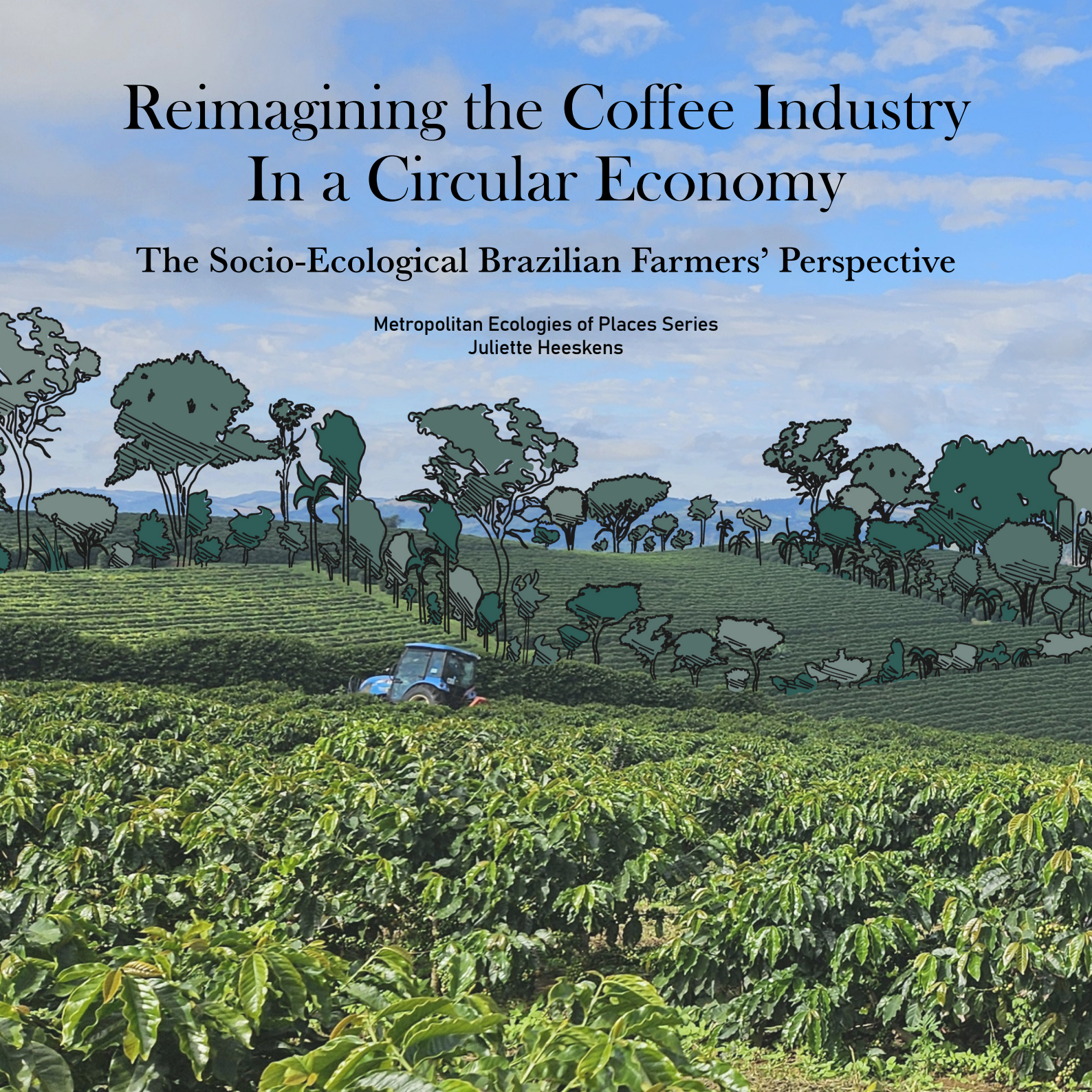
Reimagining the Coffee Industry In a Circular Economy

The Socio-Ecological Brazilian Farmers' Perspective

Metropolitan Ecologies of Places Series
Juliette Heeskens



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Abstract

Key Words: Circular Economy, Coffee Value Chain, Spatial Justice, Climate Adaptation, Climate Change Mitigation

This thesis studies how spatial circular strategies can contribute to just and climate-resilient transformation in Brazil's coffee sector. Focusing on Southeast Brazil, it explores how agricultural methods, local resource cycles, and inclusive governance can mitigate and adapt to climate impacts while creating a fairer coffee value chain.

The research reveals that while some circular practices are already being applied, barriers remain to making system change. These include economic pressures, social inequality, and policy structures that favour large-scale, conventional farming. The analysis highlights distinct challenges and opportunities across different farm types. Large farms have the highest environmental impact potential, while small farms face the most social and economic constraints.

The project proposes spatial agricultural and intervention typologies and a practical toolbox to support farmers in transitioning toward circular production. In addition, supporting policy recommendations are suggested. This approach offers a pathway to a more sustainable and fair coffee sector by aligning environmental, economic, and social goals.

TABLE OF CONTENTS

Introduction

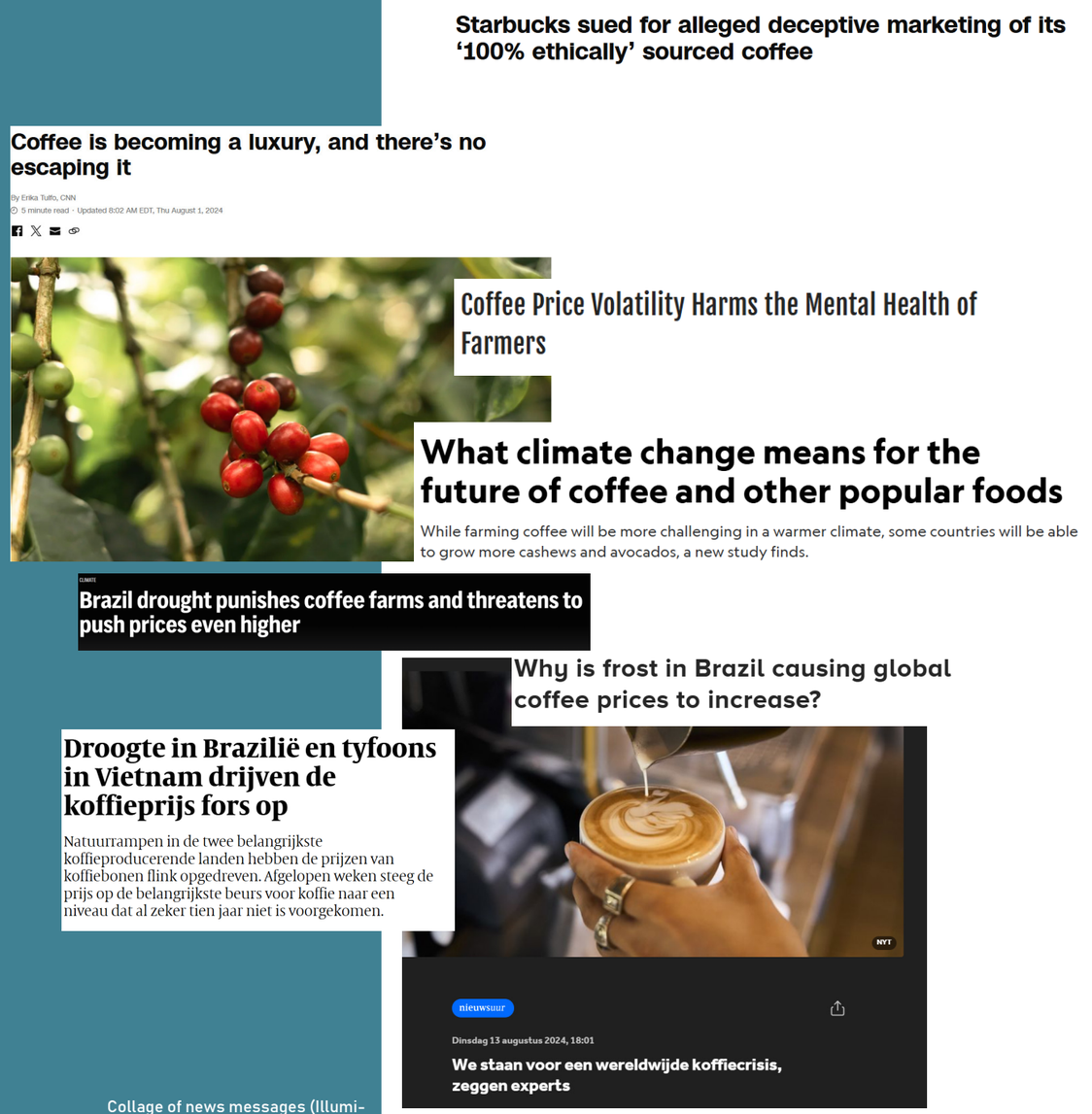
This chapter presents a general introduction to this thesis, starting with the initial fascination that led to the start of this project. It offers an overview of the coffee value chain. It highlights the key challenges that the industry is facing currently in the problem field, both globally and in the Brazilian context. The chapter concludes by sharing the research questions and the intended outcomes.

Initial Fascination

Most people like to start their day with a cup of coffee, but many do not fully understand the coffee industry. Coffee is a global product with global significance, impactful cultural implications, and big impacts within economies worldwide. Many livelihoods depend on coffee worldwide.

However, the coffee industry is a complex and impactful system facing some contemporary challenges regarding social justice and climate change, and it needs systemic change. The increasing news coverage of the coffee industry and its challenges sparked my interest, so I initiated my graduation project.

My thesis explores the interdependency of social justice, the climate crisis, and circularity in the coffee industry, emphasising the need for a future-proof transition through the eyes of Brazilian farmers.



Collage of news messages (Illuminem, 2024), (Singhal & Tarp, 2025) (AP News, 2024) (De Lange, 2024) (Nieuwsuur, 2024) (Grant, 2022) (Kavilanz, 2024)

Introduction to the Coffee Value Chain

GROWING & HARVESTING

On a coffee farm, the first stop is a coffee tree nursery. After six to twelve months, seedlings are grown enough to be moved to the actual farm, but only after three years does a coffee plant start bearing fruit (Hoffmann, 2018).
The coffee cherry is the fruit that grows, and inside are the seeds that we later call coffee beans. When the coffee cherry ripens, it turns red and can be picked for harvest. Harvesting happens in one or more cycles, with or without machinery. With more cycles, harvesters can guarantee a better quality of the coffee cherry (Hoffmann, 2018). In one go, there will be a higher likelihood of unripe cherries being included. Coffee beans are sorted afterwards and go into processing stages, where they are processed into green coffee.

PROCESSING

In coffee production, there are various ways of processing the red coffee cherries iln coffee production, there are various ways of processing the red coffee cherries into green coffee beans. The two most common methods are the washed (also called wet) and the natural (also called dry) methods. The washed method uses a depulper to separate the pulp of the coffee cherries from the coffee seed. Following the depulping, water is used to wash the seeds, and then the beans are fermented (Hoffmann, 2018).

During the natural or dry method, beans are laid out, usually on stone, bricks or a large table and then sun-dried. After drying, the cherries are hulled to remove the outer layer (Hoffmann, 2018). Following a resting period of 30-60 days, green coffee is packaged in 60-kilogram bags and is stored to be exported or transported to a roaster.

TRANSPORT/EXPORT

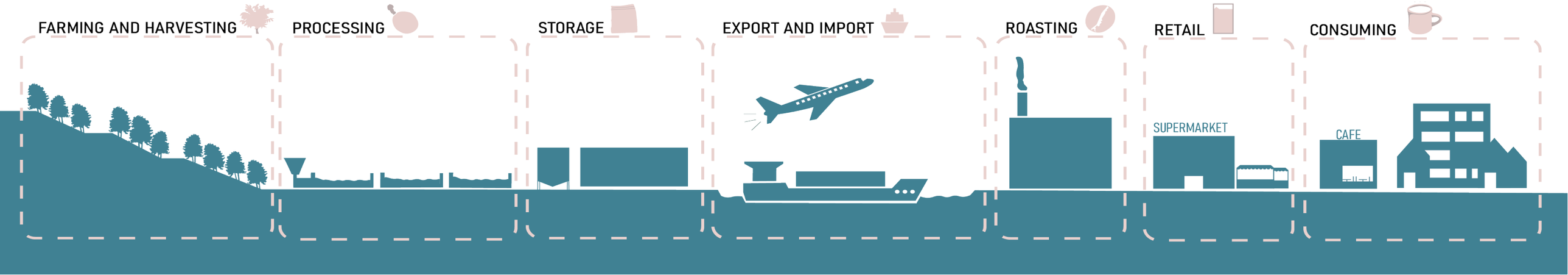
Usually, coffee is traded per shipping container on a freight ship, sometimes taking months for the coffee to be shipped. Sometimes, bad quality coffee gets shipped directly into the container without packaging (Hoffmann, 2018). In the meantime, coffee is stored in warehouses where the coffee must be packaged in air- and moisture-free environments. Typically, jute bags are used with a plastic lining and a warehouse with climate control.

ROASTING

Roasting transforms coffee from a green, unpleasant-tasting bean into a brown-coloured, flavourful one. Roasting is usually, but not exclusively, done in countries that have imported the coffee. To roast in high quantities, expensive machinery is needed (Hoffmann, 2018). After cooling the beans, they are packaged or processed into various coffee products, such as coffee pods, pads, pre-ground coffee beans etc.

RETAIL/HOSPITALITY AND CONSUMING

Most consumers buy coffee in the supermarket (Osbourne, 2024), but depending on where you are, there are various ways of enjoying your cup of coffee. In Italy, espresso is the preferred choice. In Australia, they enjoy a flat white; in the Netherlands, most people opt for a filter coffee. There are hundreds of brewing methods around the world. Coffee has become an integral part of daily life, traditions and cultures across the globe.



THE COFFEE TREE

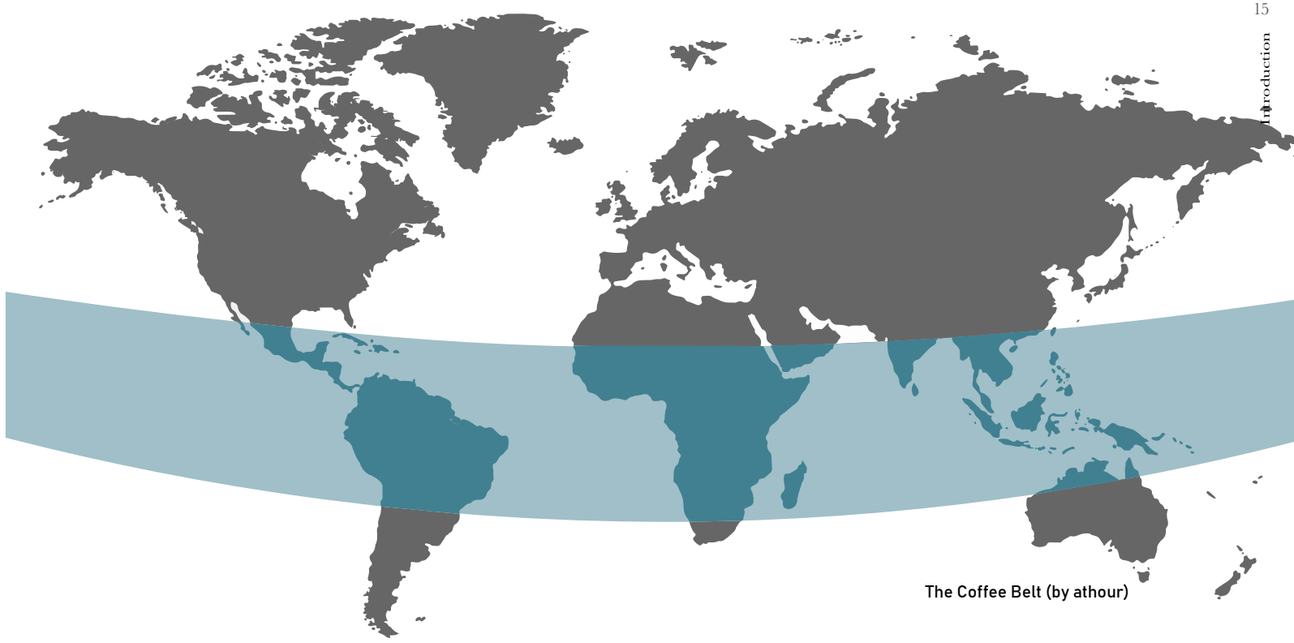
Coffee beans grow on varieties of coffee trees in the Rubiaceae family and the genus Coffea. Two species of coffee trees that are regularly grown around the world are Coffea arabica, commonly called arabica coffee, and Coffea canephora, commonly called robusta coffee. Besides these two well-known species, there are over 120 species of coffee plants (Hoffmann, 2018); however, they are not grown in the quantity that these other two species are. Within the species, varieties create a difference in taste and texture.

