coffee

growers, and cooperative employees and members with many years of experience in the field and current R&D positions.

3.5. Interview procedure

The interviews all followed a semi-structured format and were conducted individually, except for the pilot interview which included two interviewees at once. A total of 12 interviews were conducted and 13 people were interviewed. Most interviews were scheduled beforehand, while some were arranged on very short notice due to snowball sampling effects. All interviews were conducted in Spanish, eight face-to-face and four online.

The interviews held face-to-face required travelling between the two regions in focus, namely Guanacaste and Tarrazú, combined with travelling to San Jose where most of the industry experts and institutional actors are based. In the case of the cooperatives, the "walk-along" interview technique was also explored, this included talking to a coffee grower in the field and accompanying several cooperative actors around the production facilities, and cooperative coffee fields, thus learning about the specific coffee supply and value chain activities they are involved in.

The interviews held in person began with brief research and researcher introductions followed by the consent form presentation. The consent form was drafted both in English and Spanish, however, the Spanish one was the only one used since all the interviews were in Spanish. No interviews were done without informed consent or signatures (see appendices A & B). In the case of online interviews, the consent form was sent beforehand, at least 24 hours prior to the interview, allowing the interviewee to familiarize themselves with the topic background and sign the form before the interview. For this thesis, two separate interview guides were made, one for the cooperative interviews and one for the institutional/industry experts (see appendices C – F). Since the interviews were semi-structured, the interview guide emphasized four main blocks of questions, but follow up questions were allowed, and the researcher adapted the questions according to the interviewee if needed. The interviews started out with a brief introduction and then moved on to the first block of questions investigating the organization in focus, historical milestones, and any relevant background for the research. The next block of questions was related to climate change perceptions in coffee productions and interviewees were asked about main challenges faced in the respective regions, current trends and which adaptive responses are currently being implemented. The next block focused on innovations and served to understand the drivers of innovations and the extent to which climate change has

influenced the product, process or organizational innovations. The interviews ended with questions about future plans and final remarks. The interview guide was revised by an industry expert beforehand. All interviews were recorded. The interview length was set to be between 45 – 60 minutes.

3.6. Data Analysis

The analysis consists of in-depth interview transcriptions and was triangulated with field diary notes and visual data. All interviews were transcribed to facilitate the data analysis. The analysis and results section were done using the software Nvivo 12 Plus, a qualitative research tool enabling codifications of qualitative data and the discovery and grouping of common themes and keywords within the transcribed interviews. After the data collection, the data were prepared for analysis by transcribing the interviews and organizing the observation notes and pictures.

The next step was to explore the data, identifying key trends, patterns and main topics discussed. This enabled coding keywords using Nvivo, because the software uses keywords to locate text and segments and finally assigns codes. The keywords chosen are related to the aim of the thesis and also to the research questions (for codebook see appendix G). Lastly, the observations and visual data were incorporated in the analysis writing section to strengthen impressions.

3.7. Ethical considerations

Ethical considerations play a major role in this research. The interview participants were all thoroughly informed about the purpose of the research, the data gathering process, the data analysis and privacy considerations. This was facilitated with a consent form, prepared by the interviewee beforehand and presented to the interview participants prior to the interviews. The consent form serves as a guide to avoid doing any harm in the data collection, it maintains justice while analyzing the data and ensures confidentiality when writing the results. The key features of the consent form are the main purpose of the study, the name of sending organization, the method used for data analysis, and how the data will be stored after the interviews. The interviews were all recorded and deleted after the transcriptions had been processed. The interviewees' names were kept anonymous during the whole analysis process. However, the names of the companies represented were included in this thesis if the participants specifically authorized the use of the names in the consent form.

Moreover, other ethical considerations include ensuring respectful behavior and understanding of potential cultural differences during the interviews. Selecting the language carefully during the interview and in the interview guide was key to ensuring the interviewer and interviewee were on the same page. The researcher was also very aware of limiting the power dynamics and really emerged into the setting of the interview. Participants can decide to withdraw from the study at any time if needed. The participants were also given the option to view or review the final thesis before submission if desired.

3.8. Limitations

Like all research papers, this qualitative investigation has several limitations. As this thesis is based on qualitative research, it is not possible to generalize the results thus making the findings unique to the context. In the case of in-person interviews, there were times when the interviews were interrupted by colleagues entering the office or interview setting. Similarly, the COVID-19 pandemic slightly influenced the data gathering process since some interviews had to be done virtually. As a result, the researcher did experience some technical difficulties with some interviews leading to momentary interruptions, disrupting the interview flow. Though brief, this could be a limitation to the interview quality. Moreover, the participants had very different time availabilities for the interviews and therefore some interviews appear much shorter in duration with respect to others.

Another limitation was the unsuccessful inclusion of certain interviewees due to lack of interest or inability of participation in the research. Since the primary method of data collection was semi-structured interviews, there may be a risk of bias, both by the interviewee and interviewer. The interviewee bias may arise from personal points of view and opinions, whereas the interviewer bias could happen in the question formulation (Creswell, 2014).

The research questions and interview guide were formulated early on in the research process and based on existing literature at the time. However, the Costa Rican National System of Conservation Areas (SINAC) published the National Strategy and Action Plan for Climate Adaptation on April 25th, 2022. This could potentially be viewed as a limitation even though the document has been reviewed and incorporated where applicable before the submission of this thesis.

Since all the interviews were conducted in Spanish, the interviewer-interviewee language barrier should not be a problem. However, when doing the analysis, some meaning may be lost in the translation of quotes from Spanish to English.

4. Results & Discussion

This chapter aims at answering the proposed research questions presented above by using and analyzing the findings of the interviews conducted as part of this research.

4.1. Perceived climate change challenges affecting coffee production

To answer the first sub-question a), the interviewees were asked about how they believed climate change is affecting coffee production. All the interviewees in this research agree that climate change has had severe consequences on Costa Rican coffee production in recent years. When asked, the interviewees highlighted four critical issues, namely increases in temperature, changes in precipitation cycles causing drought and lack of rainfall, increased occurrence of pests and diseases, and finally having to relocate coffee plantations up in altitude due to unsuitable lands (C1, C2, C5, C6, IE1, IE1, IE3, IE4, IA1 & IA2). According to the industry experts, institutional players and the cooperatives, the most concerning climate change challenges appear to be temperature increases and changes in precipitation cycles because both lead to major uncertainties such as increased disease development. These findings appear to be in line with a recent analysis by the World Resource Institute (WRI) (2020) depicting that, "warming temperatures, greater rainfall and temperature variability, an increase in coffee diseases and pests (especially coffee rust), drought, and extreme heat are some of the main ways that climate change is affecting Costa Rica's coffee sector". The diseases in focus are coffee rust (roya), anthracnose (antracnosis) and "rooster's eye" (ojo de gallo), all caused by fungi infections but occurring at different altitudes and under particular climatic conditions. Furthermore, this confirms that in the MLP framework, climate change definitely represents landscape pressure (Chilvers et al., 2017).

i. Changes in temperatures and diseases

Similarly, one of the institutional actors illustrates the following in relation to coffee rust, "definitely the increase in temperature made us realize that this disease was a disease that was always there, but kind of controlled itself… then came this change in temperature…now it is a question of having to develop resistant varieties" (IA1). Likewise, cooperative interviewees state that, "we have

seen an increase in the temperature here, it used to be a little colder here, right now we feel the temperature a little more and, well, that influences the issue of diseases and also when we have rainfall. With very high rainfall, there is a high incidence of other diseases. Mainly anthracnosis, ojo de gallo and roya" (C2 & C6). Moreover, the concern of anthracnosis does not stop here, as one of the industry experts expresses that:

> New diseases have been identified, for example, a very important disease that 5 years ago, was not in the country or was known only in crop stages where crops were perhaps a little abandoned, with low fertilization, problems of soil acidity, which is a disease normally called anthracnosis… the farmer knew how to live with this disease, it did not wreak very, very strong havoc and only in the adult stages of the crop. It turns out that 5 years ago it began to appear in new crops, in crops that are tolerant to roya (IE1).

The associated consequences of temperature increases are also of significant concern such as the increased occurrence of diseases and the increased exposure of the coffee plant leaves to UV radiation. See the example of a leaf affected by coffee rust in figure 4 below.