From afar, a coffee plant may look similar in every variety. However, the differences lie within the way that fruit grows on the tree, the yield, the resilience towards diseases and pest etc. Growing conditions for the robusta and arabica coffee plants are also not identical. Generally, Robusta coffee can grow at lower altitudes than its counterpart, and it can resist more temperatures and diseases (Hoffmann, 2018). The downside is the taste. Arabica coffee is seen as a higher-quality coffee. However, many steps in the coffee process determine the quality and taste of the coffee.

Stages of coffee plant growth (Torch coffee company, 2018)

THE COFFEE BELT

Coffee grows in belt around the world between the Tropic of Capricorn and the Tropic of Cancer. The region includes a large part of Africa,Central and South America, the Middle East and Asia and here the perfect conditions exist for growing coffee. A combination of temperature, altitudes, rainfall is needed to create the perfect climate for the growing coffee.



The Coffee Belt (by athour)

Geographical Focus: The Brazilian Case

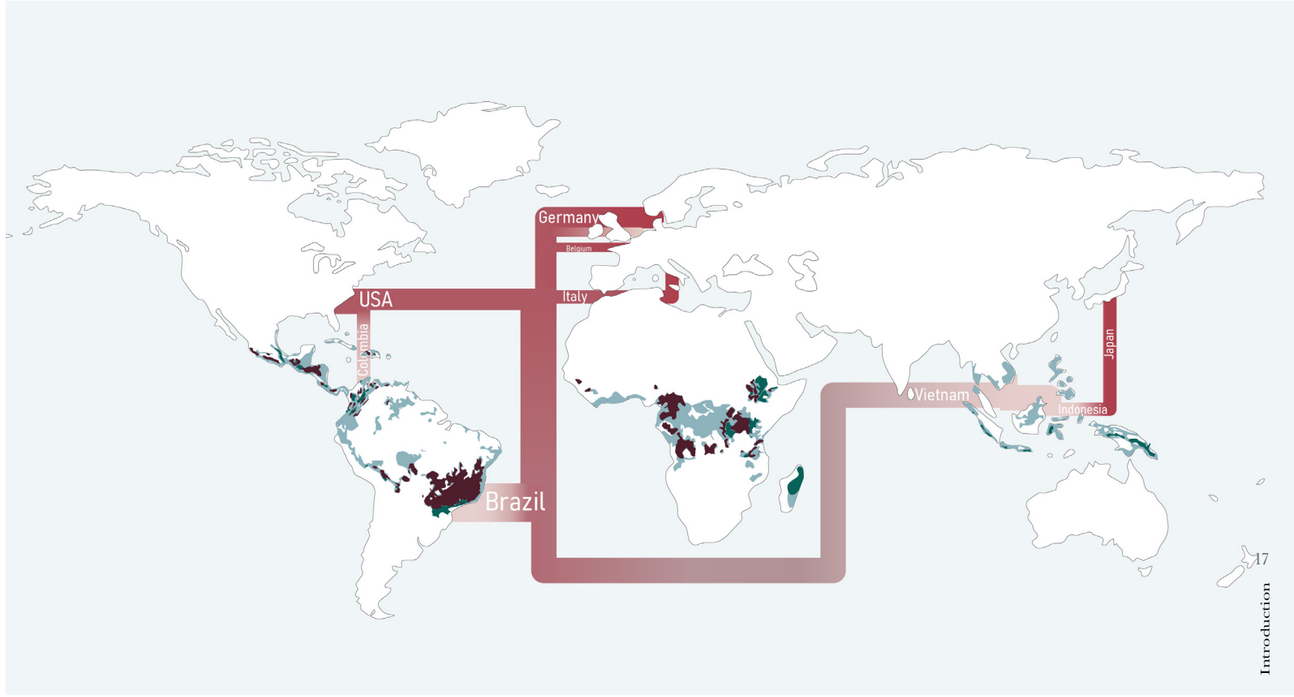
Brazil's coffee production dominates the coffee industry. Brazil is the biggest producer and exporter of coffee worldwide. They produce around 40 per cent of the worlds' coffee (Panhuysen & De Vries, 2023) and export about 25 per cent of worlds' weight in coffee year after year (Chatham House, The Royal Institute of International Affairs, 2020).

When in 2021 an abnormal level of frost was recorded, the coffee yield in Brazil was highly damaged. The regions producing the highest volumes of coffee were impacted by the frost, which killed many of the plants, after which they no longer had the capability of producing. Because Brazil is such a big player in the coffee industry, this affects the whole industry (Grant, 2022). Mostly through an increase in pricing in the coffee industry worldwide.

Brazil, and its producing regions, are feeling the increase of climate change consistently increasing throughout the years, and through drought, higher temperatures and heavier rainfall (Costa, 2024) Brazil's producing regions are facing the rise of risk of crop failure.

In Brazil, it has been said that in the main coffee-producing regions the suitability for growing coffee could decrease from 70 to 75 per cent to a small 205 per cent (Panhuysen & De Vries, 2023).

These impacts of climate change highlight the critical need for immediate action, which is why my project will specifically focus on this country.



Export and suitability of coffee around the world. data from (Bunn et al., 2014) & (Chatham House, The Royal Institute of International Affairs, 2020)

Marginally-moderately suitable land for Coffea arabica farming in 2014
Land that is negatively impacted and will become less suitable in 2050
Land that is positively impacted and will become more suitable in 2050
Importer of Coffee
Exporter of Coffee

History of coffee

THE ORIGIN OF COFFEE

The Brazilian coffee industry is a complex system with practices dating back hundreds of years. The way coffee was introduced to Brazil and the transformations it underwent still impact the system today. Therefore, it is essential to discuss how this system came to be to understand today's challenges.

The coffee plant is not native to Brazil; its introduction is linked to colonial trade, and its origins can be traced to Ethiopia. Stories go around about the origin of the coffee plant, Coffea arabica. However, the origin has not been objectively confirmed and is more of a myth or legend. Commonly, the story is about a farmer from Ethiopia who saw his goats dancing, high on caffeine. This is how coffee was discovered. Even though the goat story might be fiction, what is known is that, for a long time, coffee has been an integral part of Ethiopian culture and that it originates from the rainforest biome of that region of the African continent (Pendergrast, 2019).

Through its colonial history, the coffee plant has been distributed over more than 70 countries on five continents worldwide. The coffee expansion likely started in Yemen, when the Ethiopians ruled Yemen in the 6th century. Consequently, coffee was introduced into Arab culture. In 1536, when the Turkish empire invaded Yemen, coffee became big throughout the empire, and soon, the Turks gained a trading monopoly in the coffee trading industry (Pendergrast, 2019).

Through the smuggling of seeds and trees, coffee reached European world powers like the Dutch and British empires. The Dutch, who smuggled a tree in 1616, began growing coffee in Ceylon (Sri Lanka) and later in Java (1699), followed by cultivation in other Indonesian Islands like Bali, Sumatra, and Celebes (Pendergrast, 2019).

During this time, coffee boomed in European culture. Coffee started as an exotic beverage for the elite in the first half of the 17th century. Throughout the 18th century, consumption increased in more parts of Europe and its colonies, especially after the Boston Tea Party in 1773 (Pendergrast, 2019).

COFFEE TO BRAZIL

In Latin America, coffee was most likely introduced through a plant the Dutch gave to the French, who took it to their colony of Martinique to grow the crop. Brazil, at that time a Portuguese colony, came into the picture in 1727 after a border dispute between French and Dutch Guiana (Suriname), where the Portuguese Brazilian Francisco de Melo Palheta was gifted a bouquet of coffee seeds (Pendergrast, 2019). He planted the seeds in his home region of Pará, Brazil. Soon, Brazilians realised that the coffee plants did not grow optimally in this area, so they moved towards the Southeast of Brazil around 1770 (Tomich et al., 2021).

The system truly transformed when coffee was introduced to the Paraíba valley near Rio de Janeiro. These regions were, at the time, defined by gold mining. Due to a law making living between the Minas Gerais region and Rio de Janeiro illegal, there was a new space to cultivate more coffee (Tomich et al., 2021). Infrastructure that was built for this gold-mining economy could be used for the coffee industry. Besides that, enslaved people who used to work in the gold mines could also be “transferred” to work in coffee plantations rather than the mines (Pendergrast, 2019). The slave trade in Brazil kept increasing. By 1831, even when the British had illegalised slavery, the Atlantic slave trade kept growing. In 1850, importing enslaved people was officially illegal, with an already large number of 2 million enslaved people in the country (Tomich et al., 2021). Until 1871, Brazil maintained the slavery system (Pendergrast, 2019); at this point, all children born to enslaved people would be free, but the system had already shaped the Brazilian coffee industry.

In the nineteenth century, which is often referred to as the golden coffee cycle, the Brazilian coffee fazenda transformed social and economic systems of Brazil.

MARKET DEPENDENCY

As production expanded at the beginning of the nineteenth century, Brazil became increasingly dominant in the global coffee market. Exports in the first twenty years of the century had grown from just under two thousand pounds to almost thirteen million pounds of coffee, and twenty years later, it grew to ten times more (Coffee History — Casa Brasil Coffees, n.d.). Coffee traders were heavily influenced by political events, causing them to buy stock in large quantities, anticipating disruptions in the market, but at times these anticipations were wrong, which revealed the sensitivity of the market through plummeting prices (Pendergrast, 2019).

By the late nineteenth century, Brazil's coffee production regularly exceeded global demand, causing prices to fall. In response, the new Republican government increased the money supply. This helped coffee farmers, but it led to inflation and economic problems within Brazil (Coffee History — Casa Brasil Coffees, n.d.). When prices dropped to six cents per pound

by 1901, Brazil turned away from international solutions and introduced the 1906 Taubaté Agreement. Under this plan, state governments bought surplus coffee to keep prices stable. While the policy worked in the short term, it also encouraged more overproduction (Coffee History — Casa Brasil Coffees, n.d.). Similar efforts continued through the Inter-American and International Coffee Agreements in the twentieth century. These agreements lasted until 1989, when the United States withdrew its support. Without price controls, coffee prices fell again. By that point, the global coffee market was deeply influenced by political decisions, international agreements and Brazil's early role as the main producer.

TRANSFORMATION OF THE ATLANTIC RAINFOREST

Human systems have depended on the Atlantic rainforest biome for a long time, starting long before colonial times. One of the prehistoric ways that humans have transformed this ecosystem was through slash-and-burn agriculture (Solórzano et al., 2021). This agricultural method, using fire to deforest, was used by indigenous communities from about 10000 years BP (8050 BC). Although these traditional methods altered the forest and changed the ecosystem, they also reforested the landscape. Besides that, these practices were purely meant for self-consumption, and the scale of these practices does not compare to the scale of current practices, which are often mainly meant for exporting and feeding large parts of the world.

Since the first arrival of colonisers in Brazil, around 1500 A.D., the scale of deforestation has changed. Brazilian history after colonisation has multiple cycles: first the cycle of wood, then sugar, then gold mining, then the coffee cycle from the mid-nineteenth century, and then the rubber cycle (Burns et al., 2025). These systems were based on productivity and fundamentally changed the economy and the landscapes. The primary source of deforestation from these cycles was the sugarcane and coffee plantation system, using large-scale monocultural methods. Alongside these economic, extractive cycles, waves of urbanisation accompanied and reinforced the transitions of the landscapes, as ports, infrastructure, and urban areas expanded to accompany these industries, accelerating land modification and habitat loss. This transition changed the consistency of the biome, starting the intense fragmentation of the Atlantic forest ecosystem.

The farming methods and plantation systems characterise the Brazilian coffee system. The Southeast region is a big part of the Atlantic Rainforest biome. Coffee farmers at the time would burn a portion of the forest and plant coffee trees vertically up and down the

"The built environment of the coffee fazenda combined economic efficiency, social control, and symbolic power around material requirements of coffee production"
- (Tomich et al., 2021 p. 128)

hill. This layout would ensure owners could monitor their (enslaved) workers (Tomich et al., 2021). Generally, the coffee trees were fully sun-grown and were harvested with the least possible effort, without selective harvesting. When the soil was too depleted and a harvest year would be bad, a new piece of Atlantic rainforest would be burnt, and the process would start again.

During the Portuguese colonial period, the Atlantic forest biome transformed from a rainforest to an intensely fragmented landscape. The Brazilian Fazenda system was defined by sun-grown, monocultural fields that depleted the naturally fertile (volcanic) soil systems. The Brazilian system has traditionally been focused on quantity rather than quality, with systemic inequalities in place.

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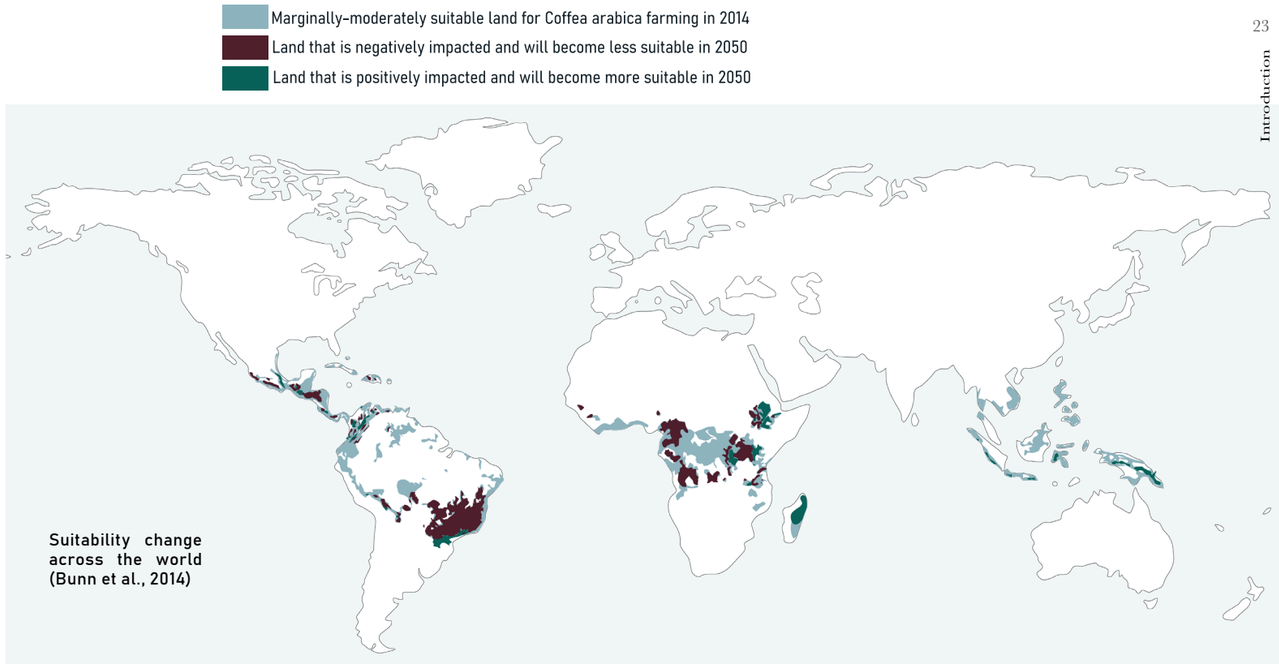
Problem Field: Our Climate is Changing

Climate change is one of the critical problems of our time, caused mainly by the emission of greenhouse gases by human activities. Activities include production with fossil fuels that generate extensive amounts of harmful by-products and human agricultural systems that demand considerable amounts of land use causing deforestation of crucial biomes like the Amazonian rainforest (IPCC, 2023). Human activity is overshooting the planet's capacity, and everyone will be affected.

In turn, climate change will have great effects on human and non-human life and its systems. Temperatures will rise, and increasingly impactful weather events will occur more frequently, causing damage to food and water systems and creating insecurity around the world.

Vital ecosystems have already degraded, and climate change is starting to be visible. Food yields are highly affected, and not all crops are able to withstand conditions unlike their



Suitability change across the world (Bunn et al., 2014)

status quo. Only one degree (Celcius) of warming will cause a decline of 7.5% of the food yield year after year (TED, 2024). When the climate is changing, our core commodities decline, and the economic and social challenges caused are intense.

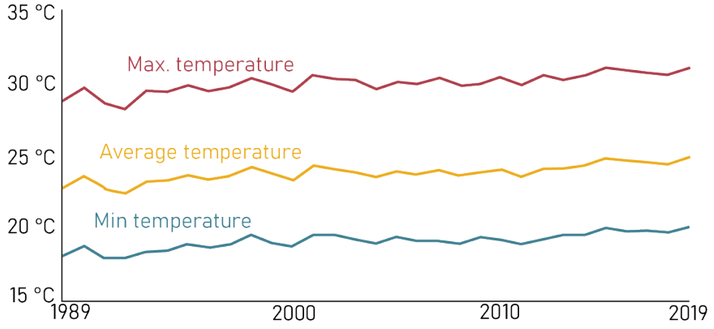
COFFEE AND CLIMATE CHANGE

Coffee production is highly dependent on the climate. Coffee plants are sensitive and labour-intensive plants that prefer a temperate tropical climate. They cannot withstand the extreme weather caused by climate change. The suitability of coffee-growing areas is expected to decline drastically by 2050 if we continue in this manner (Bunn et al., 2014). There is even the chance that wild Arabica coffee will become extinct in this century (Davis, 2017).

In addition to extreme weather events, the higher temperatures are driving coffee, which is grown in high-elevation areas, further up the mountains (Clarke, n.d.). At one moment, the top of the mountain will be reached, or the conditions will not be suitable for work. Consequently, there will be no alternative to combatting the effects of climate change.

CLIMATE CHANGE IN BRAZIL

Climate change in Brazil is a big problem and there are some specific challenges that are important to mention when talking about the Brazilian Climate.
Temperatures are rising faster than the world average, and the number of days that Brazil experiences heatwave increased sevenfold from 1961 to 2020 (WWF-Brazil, 2024). Droughts are increasing, and a decrease in river flow and increase in drought can cause wildfires and decrease in accessibility to water, food and energy production . In other regions precipitation patterns are an increased risk, causing floods and damage to the coastline. (WWF-Brazil, 2024)



Rising temperatures in Brazil (Fioravanti, 2020)

The Impact of the Coffee Industry on the Planet

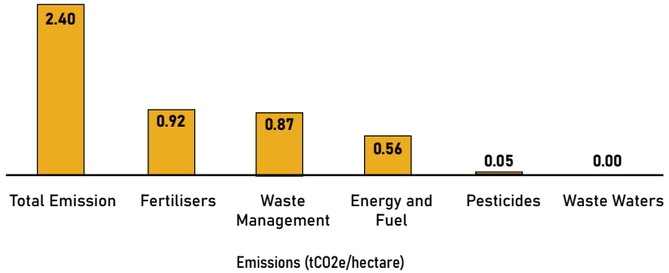
POLLUTION

The coffee industry itself contributes to damaging the climate and natural environment. Pollution emitted in many stages of the value chain is one of the most impactful consequences of coffee production. In some cases, the coffee value chain is very long. With each step, extra waste and by-products are a consequence. During coffee cultivation, carbon is emitted through fertilisers, waste, energy, and fuel use (Dedini et al., 2024).

In additon to emitting this carbon, there is a chance for carbon sequestration, but many places do not fulfil their potential. A case study by Dedini et al. (2024) analysed a specific group of farms in Brazil (these farms do not fall under the definition of agroforestry) with an average land area of 50.86 hectares. The average CO2e removal from the farms was -0.43 tCO2e/ha. This results in a comparatively low average removal of carbon when compared to the potential carbon capture that could be achievable. This figure even excludes the production of nitrogen fertilisers, which would increase the numbers from 0.92 tCO2/ha to 2.13 tCO2/ha, raising the farms' average emissions from 2.4 tCO2/ha to 3.61 tCO2/ha.

Next to the cultivation process, the processing step generates polluted water and waste. Besides, the more steps there are in the process, the more transport is required, which means more greenhouse gases that can be traced back to the coffee industry. With most coffee exported from the coffee belt to North American and European countries, there is inherently much

Average shares of carbon emissions of a specific group of farms in the Alta Mogiana region in Brazil. (Dedini et al., 2024)



pollution that can be traced to your cup of coffee. Generally, coffee is roasted in importing or consuming countries. This roasting process also consumes much energy, creating more emissions. Currently, there are too many linear processes in the coffee-producing value chain, which has to change.

WASTE

Only a small part of the coffee plant ends up in a cup of coffee. Besides coffee grounds that remain, there are a variety of waste streams that come from the coffee industry.

Biomass waste comes from trimmings of the coffee tree, and the coffee cherry. From the coffee cherry, only 21% remains in a green coffee bean after processing. Pulp, mucilage, leaves and husks are separated from the coffee seeds during the processing stage (Centre for Circular Economy in Coffee & International Coffee Organization [ICO], 2023).

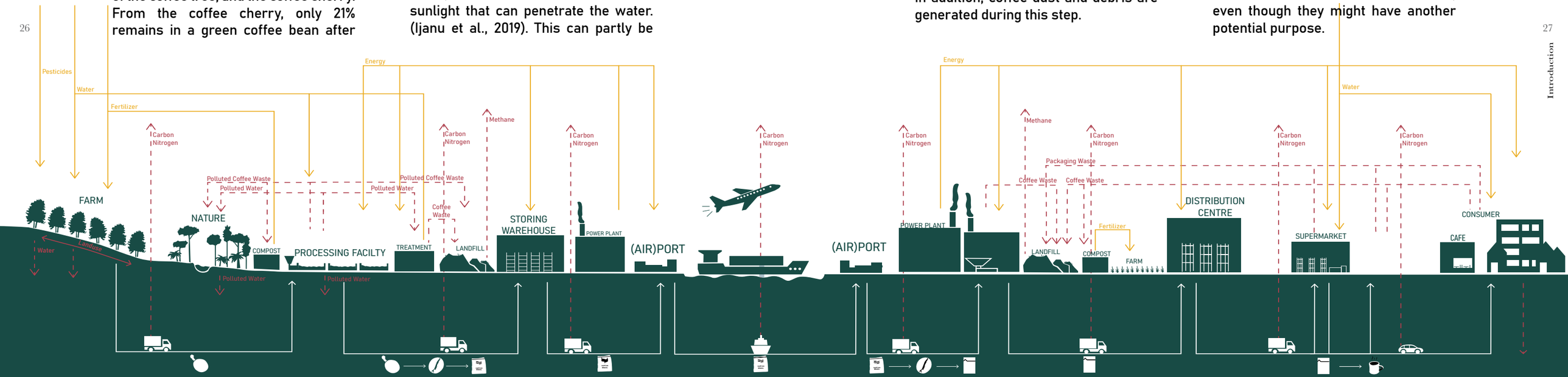
Additionally, wastewater that can be toxic, is generated at this stage of the process. When using the washed or wet processing method, 15 to 20 litres of water per kilogram of coffee can be generated. The main concerns are the possible cause of oxygen depletion in natural waterbodies, the presence of harmful chemicals, to humans and nature and the odour and colour of the water, which reduces the amount of sunlight that can penetrate the water. (Ijanu et al., 2019). This can partly be caused due to the use of chemical pesticides that are used during the growing stages of the coffee tree. These chemicals get into the water and soil and damage the natural structure of the compounds (Merhi et al., 2022).

During the storing and shipment phase of the chain, coffee is kept in plastic liners and jute bags that often go to waste since they are not shipped back to their origin country.

More of the original coffee cherry separates from the roasted coffee bean during roasting. Silverskin is the last layer that coats the coffee bean. It is chaffed off during the roasting process. In addition, coffee dust and debris are generated during this step.

In the latest steps of the coffee value chain, where coffee is bought and consumed, the waste generated mainly comes from packaging and coffee grounds. The biomass, from coffee cherry to a cup of coffee, created from one year of coffee production, is estimated to total 40.68 million tonnes, with this coffee even excluding green coffee (Centre for Circular Economy in Coffee & International Coffee Organization [ICO], 2023).

The waste streams generated from coffee often need proper treatment before being reused. Often, that does not happen. Waste streams end up in the natural environment or in landfills, even though they might have another potential purpose.



Systemic section of the coffee chain (by author)

DEFORESTATION AND LOSS OF NATIVE VEGETATION

Next to effects on the National scale, there global importance in mitigating effects of climate change in Brazil Brazil has some of the main biodiversity hotspots in the world. The Amazon Rainforest captures carbon for the whole world, and holds high importance for the water cycle and temperature regulation of the earth. (The Nature Conservancy, 2023)

Besides the Amazone Brazil contains another biodiversity hotspot called the Atlantic Rainforest or Mâta Atlantica. This vital ecosystem does not only inhabit many species but specifically many endemic species.

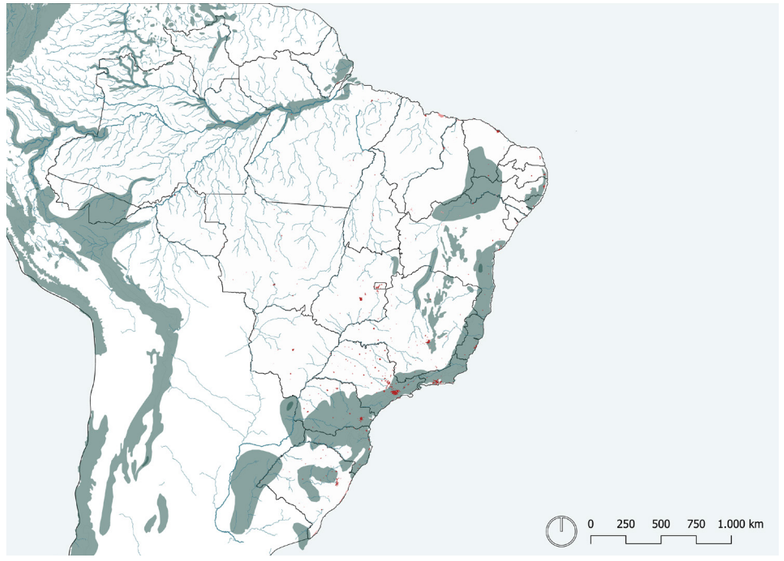
Additionally, the Atlantic rainforest is a hotspot for contributing to key ecosystem services. However, many signs of a decline in these ecosystem services are present. (Pires et al., 2021). Although this large biome has such high significance to the world, there is little left of the native vegetation from the forest. Humans have altered the forest with agriculture, infrastructure and plantations. Deforestation is a big problem in tropical rainforests and specifically in Brazil (IPCC, 2023b), with the primary source across the world being acgriculture. In the America's this number got up to around 95% from 2000 to 2010.

In the Atlantic rainforest, Historically, the arrival of humans and the colonisation of the Portuguese has altered the Atlantic Rainforest massively. The arrival of modern agriculture, cattle farming, urbanisation and industrialisation, have changed the landscape intensively. Many patches of the Atlantic Rainforest biome have been transformed and, as of now, the area looks like a mosaic, with only small patches of native forest. (Solórzano et al., 2021)

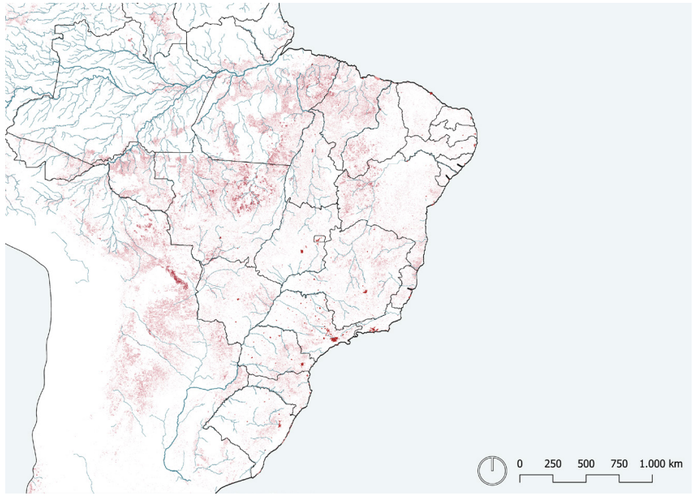
Next to human activity, wild fires are a big reason that forest are degrading, caused by the increase in drought through climate change. (WWF-Brazil, 2023). The introduction of coffee farming itself in Brazil, is also responsible for a large percentage of the deforestation of the Atlantic forest mostly in the Southeastern region of the forest (Solórzano et al., 2021).

BRAZILIAN FARMING METHODS

The standard of Brazilian coffee farming is based on efficiency and not in harmonizing with the critical natural environment. One of the main risks for nature is farming with pesticides, which is increasing in Brazil. Although



Endemic bird species in Brazil. Data (Stattersfield et al., 1998)



Forest loss due to fires. Data: (Tyukavina et al., 2022)

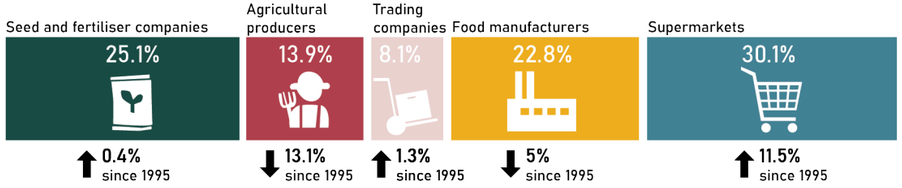
Problem field: Inequalities in the Coffee Value Chain

The global coffee chain is an imbalanced industry. One hundred million people worldwide depend on coffee for their income, and in most coffee-producing countries, farmers get paid below the poverty line (Panhuysen & De Vries, 2023). Those working at the beginning of the coffee value chain, typically farmers and processors, get much less compensation in proportion to the intensity of their labour.

The coffee industry sees the most added value within the chain after the export. Most of the value addition along the coffee chain is added when roasting, giving the beans their distinct coffee flavour, and processing them into products and packaging. Therefore, this part of the coffee chain also sees the highest return on profit. The producers of coffee, farmers, and processors have very labour-intensive jobs. However, since they are at the beginning of the chain and coffee has many steps before it is consumable, farmers generally see less profit from their beans. Often, coffee farmers do not even know what happens to their beans after they have been sold. People working at the end of the chain, retail and consumption, have a much higher profit ratio than their work intensity.

This imbalance makes smallholder farmers especially vulnerable. Producers are typically the stakeholders who have to adjust to climate change since their farms feel the effects of the changing climate the most. Extreme weather events can kill plants, leading smallholder farmers to stay behind without coffee plants for their income. The IPCC (2022) has even said that smallholder farms in South America are one of the most vulnerable groups in relation to climate change.

INCOME GAP IN BRAZIL

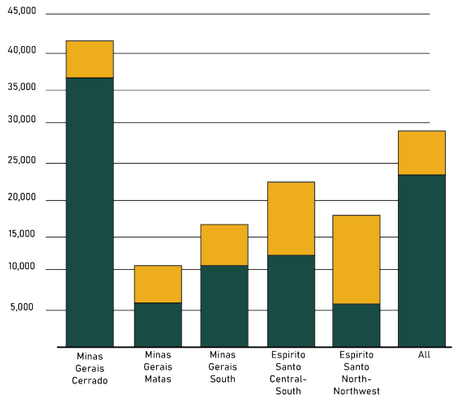


Final shares in consumer price (Ferroni et al., 2021)

Compared to other coffee-growing countries, Brazilian coffee farmers get more than the usual coffee farmers worldwide (Panhuysen & De Vries, 2023). They also earn, on average, more than the benchmark household in Brazil (Rainforest Alliance, 2020). However, these numbers are taking some things out of perspective, averaging smallholder farmers and industrial-sized farmers in the same number. Still, too many farmers have an income gap.

Earning a living income means having enough to pay for basic needs. Having an income gap means that these needs are not yet met. In a study for the Global Coffee Platform (2023), 8 out of 68 farmers in coffee-producing regions in Brazil, still have an income gap. When only including income earned from coffee growing, this is doubled. For many people, there is still a need for a compensation strategy to build a more secure income. With the growing risks of climate change, financial risks also keep increasing.