Figure 4 - Coffee leaf affected by coffee rust

Source: Photograph taken by author of this thesis in Hacienda Alsacia, Alajuela.

ii. Changes in precipitation

The changes in precipitation cycles are also concerning as they interfere with the coffee flower blooming phase, the growth phase, and the maturation process. Cooperatives in Guanacaste and

Tarrazú agree on the matter and state that, "when it rains in the summer season, the coffee is going to bloom before time. So, suddenly a coffee that should have ripened in December, is already ripe in October and in October there are still no coffee pickers" (C1) additionally, "the unexpected rain regime we did not expect affected the coffee flowering a lot. There were rains in the summer months, in January and February… causing uneven flowering that also influences the production of coffee production negatively" (C5). Furthermore, IA1 argue that not only are these effects seen in the regions in focus, but it is a nationwide issue. They state that the lack of rainfall in the critical period of the coffee plant life cycle has led to extensive reductions in coffee yield and plant productivity. The loss has been estimated to reach up to 40% of a given year's harvest (IA1).

Additional consequences caused by changing precipitation cycles are the duration and intensity of the rainfalls. One of the interviewees depicts that in 2021, it rained double as much as usual in April and half as much in May. The problem is that if it rains heavily when the coffee flower is blooming, then excess rain will destroy the flower, damaging the grain and possibly leading to lost production (IA1). Interviewee C1 further highlights that the rainy season is no longer properly defined and predictable as it used to be.

iii. Regional differences

Interestingly, even though some of the consequences of climate change are similar in Guanacaste and Tarrazú, the regions seem to be affected differently. Both coffee regions suffer from the fact that the coffee plants have developed less disease resistance, leading to rapid development, and spread of new diseases most likely resulting from increased temperatures. However, given its lower altitude and geographic features, Guanacaste is much more prone to drought and is strongly affected by lack of rainfall.

One of the institutional actors did predict this outcome, stating that "the low areas have been the most affected where the temperature has risen the most… the low areas referred to are in the Nicoya peninsula, specifically Guanacaste" (IA1). Likewise, this is supported by the cooperatives present in Guanacaste as they reflect on the matter similarly:

> The increase in temperature is something that has been perceived and the behavior of the annual cycles. Here, we normally have two cycles, summer, and winter... Here we have seen nothing... Sometimes in the summer there are rains that we expect to see clearly but that never happen, they are no longer within the cycle (C5).

> Droughts have been one of the problems in some of our areas, we have some areas that are a little warmer than here and there has been a direct effect on the plants. The other thing we have had is that, in the past, the rainy season and the dry season were very well marked. Now we have had a disparity in the periods when it does not rain (C6).

These results are supported by recent studies since the WRI (2020) states that "drought and high temperatures are the two climate impacts most frequently mentioned by coffee farmers in the Nicoya Peninsula of Guanacaste province. These are closely followed by irregular rains, variability of season length, and increased solar intensity". Morataya-Montenegro and Bautista-Solís (2020) agree and argue that Guanacaste is a region where "climate change is expected to increase the severity and frequency of extreme weather events".

Conversely, Tarrazú appears to be more affected by increased temperatures and changes in precipitation cycles. When asked what climate consequence they felt were affecting the region the most, both cooperatives agreed that the rise in temperature and the change in precipitation cycles were having equally negative effects (C1 & C4).

It is evident that climate change is having multiple effects on coffee production in Guanacaste and Tarrazú, therefore the next section will explore the adaptation measures currently being used in response.

4.2. Adaptation responses currently in practice

The objective of this section is to examine sub-question b): *What types of adaptation strategies are evident in the coffee regions Guanacaste and Tarrazú?* As climate change is expected to have strong implications for coffee farmers in Costa Rica, implementing adaptation measures could be a solution to lessen their vulnerabilities (Verburg, Rahn, Verweij, van Kuijk and Ghazoul, 2019). The adaptation measures examined, could represent the strategies and behaviors described as part of the "old" regime of the MLP framework in figure 2.

During the interview process, the participants recognized five adaptation strategies between the regions to improve coffee production and reduce the climate change effects. The five adaptation methods are presented and described in table 4 below.

Table 4 - Adaptation strategy overview

Adaptation strategies in practice			
Method	**Description**	**Guanacaste**	**Tarrazú**
Agroforestry systems/Shade-grown coffee	Planting various tree species in the coffee plantations to limit UV radiation, improve microclimate and reduce heavy rainfall effects on soil erosion.	✓	✓
Development of more resistant varieties	The constant research and development towards the discovery of new coffee varieties more resilient to the changing climate conditions and resistant to new mutations of diseases	✓	✓
Soil improvement strategies	Increasing the awareness of soil conservation by promoting microorganism development and promoting organic fertilizers and regenerative farming practices	✓	✓
Coffee plantation displacement	Spreading awareness of the increasing need to move coffee plantations to higher altitudes due to unsuitability of land for coffee production at lower altitudes	✗	✓
Switching crops	Having to switch coffee plantations out altogether with other more resilient crops due to severe climate consequences	✓	✗

Source: Own creation based on interview input

4.2.1. Agroforestry systems and shade-grown coffee

Agroforestry practices and producing shade-grown coffee appears to be the most common adaptation practice, in both Guanacaste and Tarrazú, according to two-thirds of the interview participants, including all the cooperatives, both institutional actors and a few industry experts. One of the cooperatives interviewed is the pioneer in using this strategy as they have been managing coffee plantations with agroforestry systems since the 1990's. The interviewee expressed, "the innovation that was made in the 1990's and that is still valid today is the management of agroforestry systems, sustainability, and shade management, which for me is an important innovation that was made at that time and is still valid… we have found that shade management is indispensable because here you cannot produce coffee without shade" (C5). Therefore, managing forestry systems and encouraging shade-grown coffee is indispensable for climate change adaptation and sustainable coffee production. This cooperative is not the only participant that sees a clear connection between shade-grown coffee and promoting soil benefits. One of the industry experts mentions that the implementation of agroforestry systems that create shade decouples the climate effects from the coffee plant since it creates a microclimate offering more protection and thus more resistance to increasing temperatures. Likewise, one of the cooperatives states that the shade has a double function. On one hand, the trees

create shade during periods of excess UV radiation, acting as solar protection for the coffee plants. On the other hand, the shade trees can be trimmed down during the rainy season to allow rain to get to the coffee plant roots (C1). Excess UV radiation has also become a problem in recent years due to raising temperatures. An adaptive response is explained by one of the Guanacaste-based cooperatives.

In the Tarrazú region, the common trees to use as shade are different kinds of higher altitude fruit trees such as avocado, apple, peach and plum. The combination of coffee plants with these types of fruit trees is not random but very thought through since these fruits ensure the coffee farmers an additional income during the year when it is not coffee season. This symbolizes an alternative way of adaptation, backed up by C1 as, "during coffee harvest, there is no avocado ... However, in the winter it is avocado season, so that means constant income. That is a way to adapt as well" (C1). Moreover, one of the institutional actor interviewees agrees and reflects "many growers are planting avocado with coffee for this reason they are always planting mixed forestry systems to get the most out of the system in a more complementary way" (IA2). An example of this practice can be found below in figure 5.

Coffee growers are also searching for alternative solutions to adapt against UV radiation. One of the industry experts express that, "In some cases we have resorted to using sunscreens on the leaves in times of high radiation…Basically it is being caused by climate change, the temperature has increased more, solar radiation is higher, ultraviolet rays are affecting the leaf lamina more, so it is a waxy wax layer and that layer has been weakening due to the increase in solar radiation" (IE1).

As the quotes illustrate above, the interview responses highlight that practicing agroforestry and growing coffee under shade is essential in both Guanacaste and Tarrazú. Looking at these adaptive responses from a literature point of view, a contrasting argument is seen between these findings and the research by Aguilar and Klocker (2000). The authors believe that shading trees are vital for coffee grown at lower altitudes, such as in the case of Guanacaste, but not needed in higher altitude regions, like Tarrazú, due to 'self-shading' mechanisms of higher branches and the cloudy weather conditions.

Next, the development of new coffee varieties as an adaptive response will be explored.

Figure 5 - Avocado trees planted for shade in coffee plantations in Tarrazú

Source: Pictures taken by author during fieldtrip to Finca Alto Vapor, Tarrazú.