LIVING INCOME AND COST FOR REGIONS



Income and cost for regions (Coffee Platform, 2023)

COFFEE PRICING

Arabica coffee is mainly traded on the New York Stock Exchange, and Robusta on the London Stock Exchange. The global price of coffee (the C-price) is established based on the supply and demand in the global coffee value chain. The prices are based on current markets and future contracts. Large-scale companies can buy big quantities when the coffee price is low. Besides that, the C-price distinguishes little between quality and origin. (Panhuysen & De Vries, 2023) Within the commodity coffee industry, it is quantity over quality, and the goal is always to get the cheapest coffee possible. (Panhuysen & de Vries, 2023)

More and more, a few countries lead the coffee market. Brazilian coffee dominates 40% of the coffee market, Vietnam accounts for 20% and three other countries (Colombia, Honduras, Indonesia) account for 25%. This is driven by the industry's desire to leverage economies of scale, particularly in low-margin

businesses where cost-efficiency is dominant. Companies experience these economies of scale as cost advantages when production becomes efficient (Kenton, 2024). However, this shift significantly affects the whole industry (Panhuysen & De Vries, 2023). Many nations with lower production are highly dependent on coffee for their GDP. Additionally, maintaining a diverse coffee supply chain is essential for the resilience of the coffee industry in the future, which faces risks like climate change (Panhuysen & De Vries, 2023).

CURRENT LIMITATIONS OF BIG COMPANIES

Coffee is seen as a commodity, and a few countries and companies dominate the industry. Major companies like Starbucks in the USA, Nestle, and JDE Peets control more than half of the coffee production worldwide. These big companies write reports and goals about their strategies and ambitions to have ethical purchasing and become more sustainable. There are improvements, however, their main goals, however, still seem to be focussed on growth, efficiency and gain profit yearly. These goals seem conflicting.

Starbucks, the biggest coffee company worldwide, seems not to be able to guarantee the fulfilment of these goals. Their 100% ethical claims are found to be false, and multiple violations of workers' rights and conditions have been traced to their supply chain. This includes modern slavery on Brazilian farms, the illegal trafficking of migrant workers, child labour in Guatemala, and instances of sexual abuse in Kenya (Milman, 2024).

Besides that, they do not publicly share the list of farms certified by their seal called C.A.F.E. (Repórter Brasil et al., 2023). The opaque supply chains of these major businesses are part of the problem. Transparency and traceability often lack, making it nearly impossible to check their claims, with which they market their coffee. Additionally, the methods used by the certifiers to assess the situations on these farms are not known to the public (Repórter Brasil et al., 2023), making their claims even more difficult to review.

WORKING CONDITIONS.

In Brazil specifically, some particular injustices stand out. Rainforest Alliance (2020) found Brazil's biggest challenges in the coffee industry. They assessed workers' rights, finding as a standout problem that accommodation for workers on coffee farms is inadequate. There is no proper legislation on accommodation for workers, and there have been reports of poor living conditions. The high use of pesticides on Brazilian coffee farms also poses a danger to labour conditions, exposing workers to chemical substances. Even though there are laws about protective gear, law enforcement lacks, and there is a high chance that these chemicals are not handled correctly (Rainforest Alliance, 2020).

Conditions are so bad that SOMO (2024) found examples of modern slavery on Brazilian Coffee farms. Examples that violate fundamental human rights. Examples are: the absence of employment agreement, irregular payment, illegal dismissals, insufficient hygiene, failure to provide protective equipment, no available drinking water and more. All of these were present in the supply chain and can be traced back to major players with lots of power in the coffee value chain, like Starbucks, Nestlé and even Rainforest Alliance-certified farms (SOMO, 2024). Working conditions for general workers, specifically women, present extra challenges. The Brazilian government has tried to close the gender gap, yet there is still a gap between women and men in the coffee industry. For the same jobs, women get a different price, and women still do not have the same responsibilities and opportunities as men (Rainforest Alliance, 2020).

Accomodations on farms found in Brazil. (SOMO,2024)

Problem Statement

The price of coffee is the highest it has been in a long time (Davis, 2017). At the same time, it is becoming more difficult and less attractive for a coffee farmer to stay in the business (NOS, 2024). Coffee plants are susceptible to climate change, and high temperatures and extreme weather events caused by climate change are hard for them to withstand. Research even suggests that this coffee plant could become extinct during this century solely due to climate change (Davis, 2017).

Besides that, the coffee supply chain is long and wasteful. Coffee production produces many waste streams, including contaminated water and coffee remains, which result in pollution and degradation of the natural environment (Ijanu et al., 2019). Only one to five per cent ends up in your morning cup of coffee (Centre for Circular Economy in Coffee & International Coffee Organization, 2023).

Although Brazil stands out as the only country where coffee producers, on average, earn enough to earn a living income from coffee (Panhuysen & De Vries, 2023), the country faces considerable challenges. Due to the effects of climate change, the suitability of land for growing coffee will drastically diminish (Bunn et al., 2014), and farms will have to adapt and mitigate the consequences of climate change.

Historically, coffee production, other agricultural practices, infrastructure, and urbanisation have highly altered the landscapes of the Atlantic Rainforest (Solórzano et al., 2021). Less than 30% of the native vegetation in the Atlantic rainforest remains. As a result, there is a high need for preservation and restoration in the currently sun-grown and pesticide-using-dominated country (Somarriba & Arlene, 2018).

These consequences negatively affect 125 million people worldwide who depend on coffee for their livelihoods (NOS, 2024). Many farmers worldwide still live below the poverty line (Panhuysen & De Vries, 2023) or cannot get a living income by only producing coffee (Global coffee platform, 2023).

Moreover, Rainforest Alliance et al. (2022) found multiple issues related to the conditions and rights of people working in the coffee sector, specifically in Brazil. Gender equality, agrochemical handling on farms, and accommodation standards are not yet being met.

Current policies and strategies still lack the concept of a circular economy. A socio-ecological strategy that implements circular practices is needed in the coffee value chain. This strategy could build resilience in the environmental transition, fighting the effects of climate change, and shift the industry into one focused on longevity and justice.

Research Questions

MAIN RESEARCH QUESTION

“How could the implementation of a socio-ecological spatial strategy including circular interventions mitigate and adapt to the effects of climate change while creating a more fair value chain for coffee producers in Southeast Brazil?”

SUB QUESTIONS

1: Which circular economy practices can be implemented in the coffee value chain and how has this been done so far?

2: How do these circular economy practices contribute in adapting to and mitigating the effects of a changing climate and what stakeholders are involved?

3: How can the circular economy practices enhance a fair coffee value chain and what stakeholders are involved?

4: Which archetype of Brazilian coffee farmers can have the biggest impact on the climate transition and on social justice while transforming towards circular production?

5: How can these circular practices be used to implement changes in a case study in Brazil?

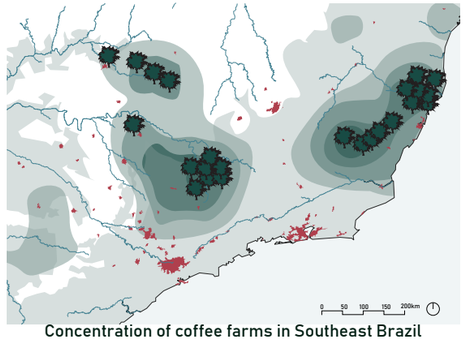
Outputs

This thesis will begin with a national-level analysis but will focus in on a local scale for deeper insights, with all final outputs tailored to the local context. It will deliver three main outputs: (1) a multi-criteria analysis to assess the potential impacts of circular interventions for different Brazilian coffee farmer types; (2) a set of design typologies for sustainable agricultural practices and circular interventions; and (3) a practical toolbox tailored to farmers of the Brazilian case study region, integrating these design typologies to support decision-making and implementation. Together, these outputs aim to bridge theoretical concepts, such as, justice, circular economy, and climate transition.

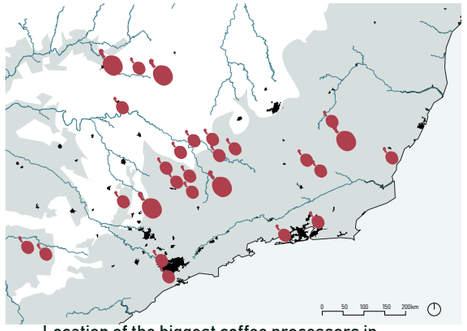
Brazilian Context

This chapter explores the Brazilian coffee farming system and contextualises this significant industry. It goes into the distribution throughout the country, the general system and layout of a coffee farm and dives into the variety of Brazilian Coffee farms.

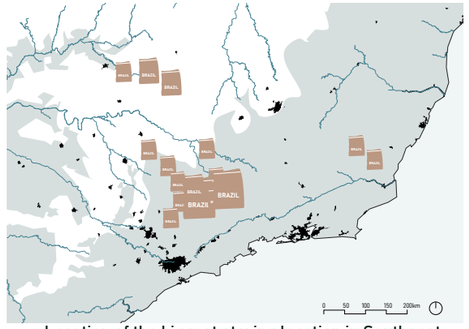
Distribution of the Brazilian Coffee Industry



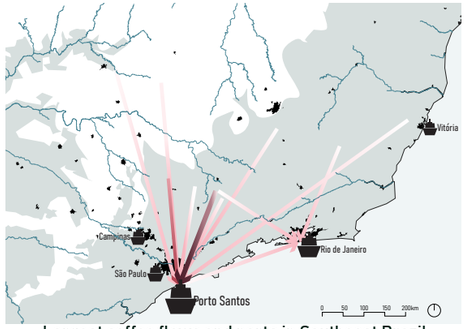
Concentration of coffee farms in Southeast Brazil
Data from (Instituto Brasileiro de Geografia e Estatística - IBGE, 2016/2017)



Location of the biggest coffee processors in Southeast Brazil Data from (Instituto Brasileiro de Geografia e Estatística - IBGE, 2016/2017)



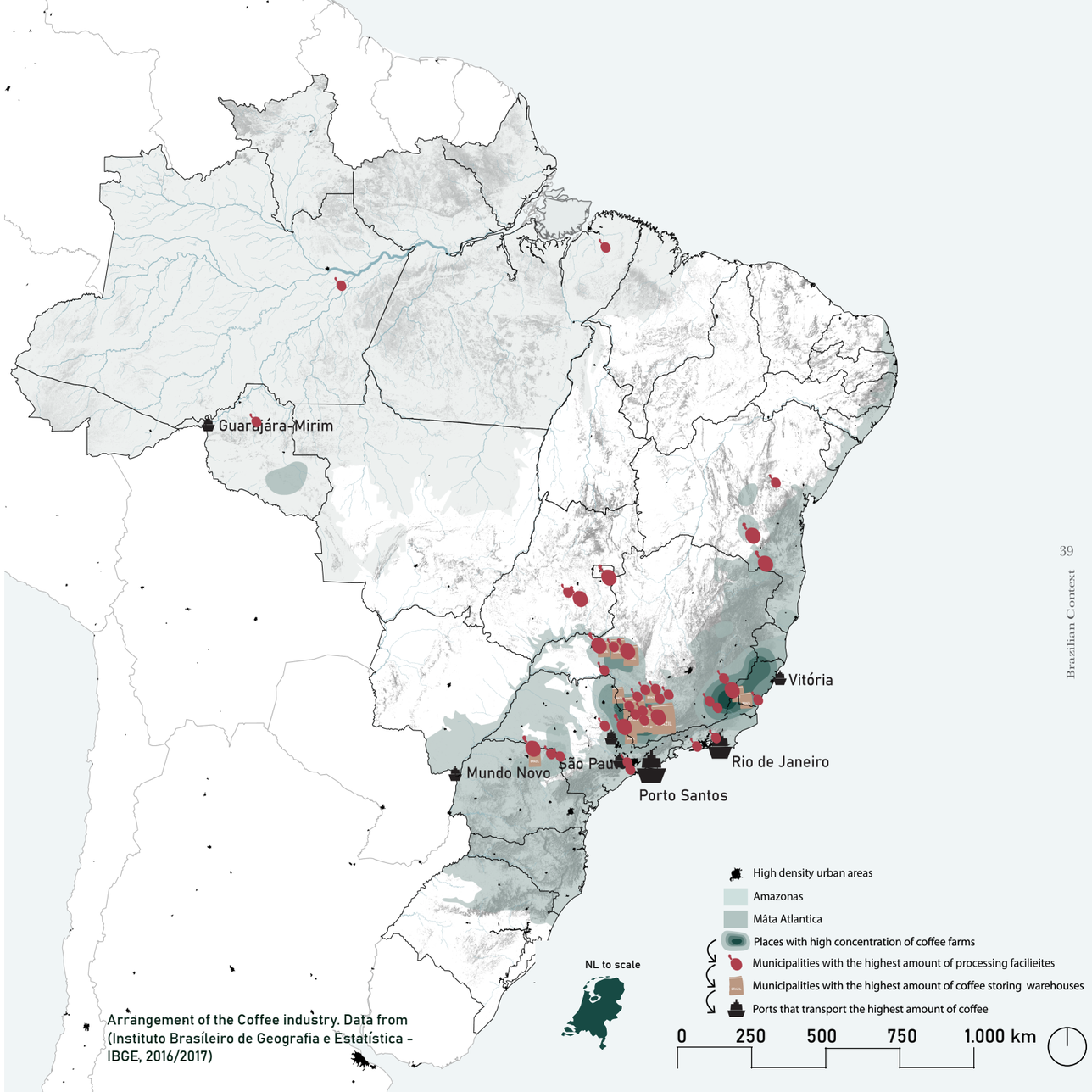
Location of the biggest storing location in Southeast Brazil Data from (Instituto Brasileiro de Geografia e Estatística - IBGE, 2016/2017)



Largest coffee flows and ports in Southeast Brazil Data from (Instituto Brasileiro de Geografia e Estatística - IBGE, 2016/2017)

The main area where coffee is grown is around Southeast Brazil, where the largest cities are, and the Atlantic rainforest is located. The industry is concentrated in the regions: Minas Gerais, Espírito Santo, São Paulo and Rio de Janeiro.

Coffee is grown, processed and stored in these regions. All the stages of the coffee industry happen in the same region, before being exported. The main harbour for export of coffee is the one of Porto Santos. (Instituto Brasileiro de Geografia e Estatística -



Arrangement of the Coffee industry. Data from (Instituto Brasileiro de Geografia e Estatística - IBGE, 2016/2017)

IBGE, 2016/2017)

Minas Gerais has the highest coffee production, followed by Espírito Santo. The main difference is that coffee in Espírito Santo is mostly Robusta or Brazil, often called Conílon coffee. (Instituto Brasileiro de Geografia e Estatística - IBGE, 2016/2017)

MINAS GERAIS

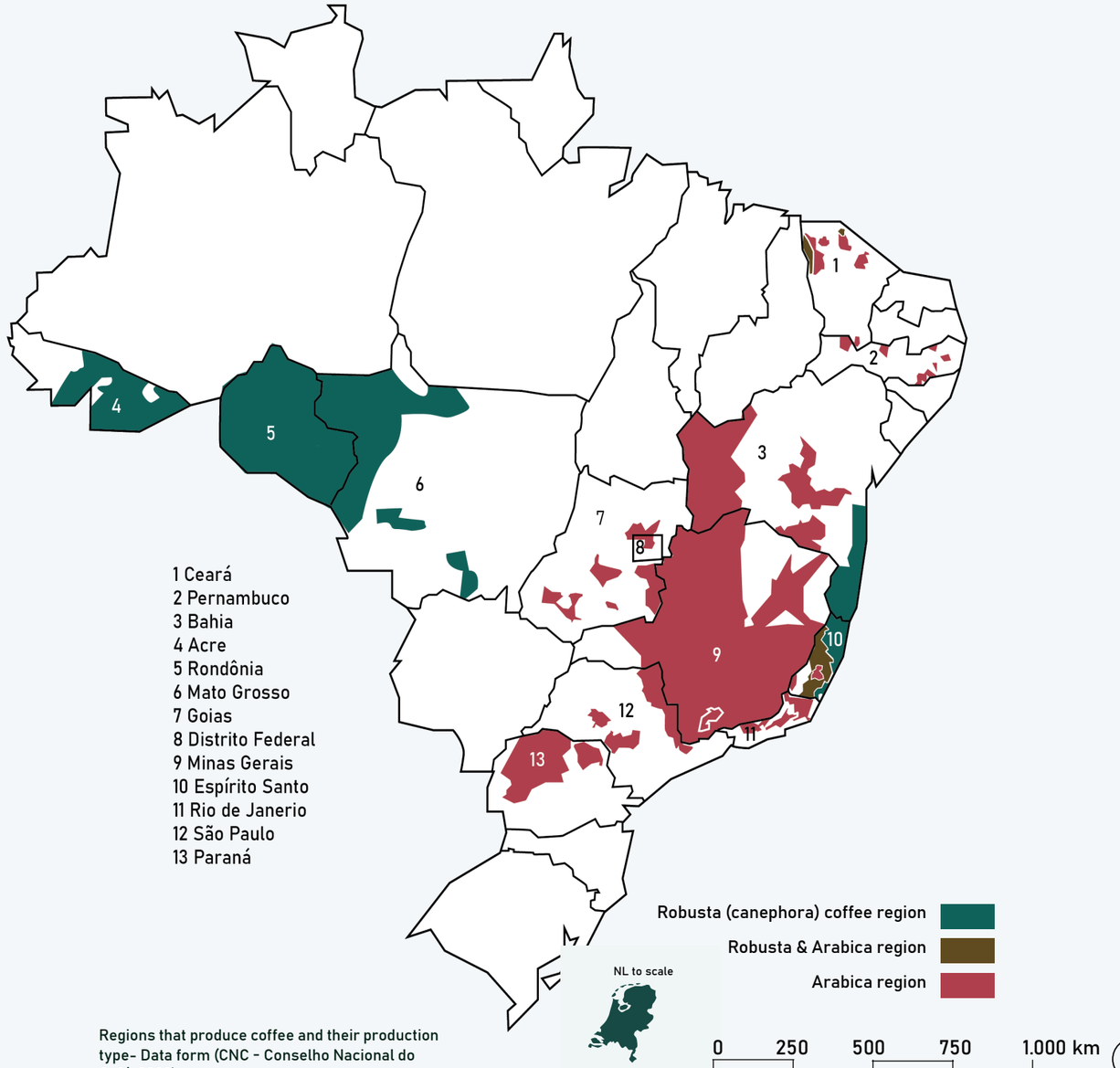
Minas Gerais features a tropical to highland tropical climate and encompasses four major biomes: the Atlantic Rainforest, Cerrado, Campos de Altitude, and Mata Seca. Elevation in the region ranges from 900 to 1,500 meters above sea level (Global Coffee Platform [GCP], 2023). Minas Gerais accounts for approximately 43% of Brazil's total coffee production and supports various farm types.