4.2.2. Development of new coffee varieties more resistant to climate changes and diseases

An additional imperative adaptation strategy identified is the development of more resilient coffee varieties. The Costa Rican Coffee Institute (Instituto del Café de Costa Rica from here on ICAFE) oversees the development of new varieties, approving them and distributing these to smallholder farmers around the country. Due to more frequent plagues and diseases, the overall productivity of the coffee sector has been declining, therefore the need for more resistant coffee plants is urgent. One of the interviewees affirmed the following on the topic:

> Productivity has been greatly affected by pests and diseases that were perhaps occasional before, but now more recurrent or more problematic ... we are working on the creation of new varieties or the development of varieties that are more tolerant to certain diseases such as coffee rust ... in some cases, we are seeing that it is not enough to make this variety and offer it to the growers, it must be complemented because when you tell a grower that this is a tolerant variety, they let their guard down and stop taking care of their plantations (IA2).

The idea behind the ICAFE is that they have experimental farms around the country where they develop and test new coffee varieties in various climates to ensure maximum productivity and

resilience. Moreover, management and monitoring of the coffee plantations is highly encouraged, as the ICAFE interviewee states, "the issue of monitoring is something that, if you insist, is one of the best practices" (IA1).

Another interesting example stems from the idea that one of the industry experts interviewed started experimenting with new coffee varieties and "they developed some very interesting varieties, very productive, very tolerant to [coffee] rust, but they were starting with this problem related to anthracnosis and sudden resistance to coffee rust. So, they began to investigate together with ICAFE" (IE4). The adequate development of new varieties suitable for various climates and geographical regions is currently a key point of the sustainable transformation agenda. One possible consequence if this is not reached is illustrated by another institutional actor interview, who says, "the development or search for varieties that are more suitable for other types of climates is crucial in order to continue with coffee… otherwise, the most feasible thing to do might be to switch to other crops, which is unfortunate and drastic, but it can be like that" (IA2). This method for adaptation is being implemented nationwide, therefore present in both Guanacaste and Tarrazú.

4.2.3. Soil improvement strategies

The soil conditions seem to be underrated in the existing literature. However, research does state that excessive use of chemical fertilizers has negative consequences on soil and leads to soil degradation (Castro-Tanzi, Dietsch, Urena, Vindas and Chandler, 2012). The interview results emphasize the importance of having healthy soil for coffee production and the importance of constantly preserving it. Several participants stated that the key to using soil conservation as an adaptive response was to raise awareness and hold workshops for coffee growers and technical personnel (C4, IA2, IE3).

The trends nowadays focus on going back to more ancient agricultural practices, opposite of overexploiting the scarce land and resources. Therefore, the concept of regenerative agriculture has become popular among coffee growers in Costa Rica (Elevitch, Mazaroli & Ragone, 2018). This supports the idea that there is a push and existing incentives to move from the old regime, focused on chemically-intense fertilizers and traditional agricultural practices, to improved modern practices, thus reflecting a potential undergoing sustainability transition as portrayed by Chilvers et al. (2017), Geels (2011) and Kuokkanen et al. (2018). Specifically, one of the industry experts interviewed acknowledged that:

> The topic of regenerative agriculture, which is basically investing a lot in creating soil instead of contaminating the soil or reducing it. We are making soil by adding microorganisms, organic matter and although it may not seem like it, having a healthy soil implies having a healthy plant, right, so the plant tends to be more resilient and display a stronger root system to cope with the effects of climate change (IE3).

The notion of regenerative agriculture is also an example of transformative adaptation, thus in line with the theoretical framework (Ferdinand et al., 2020). The concept of developing and adding microorganisms to increase soil resilience will be explored in the section on innovations. But first, the next adaptation strategy will be looked upon, namely coffee plantation migration to higher altitudes.

4.2.4. Coffee plantation displacement

Drastic increases in temperature have changed the optimal conditions for altitude coffee production in the Tarrazú region. Up until recently, the optimal altitude for top quality signature Tarrazú coffee was between 1200 – 1900 meters above sea level (IA1). One of the cooperatives from the region reveals that "ten or fifteen years ago, Copey, a community 8 km away, did not think of planting coffee, they had high altitude fruit trees such as apple, peach, plum, and avocado because it was very cold. Today, the best qualities of coffee that are winning excellence awards are produced in Copey" (C1). To exemplify, this cooperative has a gourmet coffee brand produced from coffee beans from their own cooperative farm located in the mountains at an altitude between 1920-2030 meters (see figure 6).

Likewise, the concept of moving coffee plantations up in altitude due to increasing temperature and sub-optimal conditions is backed up by several other interviewees. One of the industry experts discloses, "the altitudinal band is rising and here in Costa Rica. We can see that in areas that before were very difficult to imagine as suitable to produce coffee ... are now used for planting coffee, so here in Costa Rica we are planting at 2000-2200 meters above sea level which were altitudes that were not appropriate for coffee production in the past" (IE3). Moreover, this type of displacement aligns with goal number 1 of the transformative adaptation framework (Carter, Ferdinand & Chan, 2018).

Figure 6 - Cooperative-owned coffee plantation in Tarrazú at an altitude of 1920 meters above sea-level

Source: Own photography – Tarrazú

However, such adaptation responses do not come without repercussions. Firstly, "when the plant is in such high altitudes, being a tropical plant, there is less respiration, so the size of the fruit is reduced" (IE1) thus extending the harvest period and requiring more resources to produce less or the same amount of coffee as before in optimal altitudes. Likewise, Costa Rica is known for its extended areas of forest conservation and protected areas. Tarrazú is home to several hectares of protected forest, "what happens when, in certain regions, it turns out that these mountains or these lands are dedicated to forest conservation but also the perfect altitude for the production of the coffee that we know to be of the highest quality?" (IA2). Sain, Thomas and Cenacchi (2019) believe that even though migrating to higher altitudes brings certain constraints to the local farmers, it is a hopeful solution that coffee farmers in Costa Rica may adapt successfully to climate change.

The shift in coffee plantations is a phenomenon taking place to some extent in Tarrazú, however, it is not a long-term solution since land is limited and shifting requires extensive amounts of resources which most local coffee growers do not have. The idea of moving up in altitude is not an adaptation strategy manifested in Guanacaste. However, Guanacaste has other challenges such as switching crops that need to be addressed which will be discussed subsequently.

4.2.5. Switching crops – Oranges are the new coffee

Unfortunately, the negative impacts of climate change have in some instances been so extreme that coffee farmers have decided to switch from coffee to other more potential crops altogether. This is an example of transformative adaptation to climate change (Carter & Tye, 2018). The reason behind this rising trend is that old coffee plantations with poor productivity and potential for climate change resilience and improved soil conditions dominate certain parts of Guanacaste. Therefore, an alternative adaptation solution has been observed, switching to "citrus, mainly oranges, have become more important activities in recent years, given the difficult stage of production and prices…There were coffee producers who switched 100% to oranges and others who did it gradually. There have been very few who really love the coffee activity and do not want to retire from it. That is why we feel the commitment to support them as much as possible" (C5). According to a study by World Resource Institute (WRI), farmers in this region who made the switch are already benefitting from the change, featuring higher prices, lower production costs and more disease resistance. The only concern currently is the medium-long term sustainability and vitality of the activity given the continuous climate change consequences.

Existing studies reveal that "while citrus seemingly provides opportunities to build resilience to climate change, increase profits, and maintain agricultural livelihoods, many farmers are still more passionate about growing coffee, given its cultural significance and intergenerational legacy" (Ferdinand, Tye, Gebregziabher, Suberi & Carter, 2020). Moreover, research suggests that farmers recognize a preference for growing coffee "due to its long-term positive impact on biodiversity and ecosystems" (Ferdinand et al. 2020). Yet, as climate impacts intensify, coffee growers may be left without the option to continue growing coffee and may be forced to switch crops to alternatives like citrus fruits. The challenge then might be access to reliable information, financial aid and tools (Ferdinand et el. 2020). Reflecting back on the MLP framework, this is an example of social experimentation within the niche level, since it challenges current methods of production and experiments with new nice solutions (Chilvers et al., 2017).

The next section will explore the existing and forthcoming innovations within the coffee sector and their drivers. The innovations will be distinguished based on product, process and organizational.