The southern portion of the state, known as Sul de Minas, is the leading coffee-producing subregion, contributing around 30% of the nation's total production (Costa, 2021). This area is characterised by diverse farm sizes, with a strong presence of family-based agricultural systems. Other notable coffee-producing areas within Minas Gerais include Cerrado Mineiro, known for its flat topography and large-scale, mechanised operations (GCP, 2023), and Matas de Minas, which is distinguished by its predominance of smallholder farms.

ESPÍRITO SANTO:

Espírito Santo is Brazil's leading Robusta coffee, while also ranking third in national production of Arabica coffee, with approximately 160,000 hectares dedicated to its cultivation. The state has a tropical wet climate and contains a mosaic of coastal, highland, and mountainous zones, with altitudes reaching to 1,000 meters. The region is entirely situated within the Atlantic Rainforest biome, and the region's native vegetation ranges from dense forest to open ombrophilous formations (GCP, 2023).

Robusta cultivation in Espírito Santo is typically conducted on highly mechanised and irrigated farms. In contrast, Arabica coffee production tends to rely on less mechanisation, with only about 5% of crops receiving irrigation (GCP, 2023). Arabica production in the state is primarily based on family farming and takes place in cooler, mountainous areas.



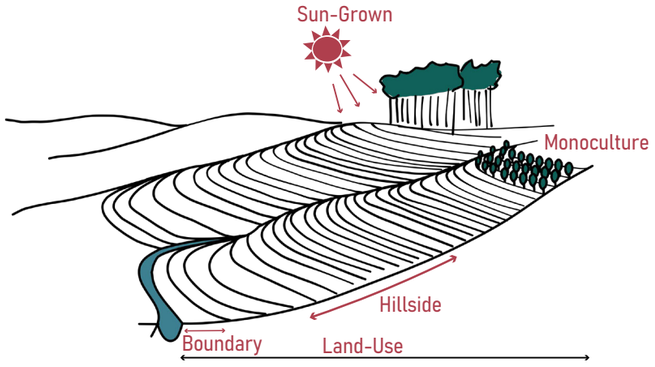
Regions that produce coffee and their production type- Data form (CNC - Conselho Nacional do Café, 2020)

Brazilian Farming System

BRAZILIAN FARMING METHODS

The standard of Brazilian coffee farming is based on efficiency and not in harmonizing with the critical natural environment. One of the main risks for nature is farming with pesticides, which is increasing in Brazil. Although pesticides increase efficiency and productivity at first, there are many negatives that have been tied to the use of pesticides. They are used for pest control and management of diseases on crops, but in the long run they do more harm than good. Links have been made to human health risks, soil degradation and decay to the the natural environment and ecosystems (Aktar et al., 2009). An example is the decrease of species of butterflies and the presence of pesticides in the wastewater that comes from the coffee landscapes. The use of pesticides has increased by 190% in the past decade, and more and more pesticides which are banned in the EU, are being approved in Brazil (WWF-Brazil, 2023).

Besides pesticides, the typical way of coffee farming in Brazil uses a sun-grown, monocultural way of farming (Panhuysen & De Vries, 2023). 95% of the farms are using a sun-grown way of coffee farming (Somarriba & López Sampson, 2018). While efficient, this way of farming is not future-proof. There is a high biodiversity loss, soil degradation and a need for chemical fertilisers and pesticides. Although these farms might seem green, they are coffee desserts, negatively affecting the native vegetation in the area (Rondonuwu, 2024).



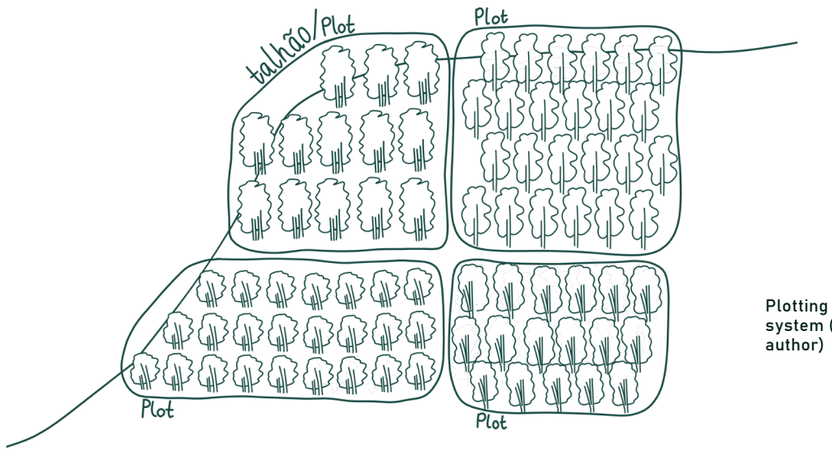
Various plots on a Brazilian Coffee farm (by author)

LAYOUT

The layout of a Brazilian coffee farm is divided into several plots or “Talhões.” One “Talhão” is a homogeneous plot of coffee trees, usually consisting of the same variety of coffee trees with the same spacing. There are small sand roads between these plots, usually big enough for a tractor to pass. The same agricultural practices are used on one of these plots. Soil management, harvesting methods, and inputs will be the same within plots but vary throughout the farm. This variety helps decrease the monoculture slightly and helps reduce the spreading of diseases when using more resistant varieties of coffee trees. When changing or experimenting with management methods, new varieties or other methods, this is often done per plot to test the performance.

This system of laying out coffee trees did not yet exist when the coffee tree entered Brazil, but was invented by the Brazilians to create an efficient system that worked in the area. It started in 1798 when Pierre-Joseph Lobarie published a manual (Tomich et al.,

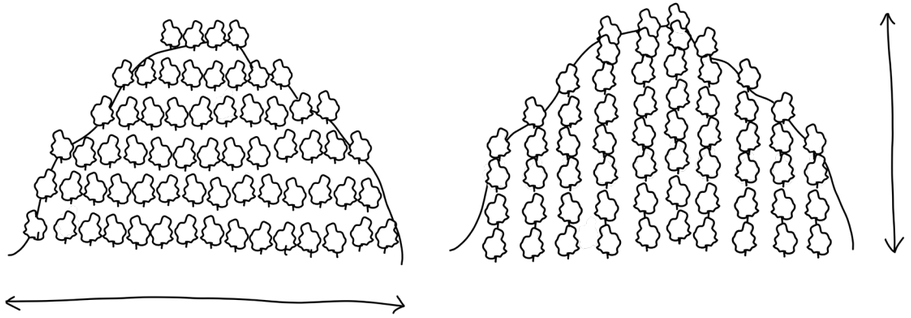
Plots on a Brazilian Coffee farm (by author)



Plotting layout system (by author)

2021). Coffee cultivation had recently moved from the Northern regions of Brazil to the Southeast near Rio de Janeiro. He had realised that elevation and climate were suitable, but not ideal for coffee growing and started to think of ways to adjust the cultivation system to the location. This farming system, characterised by symmetrical, structural, and systematic rows divided into plots, with the built environment designed to be evenly organised in alignment with the plan, was made to reach maximum outputs in the new regions. This system lowered the spacing between the trees and started growing the plants in the sun (Tomich et al., 2021).

Since this was in times when slave labour was at its height in Brazil, there were consequences in that regard as well. Lobarie started by making slaves responsible for 150 litres of coffee per slave per day, later increasing the amounts. (Tomich et al., 2021) This organised system lowered the need for slaves, though. In 1789, the biggest coffee producer needed 158.000 slaves for 32.000 metric tons of coffee, while with this system, Lobarie only needed 7662 for 8100 metric tons of coffee, decreasing the amount needed per metric ton by about 80 per cent. (Tomich et al., 2021) They called this the “spatial revolution” in coffee cultivation, which started the organised way of production and now characterises the Brazilian coffee production culture.



Horizontal vs. vertical coffee layout (by author)

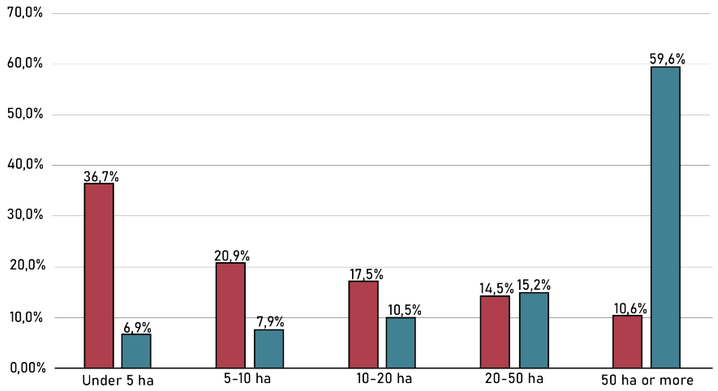
There are two ways to structurally arrange coffee trees: horizontally or vertically. Historically this vertical layout was a way for the owners to keep order over the slaves while working. Nowadays, the horizontal layout is most commonly used in coffee fields in the region, although bigger, more mechanised farms are starting to use the vertical methods more. These vertical methods allow for machinery to access the fields better.

Painthing of a historical coffee plantation Benincasa and Grupo de Pesquisa Patrimônio, Cidades e Territórios (2006)

Brazilian Coffee Farms

Brazil offers a large territory that is suitable for coffee growing, which might explain the huge production numbers. Brazil's coffee industry is not just a global leader in production but also a complex network of farming systems shaped by economic forces, labour practices, and technological advancements. The Brazilian coffee farming context significantly differs from other coffee-producing countries (Panhuysen & De Vries, 2023). They include highly mechanised large-scale operations to small family-run farms reliant on manual labour. The ratio of smallholder to industrially-sized farms is drastically different, including fewer small-scale farms than in other countries. The mainstream of Brazilian farms is based on efficiency, and small Brazilian farms would not be classified as small in countries like Colombia and Ethiopia (Moda et al., 2024). The ratio of the amounts of these farms and coffee produced is also interesting. The bigger farms produce the majority of coffee in Brazil, while this is the smallest group when counting the farm types. The biggest group of farms is less than 5 hectares, although this group produces the lowest amount of coffee (Moda et al., 2024).

This initial exploration of the farmer types delves into the typical features of each type, such as the use of mechanisation, reliance on pesticides, and manual labour. These features define five archetypes and allow them to be grouped into categories based on size (Based on Coffee producer country profile: Brazil (Moda et al., 2024). This analysis will give a better understanding of the dynamics present within the Brazilian coffee sector.



Breakdown of number of farms, and coffee produced, by farm size/archetype – Arabica coffee. (Moda et al., 2024)

Brazilian Farm Archetypes

ARCHETYPE 1: EXTRA SMALL "FAMILY" FARMERS:

These smallholder farmers account for a share of about 37 per cent of the coffee producers in Brazil. Still, only seven per cent of the coffee is produced, resulting in low productivity per hectare. These farms are generally family farms. Often, these farms are located in mountainous territories where there is no possibility for mechanisation. That is part of the reason that there is manual harvesting at these farms. The environments of these farms typically have more presence of natural vegetation as well as low use of pesticides. Through manual harvesting, there is a high need for hired labour, which is often seasonal. These farms are seen as medium-technology.

ARCHETYPE 2: SMALL "FAMILY" FARMERS

Twenty one per cent of Brazil's producers have five to ten hectares. Although there are similar classifications for this type of farm, compared to the previous one, they have the highest yield per hectare for all the farms. They produce eight per cent of the coffee production in Brazil. These farms are also fully dependent on manual labour but are designated with a label of high-technology. These farms have a very low use of pesticides and are still dependent on hired labour, despite being called family farms.

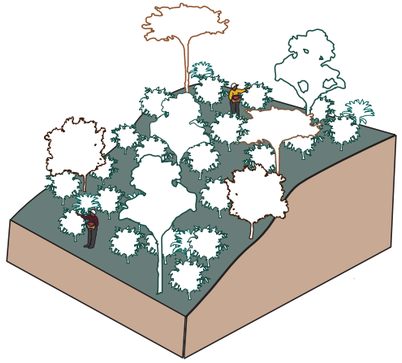
ARCHETYPE 3: MEDIUM "FAMILY" FARMERS

The amount of farms that fall into the category of medium-sized is eighteen per cent of the Brazilian farmers. These are the first types, not fully dependent on manual harvesting, using, for example, a hand-held harvester. Consequently, the decrease in hired labour is significant. The size of the farms often relates to the number of other species present. In turn, the need for pesticides increases, and natural pest control decreases with a lower density of shade planting.

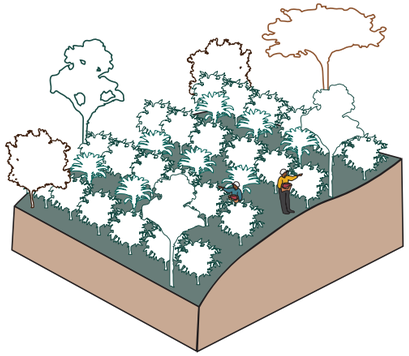
ARCHETYPE 4: LARGE "FAMILY" FARMERS

Fifteen per cent of the producers, who produce fifteen per cent of the Brazilian coffee, have a farm of ten to twenty hectares. These farms are high-tech and semi-mechanised. The larger these properties become, the more mechanised and less reliant on hired labour they are. Employees can, therefore, be rather permanent rather than hired. These farms are also more likely to process part of their coffee.