4.3. Innovations and their specific drivers

4.3.1. Overall drivers of innovations

This section aims at answering sub-questions c) and d): *What innovations are being developed by coffee cooperatives in Guanacaste and Tarrazú? & What are the main drivers of these innovations?*

The innovations examined can be categorized into three categories: product-, process- and organizational innovations. Determining what the general drivers of innovation are within the coffee industry and particularly, what makes the coffee cooperatives innovate is fundamental for the purpose of this thesis. Looking at the greater picture, it is evident that institutional actors and industry experts believe the main driver of innovation is, "the need, definitely" (IA1). This resonates with the idea that climate change is exerting pressure on the landscape and their motivation to innovate feels more "like a moral obligation" (IA1). Contrarily, industry experts argue that "innovation makes you anticipate the crisis... being innovative is like a lifestyle and an innovative company usually stays in a vicious circle of doing things differently and that makes a different vision" (IE3). This could place the industry experts at the regime level of the MLP framework, suggesting some interest in incremental innovation but not exactly forming part of the radical niche level innovations.

In relation to crisis, one of the surprising innovation drivers that emerged from all the interviewees is how the war between Russia and Ukraine is affecting innovations currently. The dominating point of view is well summed up by one of the industry experts in the following statement:

> This year with these fertilizer prices is the year of opportunity for this type of initiative. So we are going to test a lot of initiatives... it is clear that there is a huge push from outside to inside but it is the best time to innovate…the goal is to help the environment and be less dependent on chemical and imported fertilizers (IE3).

The negative effects perceived by the interviewees are in line with very recent articles on the subject. A study by the Economic Commission for Latin America and the Caribbean reveals that the agricultural sector is one of the most directly affected sectors by the crisis, given the decline in raw material supply. Specifically, the article illustrates that major supply shocks are greatly affecting the fertilizer market globally. In addition, "coffee farmers face a similar scenario in Costa Rica, Guatemala and Nicaragua, where lower-productivity fertilizer alternatives are already being considered to offset the price increase and the reduced supply of imported fertilizers. The International Coffee

Organization (ICO) estimates that world coffee production will fall by 2.1% in the current commercial year" (Canton, 2021). It is evident that the ongoing crisis is affecting fertilizer development more than anything else, therefore it will be explored further in the product innovation section.

Similarly, when the cooperatives in Guanacaste were asked what the main driver of innovation was, they responded that the market forces them to innovate, since "the market forces us to constantly change". Both the ongoing war, the high fertilizer prices and the market represent landscape elements that are driving innovations on a cooperative level. This is quite interesting and further confirms how climate change can be a driver but also how crucial energy prices (fertilizers), scarcity of resources and the overall market determine innovation and transition speed (refer back to figure 2).

Furthermore, one of the cooperatives said that the fact that they were a small team of young professionals and coffee experts was a very important enabler since they all work towards the same goal but have many ideas for the future and are well below the average coffee producer age. The other cooperative stated that the main driver of their innovations is the well-being of the coffee growers because "without them, there will be no cooperative". They also mentioned the NAMA café program as being an innovation enabler and getting them on the right track towards more sustainable and conscious environmental production, portrayed by "the NAMA coffee program has been the driving force in several areas and specifically that of carbon footprint" (C5).

Analogously, the cooperatives in Tarrazú both portray the "need of helping and providing answers to their associated producers" as the main drivers of innovations in their case. This is even more evident in the following quote: "what drives us to innovate? The well-being of the producers. Why? Because we work for them. We are a cooperative and the day they are not there, the cooperative will not be there" (C1). This underlines the importance of community and how cooperatives really do promote sustainable development through collaboration (Gertler, 2001). Each cooperative innovation and the respective driver will be explored next.

4.3.2. Cooperative product innovations and their specific drivers

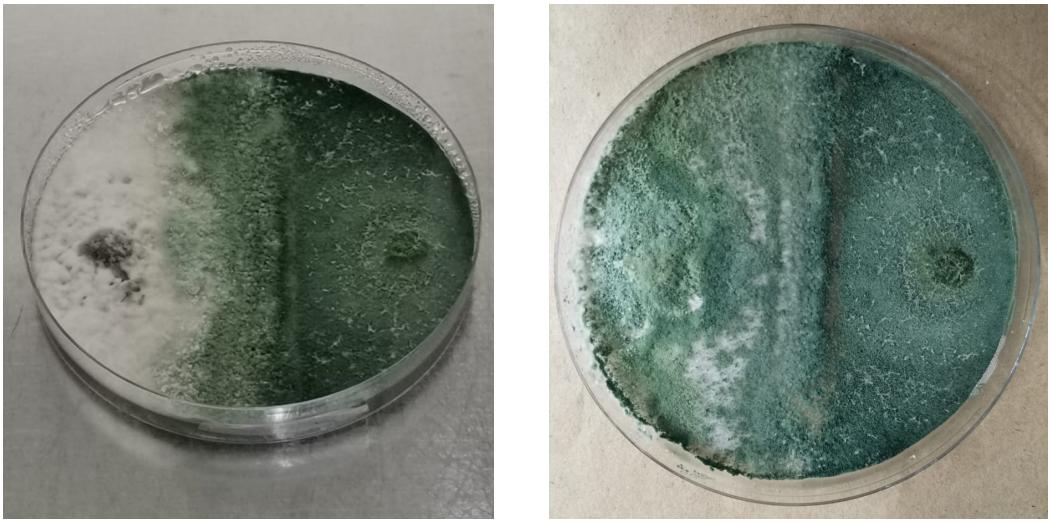
Constant improvement and research and development are core ideas pertaining to the cooperatives, institutional actors, and industry experts in the coffee industry. Therefore, examining product innovations is vital. Product innovations refer to "the introduction of a new good – that is one with which consumers are not yet familiar – or a new quality of a good" (Simonetti, Archibugi & Evangelista, 1995).

The interviews revealed that there are three main areas of product innovation within the coffee sector, a) products stemming from microorganisms, b) organic fertilizers and alternatives and c) coffee derivative products with added value. The analysis reveals that there is product innovation in the cooperatives, but climate change is not the principal driver as expected. Climate change is seen as more of an accelerator of innovations rather than a direct driver.

Examining the concept of microorganisms, the first group of innovations discovered are a set of products containing different combinations of fungi, lactic bacteria, yeasts, and phototrophic bacteria. These products serve as soil fortifying and help regenerate healthy soils by bringing back organic matter. Referring to the theory, these products are an example of niche solutions, specifically under alternatives and options since they provide product innovations that stimulate and accelerate the transition to a new regime where bio-based products are at the core.

Figure 7 - Microorganism innovation that kills pathogens affecting the coffee plants

Before After



Source: Authors own photographs from cooperative in Tarrazú

The second category of innovation is organic fertilizers. These products also fall under the alternative niche solutions and promote the sustainability transition since they seek to find alternatives to conventional chemical fertilizers. Both the cooperatives in Guanacaste and in Tarrazú use the coffee fruit pulp and convert it into organic compost by drying it and redistributing it to the coffee growers.

From the interview knowledge gained, it seems that research efforts are focused on organic matter regeneration and limiting the use of chemical fertilizers. This is depicted in the following excepts:

> In light of the ongoing fertilizer crisis, we detected an opportunity and decided to go a step further... So based on that need that was detected, 2 new products were developed, and we started with a pilot project. And that ... was in a matter of 6 months This new product is coffee pulp supplemented with calcium and magnesium which benefits coffee… This is an alternative (C4).

> We elaborate organic fertilizers from the derivatives of the coffee berry, and we enrich it with raw materials … such as calcium and magnesium sources (C6).

The crisis and current sky-high conventional fertilizer prices and the limited supply is serving as an important innovation driver. The cooperatives primarily in Tarrazú, have taken advantage and rapidly developed alternatives, "we have been working on organic fertilizer solutions and alternatives to chemical fertilizers since approximately 2011. However, with the current high fertilizer prices and ongoing crisis we felt an urgent need to respond and develop an alternative product with the idea of reducing the dependence on conventional fertilizers in the future" (C4). Therefore, it can be established that the cooperatives in Tarrazú are actively innovating and leading the way in terms of transition pathways.

While the cooperatives in Guanacaste also view the crisis as an opportunity, they have several ideas for alternatives, but have not developed any concrete products yet. This is reflected as they state, "the international fertilizer prices are extremely high at the moment, as a result of the war between Russia and Ukraine. Therefore, we need find alternative options in order to respond to this problem" (C5). Despite not having developed any concrete products yet, they have several ideas and the fact that they identify the opportunity to act now shows their innovative potential and willingness to promote sustainability transitions.

The last group of product innovations are products with added value derived from coffee beans or the coffee berry. This idea can be tied back to the literature on transformative adaptations, stating that transformations lead to the development of innovations or products with added values (Ferdinand et al., 2020). Here, all the cooperatives have similar products, some have the prototypes ready, and others are already being commercialized. The driver behind these innovations is to some

extent climate change, to some extent the variable coffee prices and to some extent the needs of the coffee producer. In terms of climate change, it serves as an indirect driving force since coffee growers can no longer solely depend on coffee due to the changing yields and fluctuating productivity. Several interviewees reflected on the idea that creating value-added products give coffee growers an additional source of income and security in case a harvest turns out to be less than expected or the prices for coffee drop. One of the Tarrazú cooperatives said the following:

> The cooperative invests in this type of things because these types of products are of a higher added value and do not necessarily depend on a price that is fixed in the stock exchange of New York. If we manage to develop new products…With a very high quality, we can put a good price on this product and earn the Differential (C4).

Examples of products developed by cooperatives are coffee ground flour, coffee berry tea, green coffee capsules, collagen crème made from coffee grounds, face masks, coffee liquor and coffee wine. with a value-added are shown below in figure 7. "That's a way of adapting as well, creating an additional economic income" (C1). From an MLP perspective, these products could fall under the radical innovations on niche level and show that cooperatives are in a quite advanced state of innovations towards regime destabilization (Chilvers et al., 2017; Geels, 2011).

In addition, it appears that cooperative flexibility is also an essential driving force in terms of product innovations, "the agility with which the cooperative reacts is important. Why? Well, otherwise we would have stood with arms crossed waiting for the producers to solve their problems themselves… we cannot stand idly by, we have to offer an alternative. The new products… are the basis for this" (C4). Several authors agree on the idea that product innovation is a valid strategy for climate change adaptation (Ponce Oliva, Huaman, Vasquez-Lavin, Barrientos & Gelcich, 2022). As Geels (2011) illustrates, the niche level features fewer governing rules and norms and is the locus of innovations due to the freedom to innovate.

Figure 8 - Examples of value-added products

Source: Own photography – From left to right: Coffee ground flour, coffee berry tea, green coffee capsules and an exhibition of products

4.3.3. Process innovations

In contrast to product innovations, process innovations refer to the "introduction of a new method of production, that is not yet tested by experience… and can also exist in a new way of handling a commodity commercially" (Simonetti, Archibugi & Evangelista, 1995).

Drought, due to lack of rainfall, is an environmental factor affecting coffee production and represents a driving force for one of the process innovations. As a response, coffee cooperatives have been addressing this issue by developing and implementing irrigation systems. This is one example of an adaptive response that is only seen in one of the regions in focus, namely in Guanacaste, due to the lower altitude and geographical conditions.

Another important process innovation is the carbon footprint tracking and measurement system. The driver of this innovation is based on the NAMA (Nationally Appropriate Mitigation Actions) café initiative formulated in 2014. This idea was established by the MAG and ICAFE in collaboration with the German company, GIZ. The purpose of the NAMA café is to promote climate change mitigation actions and sustainable agricultural practices, ensuring environmentally sustainable and lower carbon footprint coffee around Costa Rica. This initiative has been a driving force for most of the cooperatives and can be considered part of the niche level under social experimentation due to the change in behaviors (Geels, 2004). For example, "the NAMA coffee program has strengthened

the field by encouraging the calculation of the carbon footprint and keeping records of carbon emissions from the different phases of production. Correspondingly, the NAMA program provided tools and training we didn't have before" (C5). Furthermore, C4 expressed that because of the NAMA program, they determined "that 80% of the greenhouse gas emissions are generated in the handling of the coffee pulp and its residue". As a result, the NAMA program encouraged a strong focus on environmental impact while maintaining high levels of productivity. The NAMA also promoted ten best practice principles known as *Buenas Practicas Agricolas (BPA's).* A list of these can be found in Appendix H. One of the interviewees express that, "for me, the carbon neutral certification was an innovation … based on that, we have been doing things, such as the installation of solar panels. 80% of our processes use solar energy... we have 250 solar panels which create several opportunities" (C1). It is also important to mention that C1 are the pioneers in carbon neutral coffee, becoming the first carbon-neutral certified coffee worldwide in 2011.

Another example of process innovation is the way most cooperatives have started transforming the coffee fruit into something valuable. For example, with help of new machinery and funding, the cooperatives in Tarrazú have been able to process coffee pulp and re-distribute it to the associated farmers. This, however, is not the case in both regions. In one part of Guanacaste in particular, "at the moment we do not have all the tools we would like to have, for example, we would like to add value to the coffee pulp, to extract flour from the pulp that has a high antioxidant content, important nutrients. But the equipment to develop this is very expensive" (C5). This reflects yet another important difference between Guanacaste and Tarrazú. It seems from interview evidence that Guanacaste lack more resources compared to the cooperatives in Tarrazú. The cooperatives in Guanacaste show innovative potential and have several ideas for the future, whereas it appears that the cooperatives in Tarrazú are a step ahead, already developing some of these "future plans".

4.3.4. Organizational innovations

From an organizational point of view, the innovations pointed out by one of the institutional actors related to climate change and adaptability is the development of weather monitoring applications for smartphones, which provide coffee growers with more or less accurate weather predictions such as precipitation forecasts and disease control tools. Furthermore, the concept of full transparency and traceability along the coffee value chain is key to ensuring top quality coffee in Costa Rica. This can be considered an organizational innovation initiated by ICAFE, "we have a statement

of traceability and sustainability and possess the traceability of coffee from all over the country, from always until now, of course, before it was achieved as paper but now we have digitalized everything" (IA1). These innovations are aligned with the goals proposed by transformative adaptation literature, particularly goal 3 referring to altered production technologies (Carter, Ferdinand & Chan, 2018).

The driver of such innovations appears to be the need of the coffee producers around the country and the specific demands of society, such as customer demands influencing transparency and digitalization.

4.4. Barriers to adaptation and innovations

The last sub-question will be explored in this section, *What are examples of innovation barriers and how does the innovative capability differ among cooperatives in the regions examined?* For this research, barriers refer to factors that in one way or another inhibit the innovative potential of the regional cooperatives. One barrier that was mentioned by all the cooperatives in both regions is the higher average age of the coffee growers, bringing more objection to changes and new ways of doing things. According to the MLP framework, age could be considered part of the behaviors under the old regime, thus adding pressure and in some ways decelerating niche innovations. When asked about the main barriers to innovation in the interviews, these were some answers that stood out:

> There are several factors, I think I mentioned it before. Our associates are, because of age and cultural aspects, very conservative (C1).
>
> On country level, producers generally resist the change of new things when there is something new to do. In the end they say 'no, I'd rather stick with the old, the known, than the new to be known'. So we have seen a bit of resistance. What we have worked a lot on is to show them in a visual and practical way ... we bring interested producers, and we show them what we are doing, and we have been capturing a little more attention with respect to that and people have been understanding and seeing the importance of changes (C6).

As a result, one of the major challenges facing the coffee industry in Costa Rica is the high average age of coffee producers.

Moving on, the next most important barrier identified is the lack of resources, and specifically the lack of financial resources. "Costa Rica has a problem, it is also not subject to many international

donations. Because in theory we are a country that is doing well" (C1). This statement sums up the opinion of several interviewees, who often add that most foreign aid goes to other central American countries such as Nicaragua, El Salvador, Guatemala and Honduras. Even though cooperatives are technically viewed as businesses, their profits are not as significant as the operating costs. The processing mills are large, require maintenance and they have to ensure fair payments for the coffee growers. Therefore, cooperatives often lack financial resources to go beyond their daily tasks and investing in other projects.

Interestingly, there seems to be a difference in the way lack of capital is a limiting factor in the two regions. Examining Guanacaste first, it is evident that cooperatives believe that, "money is always one of the biggest problems" (C6), and likewise, "they don't have the resources to invest a little more in coffee. It is a constraint in a way" (C5). Furthermore, "the coffee growers' access to credit is very limited" (C5) therefore, several cooperative interviewees from Guanacaste suggested that "if the cooperative has more resources for the producers, it would be beneficial to establish credit services" (C5). Likewise, the WRI agrees, expressing, "adaptation measures are not possible for most or are very limited due to inadequate technological and financial capacities" (WRI, 2020) which further highlights the regional difference in resources.