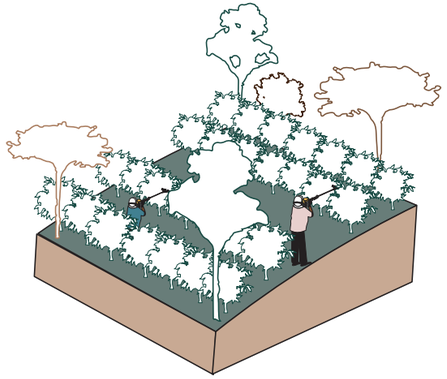
ARCHETYPE XS



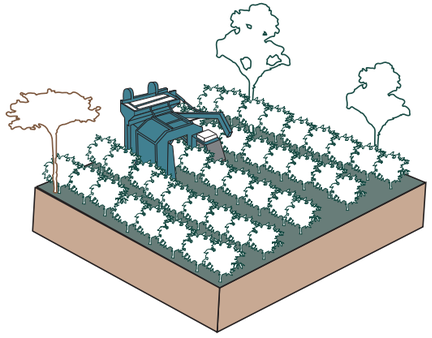
ARCHETYPE S



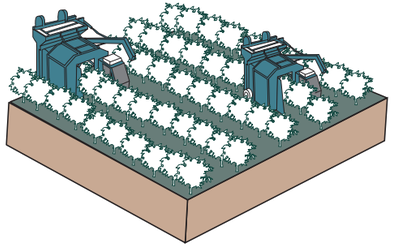
ARCHETYPE M



ARCHETYPE L



ARCHETYPE XL



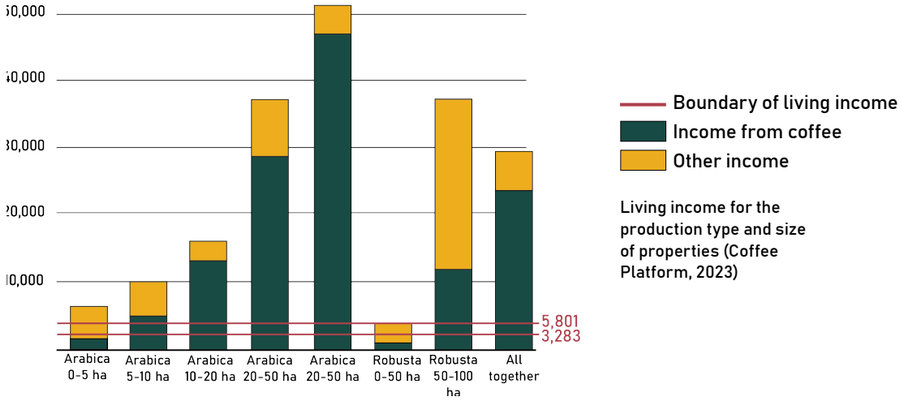
ARCHETYPE 5: EXTRA LARGE “ENTREPRENEURIAL” FARMERS

Even though the share of farms of this size is the smallest, with only eleven per cent, they have by far the highest production, with sixty per cent. These farms are highly mechanised and use the newest technologies. The process of coffee production is automated and made as efficient as possible. Farms have dense rows of coffee, created so the machines can pass perfectly. The monocultural landscapes generate a need for pesticides to control pests, diseases, weeds, and irrigation on the degraded soil. Generally, coffee is fully processed into green coffee with machines on the production grounds. Fifty hectares is by far not the biggest farm in Brazil. Multiple farms of over ten thousand hectares exist in Brazil.

INCOME OF ARCHETYPES

Generally, the trend regarding income, which is visible when dividing the farmers into these archetypes, is that farmers with a lower growing area have a lower income (Global Coffee Platform, 2023). It is possible to see the relation between regions with a high degree of non-familiar farming, bigger in size and more mechanised and irrigated farms. Who specifically stands out as a vulnerable group is the smallholder ‘family’ farmers. A large part of farmers in this archetype does not earn a living income (Global Coffee Platform, 2023).

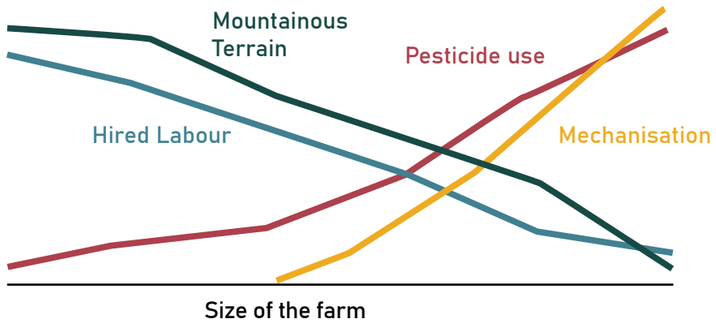
Living income and cost of living for type of coffee and size of properties



Living income for the production type and size of properties (Coffee Platform, 2023)

Brazilian Coffee Farms

Within the Brazilian farmer archetype groups, there is a clear distinction between different types of farmers and the urgent problems they face. Different archetypes experience different challenges. Small-scale family farms, while numerous, produce lower volumes and have limited influence within the value chain. They often cannot afford investments in equipment or practices that would make them more resilient to climate change (Moda et al., 2024). These farms are typically located on slopes, which prevents mechanisation and requires seasonal labour. However, they tend to produce higher quality coffee due to hand-picking and the surrounding biodiversity. Larger entrepreneurial farms operate on flatter land and rely on mechanisation and monocultures. This increases efficiency and output but reduces biodiversity and overall coffee quality, making these farms less adaptable to climate change. This situation presents a difficult choice for farmers. They can either pursue environmentally sustainable, quality-focused practices with higher costs, or prioritise efficiency and productivity at the expense of environmental health. This raises an important question: can a more circular and balanced model of farming provide a solution?



Trends within Brazilian farmer archetypes (by Author)

Conceptual Framework

Main Concepts

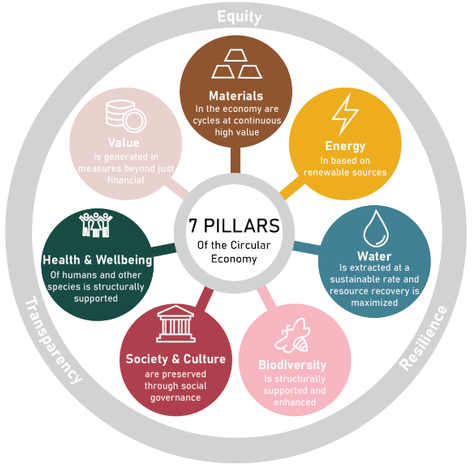
Concluding from the problem field, there is a clear need for a systemic shift in coffee production. The coffee industry needs to become more just and it needs to adapt to the challenges regarding climate change.

Two lenses of this project will be social and spatial justice and climate adaptation and mitigation. My project offers circular economy as a synergetic solution. Circular economy overlaps with both lenses and can create a more just system that can withstand a changing climate.

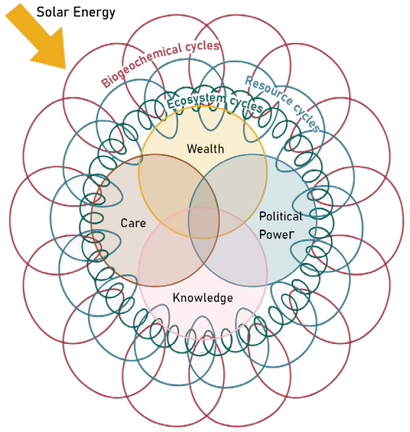
CIRCULAR ECONOMY

Growing the GDP has been the main priority of many countries for a long time. Competitiveness within the global economy is the superior goal politicians. Problems like climate change and poverty are being set aside for later and the percentage of growth that nations want to achieve keeps growing. Through increasing economic growth, inequalities keep enlarging and differences keep increasing (Raworth, 2017). Especially when wealth ends up in the wrong hands, inequalities are magnified (Friant et al., 2023)

The seven pillars of circular economy (Metabolic, 2017)



The seven cycles of circularity (Friant et al., 2023)



The main goal of this project is not economic growth. On the contrary, it focuses on creating a more balanced system, where inequalities decrease and planetary boundaries are not overshot. For the coffee industry, that means creating a system that has less impact on the environment while adapting to the transition regarding climate change and finding a solution for social problems. Without fixing these problems, the industry will never become durable or futureproof.

Material cycles are still a crucial part of the problem. The Ellen Macarthur Foundation (n.d.,) talks about a split between two types of materials, biological and technical. Technical materials are made from finite resources and biological materials are made from renewables. When designing, we have to keep in mind what system we are designing products for and in what way the material can be used after its life cycle. Mostly, the biological cycle applies to the production of coffee. Coffee production has a high impact on the environment through waste streams like pollution and wastewater and coffee grounds and these have to be treated in a conscious way. Waste products now often end up in landfills, while they could have value after their purpose has ended for the coffee value chain. These materials could be regenerated, enhancing the natural environment rather than just restoring it (Ellen Macarthur Foundation, 2022). Through regenerative agriculture, coffee production can improve soil health and biodiversity while decreasing the need for pesticides and chemical fertilisers.

A circular economy also has to include social perspectives. Metabolic (2017) describes the seven pillars of circularity including wellbeing, human activities, culture, equity and transparency. Friant et al. (2023) describe seven socio-ecological cycles of circularity, that are all interconnected. They include political cycles of power, knowledge cycles of technology, information and education and social cycles of care. To create a thriving society, all these cycles have to individually thrive as well.

Circular economy, therefore, has a broader definition than material flows. It is important that within the coffee industry, social problems are not overlooked while the attention drifts to the suitability and sustainability of the land. Transition to a circular economy has to be done justly and fairly.

CLIMATE TRANSITION

One of the lenses of the project is the transition that needs to be made towards the changing climate. Evidently, there is a need for climate action. Climate adaptation is crucial since the climate is already changing. Within adaptation, the emphasis lies on adjusting to a changing climate and designing in a way that can deal with the risks that come with climate change, like flood protection. However, in response to the changing climate, there should be an effort to mitigate the effects as well, to decrease the effects itself. to reduce the risks and to further prevent the depletion of the natural systems. Finding the balance between climate adaptation and mitigation within a sustainable transformation is important. Transitioning in itself is complex, and finding a balance is important, to tackle the root cause.

Risk framework (Simpson et al., 2021)

By adhering to the risk framework of the IPCC (2014), risks of climate change can be assessed and addressed. Important to take into account is the interconnectedness of systems and, that risks are increasingly high when systems interlink (Simpson et al., 2021). The three main pillars of the risk framework are according to the IPCC (2014):

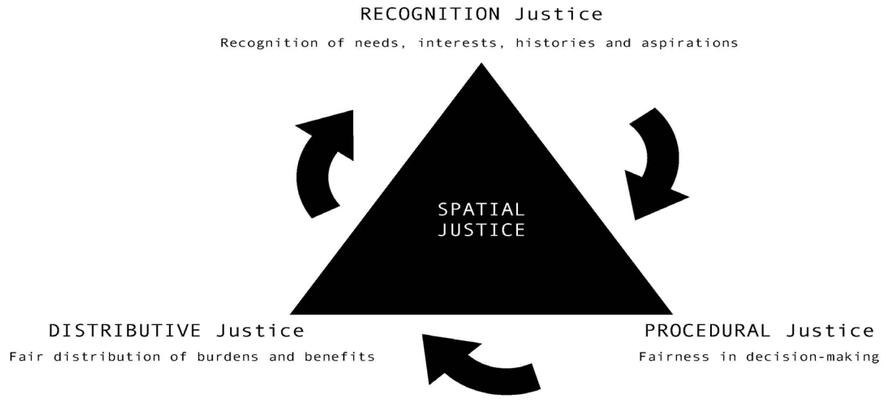
HAZARD: A damaging event or condition, which can be natural, for instance a natural disaster or extreme weather event, or human-induced, through, for example, deforestation.

VULNERABILITY: The sensitivity or susceptibility of a system, when it is exposed to a hazard.

EXPOSURE: The amount of contact that a system, person or community has with a hazard, which would increase the potential of damage to the party in contact.

An extra addition made by Simpson et al. (2021) was the pillar of response.

RESPONSE: the emphasis on the human reaction to a risk. Poor planning can lead to new challenges



Traingle of Spatial Justice (Rocco, 2023)

that could have been prevented.

Although adaptation is about decreasing the vulnerability to climate risk and mitigation aims to prevent hazards from happening, the human

response includes the efforts of adaptation and mitigation strategies. Strategies can have an opposite effect or increase vulnerability in other areas, in environmental or social settings. This is why the response has to be thoroughly and systematically assessed before implemented.

SPATIAL JUSTICE

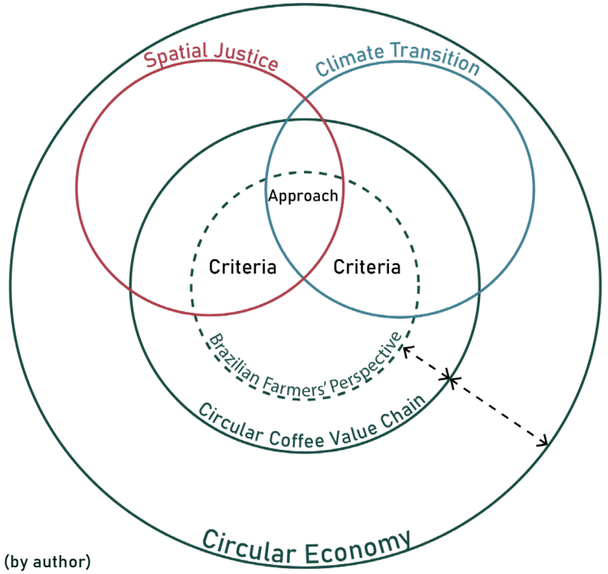
Within the problem field, many social
injustices are mentioned. Spatial justice offers a lens through which the spatial dimension of social justice is viewed. The three key pillars of spatial justice are: distributive justice, procedural justice and recognition justice (Rocco, 2023).

Distributive justice is about the distribution of the burdens benefits, opportunities and resources within a society. Designing for a fair distribution of profit, risks and resources is important. Van Der Veen et al. (2024) describe an example of designing for distributive justice for a smallholder coffee environment, including diversification strategies for their agroforestry systems, to gain better economic stability. Within Brazilian coffee production, the income gap for smallholder farmers is still apparent and labourers work in harsh working conditions, which is why there is a need for distributive strategies.

The second pillar of spatial justice is procedural justice, referring to how spaces are planned and designed and governed (Rocco, 2023). Through legislation and policies, governmental or non-governmental, institutions make decisions. Procedural justice also includes if decisions are made including the stakeholders that are impacted. Within the coffee value chain, power dimensions and inclusivity of all stakeholders is not yet present. One of the signs is the opaqueness of big companies within the coffee value chain. This is one of the key problems that have to be addressed through procedural changes.

Recognition justice is the third pillar, which entails spreading awareness of the vulnerabilities, diversities and inequalities in society (Rocco, 2023). Within coffee production, specifically in Brazil, farms are set up with the context of slavery (Solórzano et al., 2021) and often this is still visible nowadays. Besides that, protected and indigenous areas, need to get cultural and historical recognition. (Rocco, 2023)

Conceptual Framework



Conceptual Framework (by author)

The conceptual framework shows how all theories are linked to create an approach for the project. As mentioned in the problem field, coffee producers are dealing with two major themes being addressed in this project, problems related to social justice and climate change. Through the lens of circular economy, the approach will be finding potential solutions for both problems related to social justice and problems related to climate change. The criteria of the project, that will be used for the multi-criteria analysis and a later evaluation, lie in finding the overlapping solutions through circularity and spatial justice and circularity and climate transition. The approach will be focused on finding synergies in these solutions that cover all three concepts.

The second lens of the project is the Brazilian farmers' perspective. It is important not to lose sight of the context of the complete circular coffee value chain and the context of the circular economy as an ambition. Depending on what archetype of coffee farmer is chosen from the multi-criteria analysis, the framework will address different challanges.

Methodological Framework

This chapter will discuss the methodology of the thesis, illustrating how research questions will be answered. It will also discuss what methods are used for data collection and analysis, and how this will lead to the project's outputs using a mix of qualitative and quantitative data.

Approach

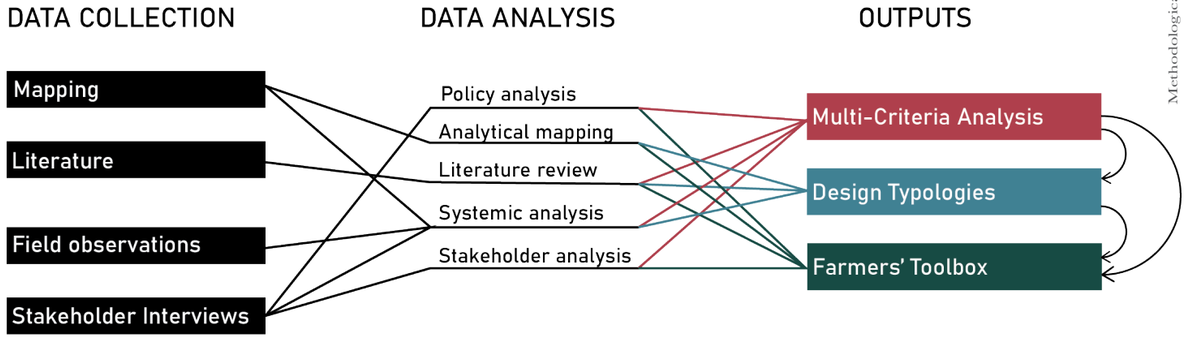
PART 1
The project starts with an analysis of the coffee industry's context. This includes an analysis of the Brazilian coffee industry to assess what problems are present and which problems are critically important to address. This was essential for planning, finding the methods, and creating a knowledge framework and conceptual framework needed to take a position within the field. This knowledge is collected through literature review and mapping.