Looking at the case of Tarrazú, the lack of financial resources seems to be less vital and for different purposes. "The main barriers that we have had is to find funding, support from external entities, public entities that help finance research … a lot has been developed with our own resources. I can tell you that 95% of our projects have been developed with our own resources.
(C4). This shows a significant difference between the two regions where Tarrazú primarily looks for research funding but has funded the majority of projects themselves in the past, whereas the cooperatives in Guanacaste seem to need more than just research funding. The interviews and research process also revealed that the cooperatives in Tarrazú already offer extended credit services to their associate members and therefore, do not lack capital in the same way as the cooperatives and their members do in Guanacaste, which is a very important aspect to consider when doing the comparison. To emphasize this notion, one of the cooperatives interviewed mentioned the following: "At the moment we do not have all the tools we would like to have in terms of investment, we would like, for example, to get an added value from the coffee pulp, extract flour from the pulp that has a high antioxidant content and very important nutrients. But the equipment to develop this is very expensive. So this is an innovation issue" (C5).

Another important barrier distinguished by the institutional actors is the lack of collaboration between academia and the agricultural sector in terms of research projects and technology transfers. This is clearly pointed out in the quote, "if there was a connection at the level of coffee research and agricultural technology transfer programs, perhaps resources would be better utilized" (IA2). This is a key point to underline and something that will affect future opportunities if not improved soon. One explanation could be that most developments and high-level research to go through the ICAFE. One of the cooperatives commented by providing a quote by a former colleague, "it is not the rich countries that do research, but the countries are rich because they do research" (C4). Interestingly, studies show that as long as climate impacts remain modest, incremental adaptations might suffice. However, with more substantial climate impacts, requirements for stronger social-institutional changes will arise, just as suggested by the MLP. Climate change will continue to add pressure to the existing regime, which will eventually destabilize when the niche innovations are mature enough to disrupt and promote a sustainability transition. Even though there are some barriers, there is also hope. Therefore, the next section will explore future opportunities in terms of innovation projects for adaptive coffee production.

4.5. Future opportunities

There is potential for future coffee production if several adaptation measures are implemented and awareness is emphasized. An interesting future opportunity was put forth by one of the industry experts who introduced the concept of carbon farming. Even though it is considered a mitigation action, it could be interesting to see if it becomes reality. Sharma, Kaushal, Kaushik and Ramakrishna (2021) describe the idea of carbon farming as a sustainable strategy for food production and other products. This innovative notion comes from the idea that soil management and cropping systems are becoming increasingly vital for agriculture, not least for coffee plantations. Therefore, promoting healthy management practices, increasing the soil quality and protecting the environmental resources is the future (Sharma et al., 2021). Many fields nowadays display soil carbon deficiencies due to droughts, erosions, and overall unhealthy soils. Thus, restoring the carbon content has multiple benefits both for the environment and from an industry expert perspective, the first goal would be to reach carbon sequestration practices because that would indicate healthy soil. Secondly, reaching a carbon positive coffee plantation is desired, "that is, the emissions are less than the sequestration. What this would imply is that this would be one more service of the farm, that is, we could sell services

for environmental payments called payment for environmental services. Then the farms could market coffee and carbon credits. For this to happen we need five years of data to be approved for the sale of credits, so now we are in the second year" (IE3). Even though this is not an adaptation innovation, it would still allow coffee farmers to adapt to climate change challenges since reaching the point of carbon positivity would require the implementation of several adaptation measures. This specific idea is linked to the transformative adaptation theory and niche innovations, as it is changing the way traditional agriculture works and introducing rather "radical ideas". Moreover, Carter, Ferdinand and Chan (2018) underline the need for transformation projects that introduce new technologies, practices, systems or structures by changing the location or nature of activities. These initiatives will serve as the seeds for the future according to the authors. In line with the carbon sequestration idea from the Guanacaste-based cooperative, it seems like they are in line with the transformative adaptation framework.

5. Conclusion

The purpose of this thesis was to understand whether climate change acts as an innovation inducer or accelerator in the context of Costa Rican coffee cooperative innovations thereby understanding the drivers of cooperative innovations. The study focused on a regional comparison between Guanacaste and Tarrazú, conducted using semi-structured interviews combined with visual data. The findings indicate that climate change is indeed affecting the regions differently and that the innovative potential of the cooperatives located in the respective regions also differs. Before conducting the interviews and the underlying research, one expected climate change to be an important innovation inducer given the crucial impact the unpredictable climate changes are having on coffee production currently and the severe consequences the sector will face in the near future if no action is taken immediately. Furthermore, the research was examined through the MLP perspective, suggesting that cooperative innovations are well underway on the transition pathway and not far from being mature enough to disrupt the existing coffee system regime. It can also be concluded that the drivers of innovations differ from innovation to innovation, but climate change acts mostly as an innovation accelerator or indirect driving force rather than an innovation inducer.

The answer to the overarching research question is not as expected. The results point out that climate change is not exclusively inducing innovations, climate change is rather serving as an accelerating factor to some extent. Moreover, it cannot be concluded that every innovation is induced or accelerated by climate change, rather that each innovation has a specific driver. Even though climate change is not the main driver of most cooperative innovations, it still plays an important role in the future of the Costa Rican coffee sector. Also evident as several innovations aim at reducing the environmental impact of coffee production processes and given the significant focus on mitigation strategies.

On a product innovation level, it can be concluded that the Russia-Ukraine conflict and the negative impacts it is having on fertilizer prices worldwide is the main driver, thus sparking innovations in micro-organism products and organic fertilizers. Organic fertilizer development has been around since long before climate change became an urgent phenomenon but with the war and current need, climate change has not induced but partially accelerated the process of alternative fertilizer development. In terms of product innovations with added value, it can be finalized that climate change acts as an indirect driver. This can be explained because the unpredicted weather conditions are changing the coffee growers' behavior, wanting to rely less on coffee and potentially increase or ensure

an additional stable income via other products. Therefore, it can be concluded that climate change serves as an indirect driver of value-added product innovations. The reason climate change is only partially responsible for these innovations is that the need for establishing an additional economic entry promoting stability for the coffee growers is crucial and thus the findings point out that the need of the farmers is also an important driver. Additionally, cooperative product innovations are very advanced in terms of niche maturity in Tarrazú, so it is just a matter of upscaling and innovation diffusion, then they would have the potential of disrupting the current regime, transitioning to a bio-based, sustainability-focused regime.

In terms of process innovations, one may say that climate change is also an indirect driver of innovations. Increased technological improvement and attention to irrigation systems in Guanacaste can be a result of recurring drought seasons and thus climate change. Process innovations in the cooperatives were often inspired by the NAMA program, whose backbone is the idea of reducing the carbon footprint, improving production methods, and ensuring environmental sustainability. Therefore, it can be determined that climate change is a partial driver of such innovations along with the need promoted by society. Lastly, evidence suggests that organizational innovations are driven by consumer demands and coffee grower needs.

The transformative pathways as described by the transformative adaptation framework, offer options on how to provide alternative, flexible, and long-term solutions while recognizing that climate change is only one factor contributing to economic, social, cultural, and political shifts. This supports the conclusion in that climate change is acting as an innovation accelerator rather than the main inducing or driving factor.

In terms of cooperatives, it is clear that they represent important actors in the sustainability transition pathway and furthermore act as innovation facilitators and promoters on the niche level. The results show that the innovative capabilities are mostly restricted by limited financial capital, not by lack of engagement or interest. In summary, the Costa Rican coffee cooperatives are on the right path to developing climate change adaptation innovations and they are actively contributing to the sustainability transition, however, the pace at which these are being developed and implemented greatly depends on and is restricted by several barriers, such as lack of resources. Therefore, the regime shift and system breakthrough have not been disrupted just yet. Improved innovation diffusion across the given coffee regions could potentially speed up the transition by increasing research collaborations and knowledge sharing sessions. Lastly, the National Strategy for Climate Change Adaptation was published recently and therefore it could potentially serve as an additional

push forward, encouraging the implementation of more adaptation strategies in the coffee sector and further future research on the topic.

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7. Appendix

Appendix A – Interview consent form in Spanish

CINPE
CENTRO INTERNACIONAL DE POLÍTICA ECONÓMICA PARA EL DESARROLLO SOSTENIBLE

LUND UNIVERSITY | SCHOOL OF ECONOMICS AND MANAGEMENT

Innovación para la adaptación al cambio climático en la producción del café de Costa Rica

Un análisis comparativo de las cooperativas en las regiones cafetaleras de Guanacaste y Tarrazú

Esta entrevista forma parte de un proyecto de investigación para la tesis de maestría sobre el tema de la transición sostenible en el sector del café y las innovaciones para una mayor adaptación al cambio climático. El proyecto está financiado y se lleva a cabo por la Universidad de Lund, como parte del segundo año de la Maestría en Innovación y Desarrollo Global Sostenible.

El proyecto será un análisis comparativo centrado en las cooperativas de café en las regiones cafetaleras Guanacaste y Tarrazú en Costa Rica. El objetivo es entender los retos, los facilitadores y las innovaciones relacionadas con la transición sostenible de la producción de café en Costa Rica, con un enfoque en las respuestas de adaptación y las innovaciones para limitar los riesgos del cambio climático.

Los actores relevantes para esta investigación son diferentes tipos de miembros de las cooperativas de café, como directores, miembros de la junta directiva, agrónomos y agricultores locales. Además, se entrevistará a expertos de la industria del café y a actores institucionales para obtener perspectivas adicionales.

El proyecto está dirigido por la estudiante de maestría Isabella Jensen y supervisado por la profesora Cristina Chaminade.

El proyecto cuenta con el apoyo del Centro Internacional de Política Económica para el Desarrollo Sostenible (CINPE), perteneciente a la Universidad Nacional de Costa Rica (UNA).

Formulario de consentimiento para la entrevista - entrevistas individuales

La entrevista se grabará digitalmente y la entrevistadora tomará notas. Tanto las notas como las grabaciones serán confidenciales. Somos conscientes de que estas entrevistas pueden conllevar riesgos al hablar de información sensible. Estos riesgos se mitigarán mediante una estricta protección de los datos en un entorno de software protegido por contraseña. Sólo la investigadora del proyecto tendrá acceso al material recogido.

Su identidad personal permanecerá anónima. No se le atribuirá directamente ninguna opinión en ningún documento que se elabore a partir de las entrevistas. Las citas podrán utilizarse de forma discreta. Sin embargo, el nombre de su empresa o institución podrá ser conocido en el informe, a menos que usted indique explícitamente lo contrario.

La información recogida en este estudio se utilizará para contribuir a la tesis. Se presentará en forma de tesis de la maestría y también podrá aparecer en forma de informe, ponencia a un coloquio y/o artículo científico publicado.

Consentimiento

Con la presente, acepto participar en esta investigación en las condiciones arriba indicadas.

Entiendo que, si decido participar en este estudio, mi participación es libre y voluntaria y tengo derecho a retirar mi consentimiento para participar o a interrumpir mi participación en cualquier momento sin penalización ni consecuencias negativas.

Acepto que se grabe mi participación en el estudio	Si ☐	No ☐
Permito el uso de el nombre de la empresa/organización en la tesis final	Si ☐	No ☐

Nombre del participante	Firma del participante	Fecha
…….	…….	……

Si tiene alguna pregunta sobre sus derechos como participante en la investigación, o no está satisfecho en algún momento con algún aspecto del estudio, puede ponerse en contacto con Isabella Jensen en el correo electrónico XXXX, en el número de WhatsApp XXXX, o en el móvil XXXX. El correo electrónico de la supervisora de la tesis, profesora Cristina Chaminade, su correo es: XXXX

Appendix B – Interview consent form in English

LUND UNIVERSITY

SCHOOL OF ECONOMICS AND MANAGEMENT

Innovation for Climate Change Adaptation in Costa Rican Coffee Production

A comparative analysis of cooperatives in the coffee regions Guanacaste & Tarrazú

This interview is part of an ongoing research project for the master thesis on the topic of sustainable transitions in the coffee sector and innovations for increased climate change adaptation. The project is funded by and carried out at Lund University, as part of the second year of the Master in Innovation and Global Sustainable Development.

The project will be a comparative analysis focusing on coffee cooperatives in Guanacaste and the Tarrazú coffee regions of Costa Rica. The scope is understanding the challenges, enablers and innovations related to the sustainable transition of coffee production in Costa Rica, with a focus on adaptation responses and innovations to limit climate change risks. The actors relevant for this research are different types of members of the coffee cooperative such as directors, board members, agronomists, and local farmers. Furthermore, coffee industry experts and institutional actors will be interviewed for additional perspectives.

The project is led by master student Isabella Jensen and supervised by Professor Cristina Chaminade.

The project is supported by Centro Internacional de Politica Economica para el Desarollo Sostenible (CINPE), part of Universidad Nacional de Costa Rica (UNA).

Interview Consent form – individual interviews

The interview will be digitally recorded, and the interviewer will take notes. Both notes and recordings will remain confidential. We are aware that these interviews may include risks by discussing sensitive information. These risks will be mitigated by strict protection of the data in a password-protected software environment. Only the project leader and the researchers in the project will have access to the notes.

Your personal identity will remain anonymous. No views will be directly attributed to you in any document that may be produced from the interviews. Quotes may be used discretely.
The name of your firm or institution may however be known in the report unless you explicitly indicate otherwise.

The information gathered from this study will be used to contribute to the thesis. It will be presented as a master thesis and may also appear in the form of a report, a paper to a colloquium and/or a published scientific paper.

Consent
I hereby agree to participate in this research on the conditions above.

I understand that if I decide to participate in this study, my participation is free and voluntary and I have the right to withdraw my consent to take part or to stop my participation at any time without penalty or negative consequences.

I hereby agree to the tape recording of my participation in the study Yes ☐ No ☐

I allow the disclosure of the company/organization/name in the final thesis Yes ☐ No ☐

Participant name	Participant signature	Date
……..	……..	……

If you have any questions about your rights as a research participant or are dissatisfied at any time with any aspect of the study, you may contact Isabella Jensen on the email XXXX or on the whatsapp number XXXX, or mobile XXXX. The thesis supervisor is Professor Cristina Chaminade and her contact email is: XXXX

Appendix C – Cooperative interview guide in Spanish

Cuestionario para las cooperativas

Pregunta de investigación:

¿Cómo está induciendo o accelerando el cambio climático las innovaciones en el sector de la producción de café de Costa Rica?

Habrá 4 bloques principales de preguntas: una introducción de la organización, preguntas sobre el cambio climático, una parte de innovaciones y preguntas personalizadas en función del actor entrevistado.

1. Presentaciones y introduction

1.1. ¿Podría presentarse a sí mismo y a su función en la cooperativa?

1.2. ¿Podría describir brevemente la historia de la organización (principales acontecimientos o **hitos**)?

1.3. ¿Cuántos productores asociados tiene?

1.4. ¿Cuáles son sus principales actividades en la cadena de valor del café?

- Caficultor
- Procesador de café
- Tostado
- Exportador
- Organización de apoyo
- Servicios cooperativos

1.5. ¿Forma parte de una alianza o consorcio cooperativo (COOCAFE)?

1.5.1. ¿Por qué?

1.5.2. ¿Cuáles son los beneficios de formar parte de una alianza como COOCAFE?

1.6. ¿En qué otras actividades fuera de la cadena de valor del café participa su organización?

1.7. ¿Cómo se distribuyen sus ingresos/ganancias en las diferentes actividades? (cuál es la dependencia de la producción de café)

2. El cambio climático

2.1. ¿Han experimentado, los miembros asociados, cambios particulares en la producción de café relacionados con el cambio climático? ¿Cuáles?

2.2. ¿Los asociados/la cooperativa están aplicando actualmente alguna estrategia de adaptación al cambio climático?

- En caso afirmativo, ¿cuáles?

- En caso negativo, ¿por qué no? ¿Qué lo impide? ¿Cuáles son los obstáculos que hay que superar?

2.3. ¿Alguna de esas estrategias implica innovaciones? En caso afirmativo, ¿cuáles?

- Nuevas variedades de café (más resistentes al cambio climático)
- Nuevos lugares de producción
- Nuevos tratamientos a las variedades existentes
- Otros (especifique)

3. Sistema/entorno de innovación: En relación con las innovaciones comentadas en el apartado anterior

3.1. ¿Qué innovaciones diría usted que han tenido el mayor impacto en la cooperativa: innovaciones de **producto, de proceso o de organización**?