PART 2
This step involves a detailed assessment of the current case study region and the specific coffee farming methods and systems to understand its systemic dynamics and challenges. During this period, a field trip to the case study region was made, where data was gathered through field observations and stakeholder interviews, primarily with farmers. Data was also gathered using mapping. Multiple analyses were completed with this data, including the current production methods, waste management, water usage, and the interactions between natural (blue-green) systems and agricultural practices. Key stakeholders were identified and mapped to assess their roles, power dynamics, and interests, which highlights inefficiencies and opportunities for integrating circular strategies. Current policies and legislation were examined to understand the governmental context and rules with which coffee farmers work.

PART 3
A multi-criteria analysis of the Brazilian coffee farmer archetypes was conducted. After a general analysis of Brazilian farmer types, archetypes of Brazilian coffee farmers were defined, and the multi-criteria analysis is a deep dive into the differences and similarities between Brazilian farmers. The criteria for the analysis were set up based on the concepts from part one, including a complete circular spectrum. Therefore, the farmer archetypes were assessed based on the status quo of their environmental, social and economic impact. This analysis evaluates what type of interventions and practices have the highest priority and make the most impact per archetype. A weighing criterion was introduced, prioritising the most important criteria for the transition towards a circular future. Besides that, the criteria deemed most important by Brazilian farmers during the interviews will also be considered in the weighing. The data used for this analysis was obtained through a literature review and analysis of the data collected during fieldwork, which consisted of interviews and field observations.

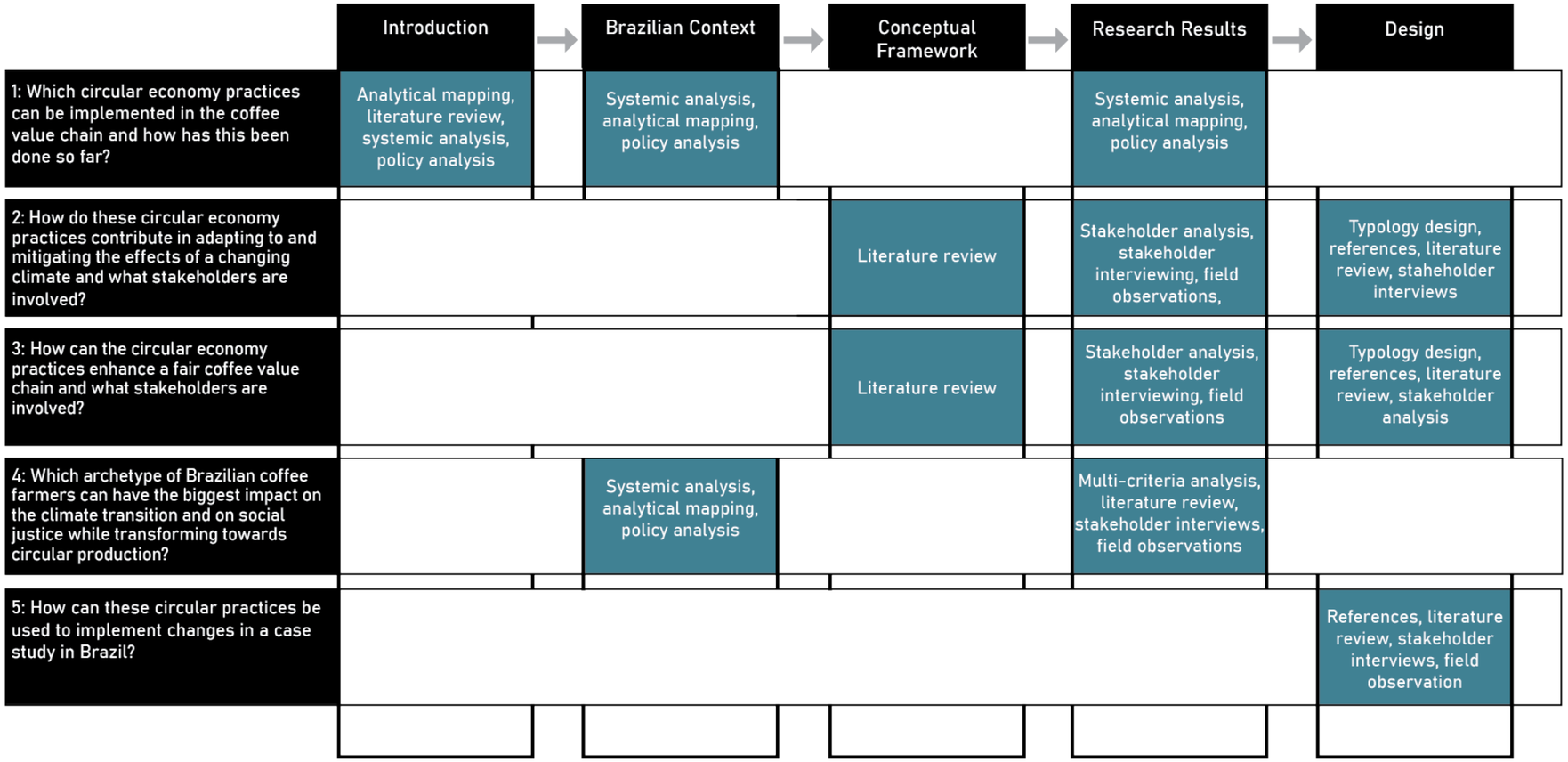
PART 4
In this project stage, circular spatial typologies were designed. Each typology integrates distinct circular interventions, such as waste reduction, regenerative agricultural practices, or a combination of multiple actions, tailored to the characteristics of the selected region. The circular typologies highlight environmental, social, and economic benefits and include practical tips like possible harvesting methods and working conditions.

PART 5
The last part of the project consists of a toolbox for Brazilian farmers. The toolbox is a practical and strategic resource to promote justice and the climate transition in Brazil's coffee sector. It aids farmers in analysing their context and gives them actionable tools to implement these circular practices and interventions. For the toolbox, the conclusions of the previous steps were used to determine the most fitting paths for farmer types. Different types will each get multiple recommended paths to follow in the toolbox. The toolbox is accompanied by policy recommendations for decision-making stakeholders to support farmers and their transformations to a circular production economy.

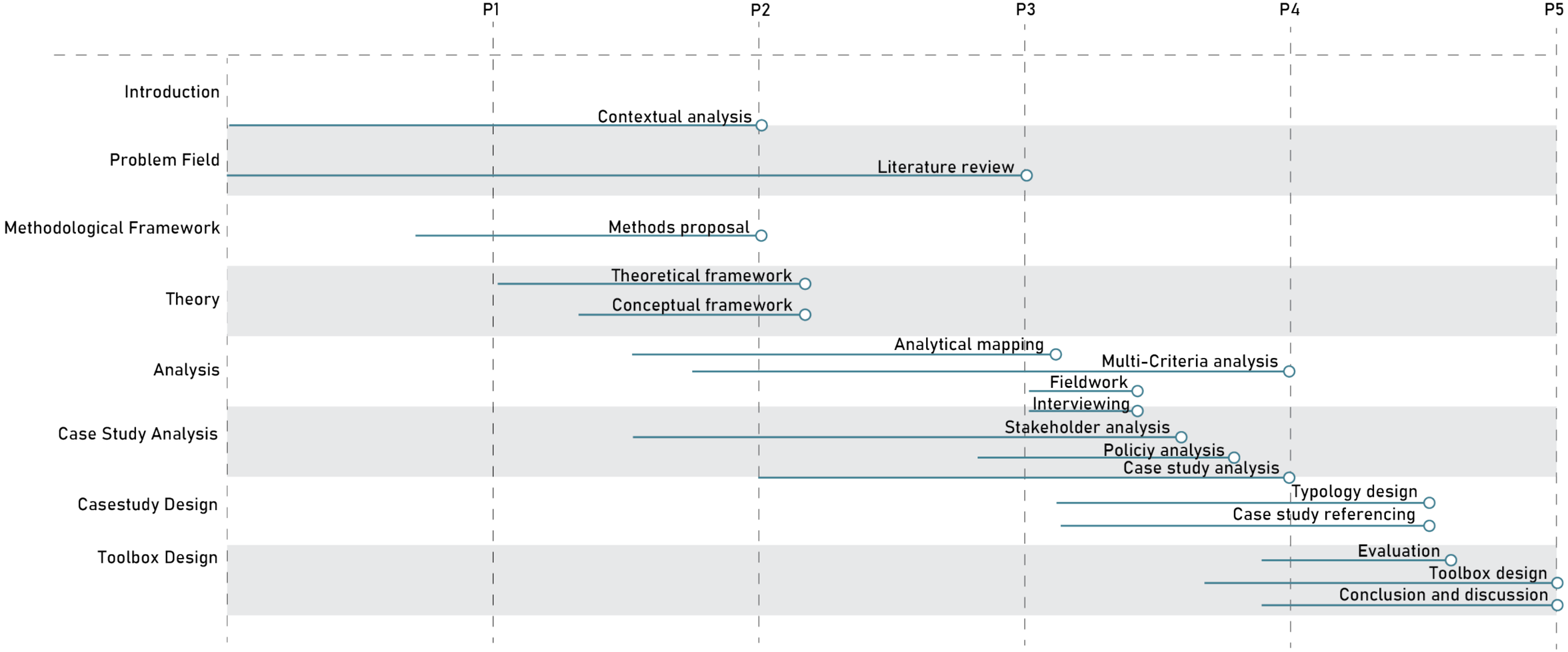


Methodological Framework

This diagram shows how the used methods will answer the sub-research questions and in what chapters this will be done.



Planning of the Graduation Project



Fieldwork and Interviews

Interviewee	Stakeholder	Farm Archetype	Reference Code
Interviewee 1	Farmer	S	F1-S1
Interviewee 2	Farmer	M	F2-M1
Interviewee 3	Farmer	XS	F3-XS1
Interviewee 4	Farmer	L	F4-L1
Interviewee 5	Farmer	M	F5-M2
Interviewee 6	Farmer	M	F6-M3
Interviewee 7	Farmer	S	F7-S2
Interviewee 8	Farmer	XL	F8-XL1
Interviewee 9	Farmer	L	F9-L2
Interviewee 10	Cooperative	-	C1
Interviewee 11	Farmer	XL	F10-XL2
Interviewee 12	Farmer	XS	F11-XS2
Interviewee 13	Farmer	L	F12-L3
Interviewee 14	Fertiliser producer	-	P1
Interviewee 15	Farmer	S	F13-S3
Interviewee 16	Cooperative	-	C2
Interviewee 17	Agricultural engineer	-	AE1
Interviewee 18	Exporter	-	E1
Interviewee 19	Association	-	A1

To analyse the case study region, fieldwork was conducted in the immediate region of Poços de Caldas, in Minas Gerais, Brazil. This fieldwork was done from April 1st to 18th, 2025. In this region, stakeholders were interviewed and farms were visited. The interviewed stakeholders were primarily farmers, but other stakeholders were included, such as cooperatives, exporters, agricultural engineers, associations, and fertiliser producers. In the rest of the report, these stakeholders and their interviews will be referred to by their reference code. Interviews with stakeholders were done in Portuguese and English. Although a basic knowledge of Portuguese is present, an external contact person was present to translate both English and Portuguese. Interviews were recorded.

QUESTIONS TO FARMERS

The questioning began with basic identifying questions, including the size of the farm and land, harvesting methods, productivity, crop types, and other roles they fulfil within the value chain. Farmers were then asked whether they had experienced substantial changes in the climate, the effects these changes had on the coffee plants, and the measures they took in response. They were also asked about current waste management practices, soil management, water usage and sources, fertiliser and pesticide use, and energy consumption.

Following this, farmers were asked about their connection to cooperatives and associations, what functions these organisations perform and whether they provide access to training or support. Additional questions addressed other forms of external assistance, such as support from governmental organisations, potential links to certifications, and the benefits received from them.

Questions were also asked regarding labour: whether farmers hired workers locally or through external employment agencies, and whether these workers were employed on a seasonal or permanent basis. Questions about income and labour conditions were deliberately excluded due to the sensitivity of this information.

In addition to current practices, farmers were asked about their ambitions to transition towards circular practices, such as adopting polyculture systems, implementing waste treatment, or sharing facilities. They were also asked about perceived limitations, including land accessibility, labour shortages, and the ability to invest in future improvements.

QUESTIONS TO OTHER STAKEHOLDERS

Questions posed to other stakeholders were aligned with the same themes. These stakeholders were first asked about their role in the coffee value chain, their functions, and the types of farmers they are connected to.

They were also asked about their current sustainability, circularity, and social programs and their goals for the future. Furthermore, questions explored how they support farmers, both generally and specifically, in achieving sustainability goals. If relevant, their connections to certifications and other organisations were discussed, including any collaboration taking place within those networks.

Research Results

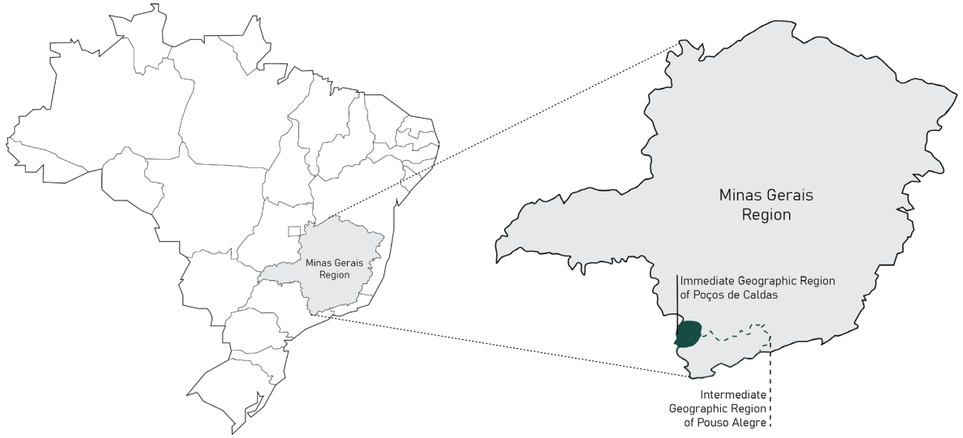
In this chapter, the research results are shared, that are gathered through literature review, and field observations and interviews. The chapter dives into the regional scale of the selected case study region and includes a site analysis, an analysis of the circularity of the region, a multi criteria analysis between farmer achetypes and the a stakeholder analysis of influential actors in the region. These outcomes are the basis for design decisions and strategies tailored to the region.