- ¿Por qué?

3.2. ¿Quiénes fueron los actores públicos, privados y organizativos más influyentes que participaron en cada innovación?

3.3. ¿Cuáles fueron los principales facilitadores/impulsores de las innovaciones?

3.4. ¿Cuáles fueron los principales obstáculos?

3.5. ¿Cómo facilita/impide el marco institucional actual estas innovaciones?

3.6. ¿Qué tendría que cambiar a nivel institucional para facilitar la investigación y el desarrollo para la adaptación al cambio climático?

3.7. ¿Cómo estimulan las cooperativas las innovaciones?

3.8. ¿A qué barreras/impulsores se enfrentan las cooperativas en términos de capacidad de innovación?

Observaciones finales

Appendix D – Institutional interview guide in Spanish

Cuestionario

Pregunta de investigación:

¿Cómo está induciendo o acelerando el cambio climático las innovaciones en el sector de la producción de café de Costa Rica?

Habrá 4 bloques principales de preguntas: una introducción de la organización, preguntas sobre el cambio climático, una parte de innovaciones y preguntas personalizadas en función del actor entrevistado.

1. Presentaciones

1.1. ¿Podría presentarse a sí mismo y a su función en la organización?

1.2. ¿Podría describir brevemente la historia de la organización (principales acontecimientos o **hitos**)?

1.3. ¿Cuántos empleados tiene? ¿Afiliados?

1.4. ¿Cuáles son sus principales actividades en la cadena de valor del café?

2. Cambio climático

2.1. ¿Qué cambios se perciben en la producción de café atribuidos al cambio climático actualmente?

2.2. Más del 70% del café de Costa Rica se produce bajo acciones de adaptación y mitigación de gases de efecto invernadero, ¿qué tipos de adaptaciones? (página ICAFE)

2.3. ¿Promueve el ICAFE alguna respuesta de adaptación al cambio climático dirigida a las cooperativas o a los pequeños agricultores?

3. Innovaciones

3.1. ¿Podría describir una breve cronología de las innovaciones específicas del café del ICAFE?

3.2. ¿Podría explicar qué es la NAMA Café y las buenas prácticas agrícolas, cómo afecta a la producción de café?

3.3. ¿En qué medida esas innovaciones son o han sido impulsadas por el cambio climático?

3.4. ¿Cuáles son las principales motivaciones que impulsan las innovaciones del ICAFE en la actualidad?

3.5. ¿Cuáles son los principales facilitadores?

3.6. ¿Cuáles son los obstáculos para la aplicación de las innovaciones en los distintos niveles de producción (cooperativas, pequeños agricultores)?

3.7. ¿Quiénes son los pioneros de las innovaciones en el sector del café en Costa Rica?

3.7.1. ¿Cuáles son los principales incentivos de las innovaciones en el café?

3.7.2. ¿Quiénes son los principales actores con los que el ICAFE colabora en las innovaciones?

3.8. ¿Qué papel juega el ICAFE en las innovaciones desarrolladas por las cooperativas?

4. Futuro

4.1. ¿En qué innovaciones está trabajando el ICAFE para la adaptación/resiliencia al cambio climático?

Observaciones finales

Appendix E – Cooperative interview guide in English

Questionnaire for cooperatives

Research question:

Is climate change inducing or accelerating innovations in the Costa Rican coffee production sector?

There will be 4 main blocks of questions

1. Introductions

1.1. Could you introduce yourself and your role in the cooperative?

1.2. Could you briefly describe the history of the organization (main events or milestones)?

1.3. How many member producers do you have?

1.4. What are your main activities in the coffee value chain?

- Coffee grower
- Coffee processor
- Roasting
- Exporter
- Support organization
- Cooperative services

1.5. Are you part of a cooperative alliance or consortium (COOCAFE)?

1.5.1. Why?

1.5.2. What are the benefits of being part of an alliance such as COOCAFE?

1.6. In what other activities outside of the coffee value chain does your organization participate?

1.7. How is your income/profits distributed in the different activities (what is the dependence on coffee production)?

2. Climate change

2.1. Have the associate members experienced particular changes in coffee production related to climate change? Which ones?

2.2. Are the members/cooperative currently implementing any climate change adaptation strategies?

- If yes, which ones?
- If not, why not, what is preventing it, and what are the obstacles to overcome?

2.3. Do any of these strategies involve innovations? If so, which ones?

- New coffee varieties (more resistant to climate change)
- New production sites
- New treatments for existing varieties
- Other (specify)

3. Innovation system/environment: In relation to the innovations discussed in the previous section.

3.1. Which innovations would you say have had the greatest impact on the cooperative: product, process or organizational innovations?

- Why?

3.2. Who were the most influential public, private and organizational actors involved in each innovation?

3.3. What were the main facilitators/drivers of the innovations?

3.4. What were the main obstacles?

3.5. How does the current institutional framework facilitate/impede these innovations?

3.6. What would need to change at the institutional level to facilitate research and development for climate change adaptation?

3.7. How do cooperatives stimulate innovations?

3.8. What barriers/drivers do cooperatives face in terms of innovation capacity?

4. Future plans

Concluding remarks

Appendix F – Institutional interview guide in English

Institutional Interview Guide

Research question:

Is climate change inducing or accelerating innovations in the Costa Rican coffee production sector?

There will be 4 main blocks of questions: an introduction of the organization, questions on climate change, a part on innovations and customized questions depending on the actor interviewed.

1. Introductions

1.1. Could you please introduce yourself and your role in the organization?

1.2. Could you briefly describe the history of the organization (main events or milestones)?

1.3. How many employees do you have? Affiliates?

1.4. What are your main activities in the coffee value chain?

2. Climate change

2.1. What changes are you perceiving in coffee production attributed to climate change today?

2.2. More than 70% of Costa Rican coffee is produced under adaptation and greenhouse gas mitigation actions, what types of adaptations (ICAFE page)?

2.3. Does ICAFE promote any climate change adaptation responses aimed at cooperatives or small farmers?

3. Innovations

3.1. Could you describe a brief chronology of ICAFE's coffee-specific innovations?

3.2. Could you explain what the Coffee NAMA and Good Agricultural Practices are and how they affect coffee production?

3.3. To what extent are or have these innovations been driven by climate change?

3.4. What are the main motivations driving ICAFE's innovations today?

3.5. What are the main enablers?

3.6. What are the barriers to the implementation of innovations at different levels of production (cooperatives, smallholder farmers)?

3.7. Who are the pioneers of innovations in the coffee sector in Costa Rica?

3.7.1. What are the main incentives for innovations in coffee?

3.7.2. Who are the main actors with whom ICAFE collaborates on innovations?

3.7.3. What role does ICAFE play in the innovations developed by the cooperatives?

4. Future

4.1. What innovations are ICAFE working on for climate change adaptation/resilience?

Concluding remarks

Appendix G – Nvivo Codebook

Name	Files	References
Adaptation Methods	6	21
Agroforestry systems	7	11
Development of new coffee variants	4	7
Displace coffee plantations	4	7
Irrigation system development	1	1
Shade-grown coffee	6	9
Soil improvement	4	4
Barriers	6	20
Climate-Change Challenges	8	58
Changes in precipitation cycles	4	9
Diseases and plagues	6	13
Drought and lack of rainfall	3	10
Increased temperature	8	8
Collaborations	9	17
Cooperative role in innovation	1	2
Funding	7	8
Future projects	6	16
Innovation Drivers	6	18
Innovation pioneers	5	7
Mitigation Actions	6	12
Nama Cafe	5	10
Opportunities	6	17
Organizational Innovation	5	15
Process Innovation	3	8
Product Innovation	6	21
Microorganisms	1	3

Name	Files	References
Organic fertilizers	0	0
Value added approaches	4	5
Regional differences	5	16
Productivity	3	3
Technology transfers	4	6

Appendix H – The 10 Best Agricultural Practices promoted by the MAG and identified by NAMA Café

The Coffee NAMA identified at least nine GAPs that include the following topics:

- Varieties and Renovation
- Soil Conservation
- Farm Management
- Fertilization and Nutrition
- Pests and Diseases
- Weed Management
- Pruning
- Irrigation
- Agroforestry Systems