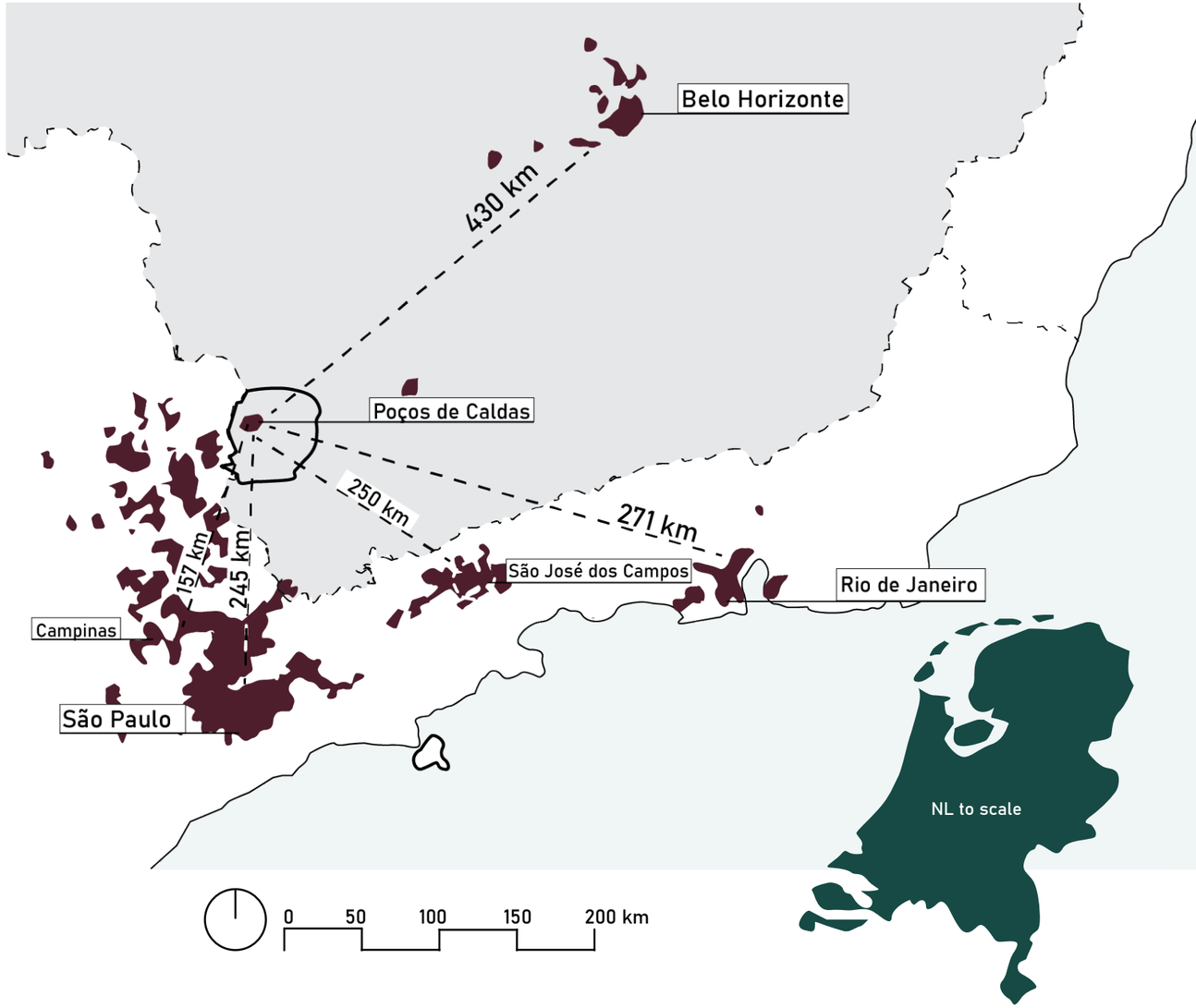
Site Analysis

LOCATION

The case study region where the fieldwork has been conducted is the immediate region of Poços de Caldas, sometimes referred to as part of the “Região Vulcanica” or “Volcanic Region”. This region falls within the intermediate region of Pouso Alegre, which lies in the south of the state Minas Gerais. The region borders the neighbouring state of São Paulo. This region falls within the Atlantic rainforest biome with mountainous landscapes. The region includes eight municipalities, with the municipalities being Poços de Caldas, famous for its thermal springs and Andradas, famous not only for its coffee but also for its vineyards.

The region is strategically located near the coast of the country, 160 kilometres away from one of the industrial hubs in Brazil, Campinas, “only” 245 kilometres away from the biggest city of the country, São Paulo and about 430 kilometres away from the capital city of Minas Gerais, Belo Horizonte.

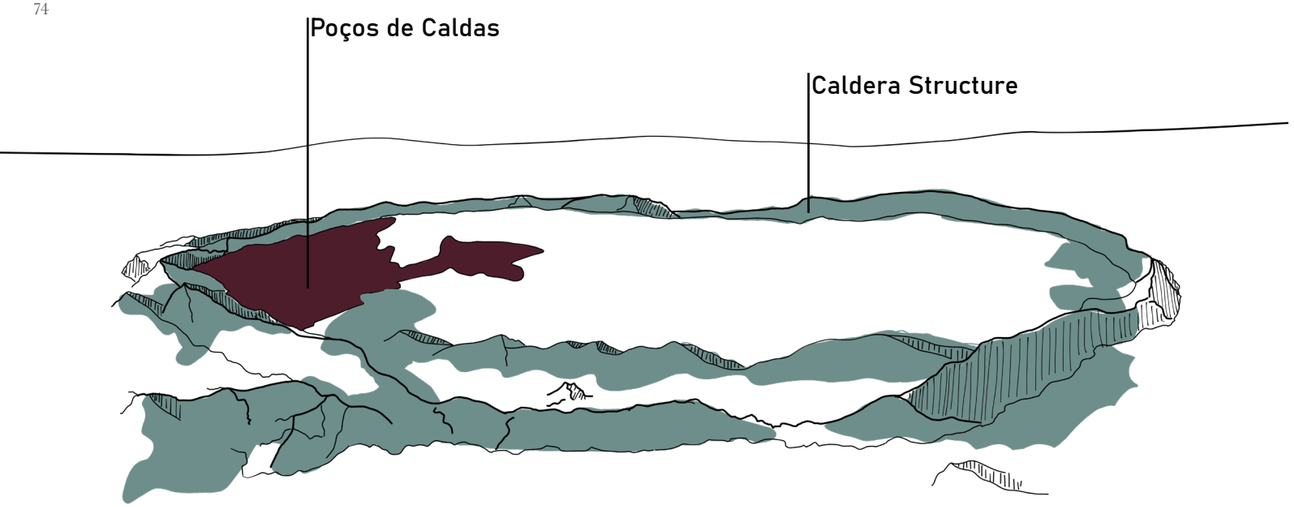




Volcanic Caldera

A characteristic feature of the region is its volcanic location, partly where it gets its mountainous terrain from, reaching altitudes from 700 meters to 1300 meters. The municipality of Poços de Caldas itself is located within an extinct volcanic caldera (Portal Minas Gerais, 2025), which forms a circular shape with a diameter of about 33 kilometres, with Poços de Caldas' urban fabric at its base (Schorsner & Shea, 1992).

This geological feature was formed during the continental break-up of the South American and African continents. Volcanic eruptions, followed by ground collapsing inward, formed a caldera (Schorsner & Shea, 1992). This volcanic history is why the soil contains rocks naturally enriched with rare earth minerals, like bauxite and potassium (Schorsner & Shea, 1992).



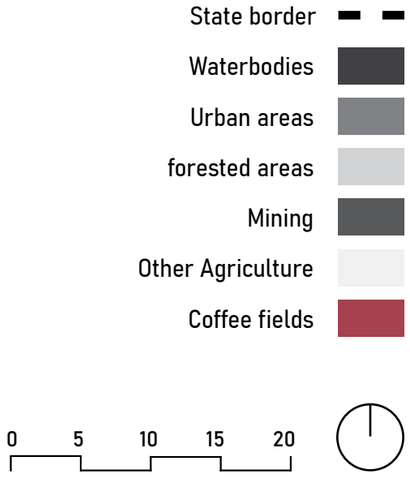
Poços de Caldas at the foot of the Caldera (by author)

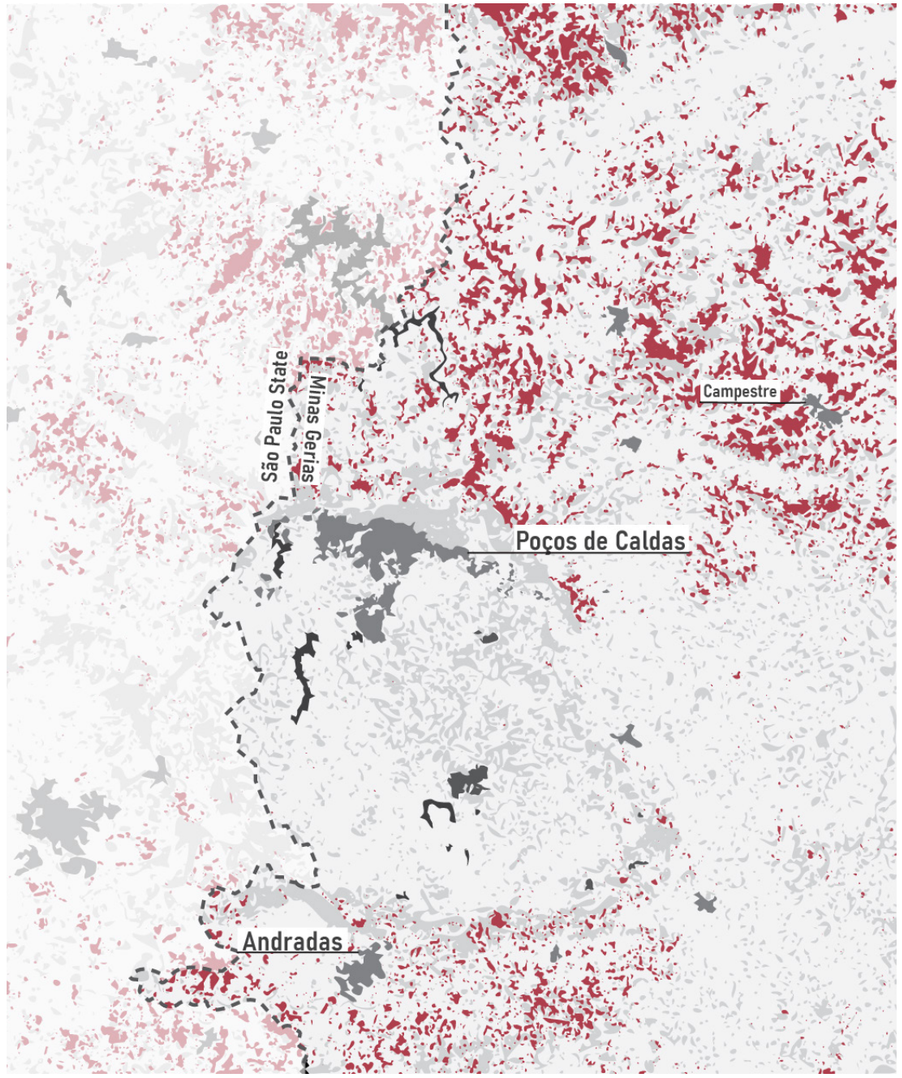
Poços de Caldas at the foot of the Caldera (by author)

Fragmented Coffee Landscapes: Coffee Fields

The landscapes of the case study region are mountainous and filled with coffee farms, Atlantic rainforest, small cities and industries.

The coffee landscapes are concentrated north and the south of the volcanic caldera, in a high concentration. Of all perennial crops in the immediate region of Poços de Caldas, 97% are Coffee (IBGE - Censo Agro 2017, 2017), which underpins the importance of the coffee crop in this region.

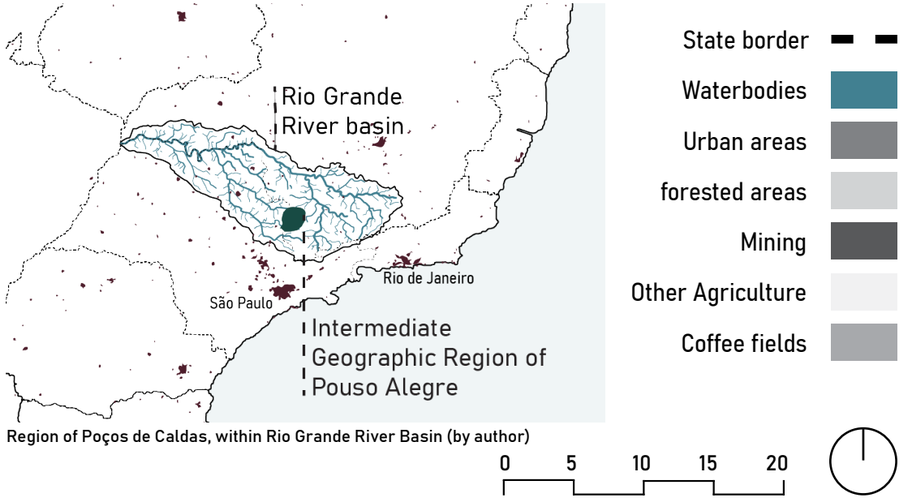




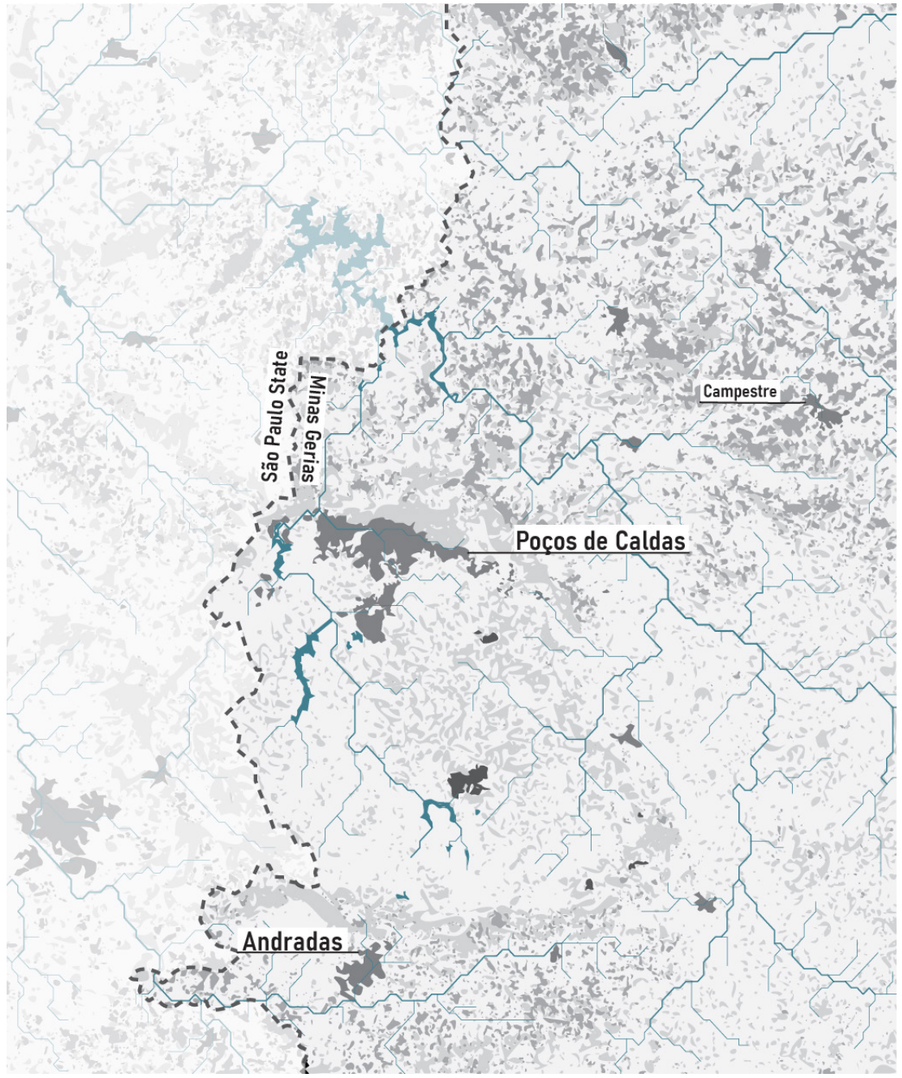
Land Cover Map of Brazil - Coffee Fields
Based on data from MapBiomas Collection 7.0 (2021), accessed via QGIS plugin. Map created by the author using QGIS

Fragmented Coffee Landscapes: Waterbodies

The case study region is located in the Rio Grande river basin which starts its tracks in the Mantiqueira mountain range near the cost of Brazil. (The Editors of Encyclopaedia Britannica, 1998b)



Region of Poços de Caldas, within Rio Grande River Basin (by author)

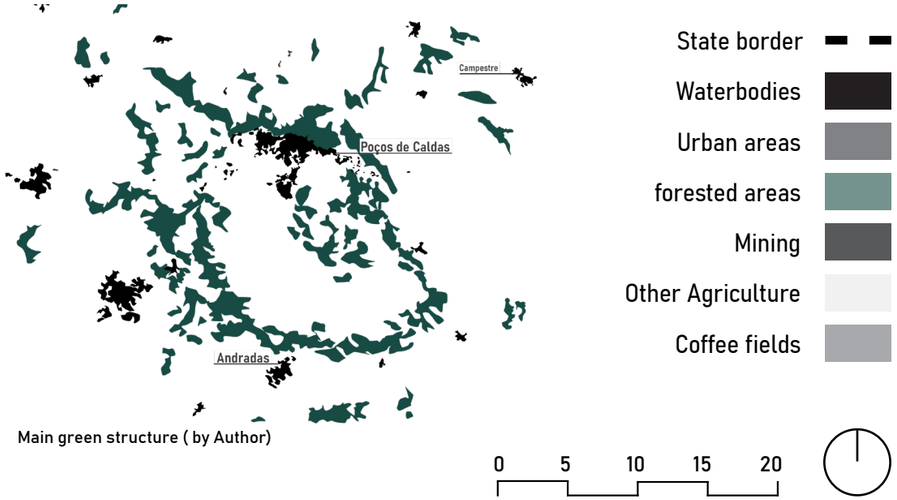


Land Cover Map of Brazil - Waterbodies
Based on data from MapBiomas Collection 7.0 (2021), accessed via QGIS plugin. & Lehner, B., Grill, G., & Thieme, M. (2013). HydroRIVERS. Map created by the author using QGIS

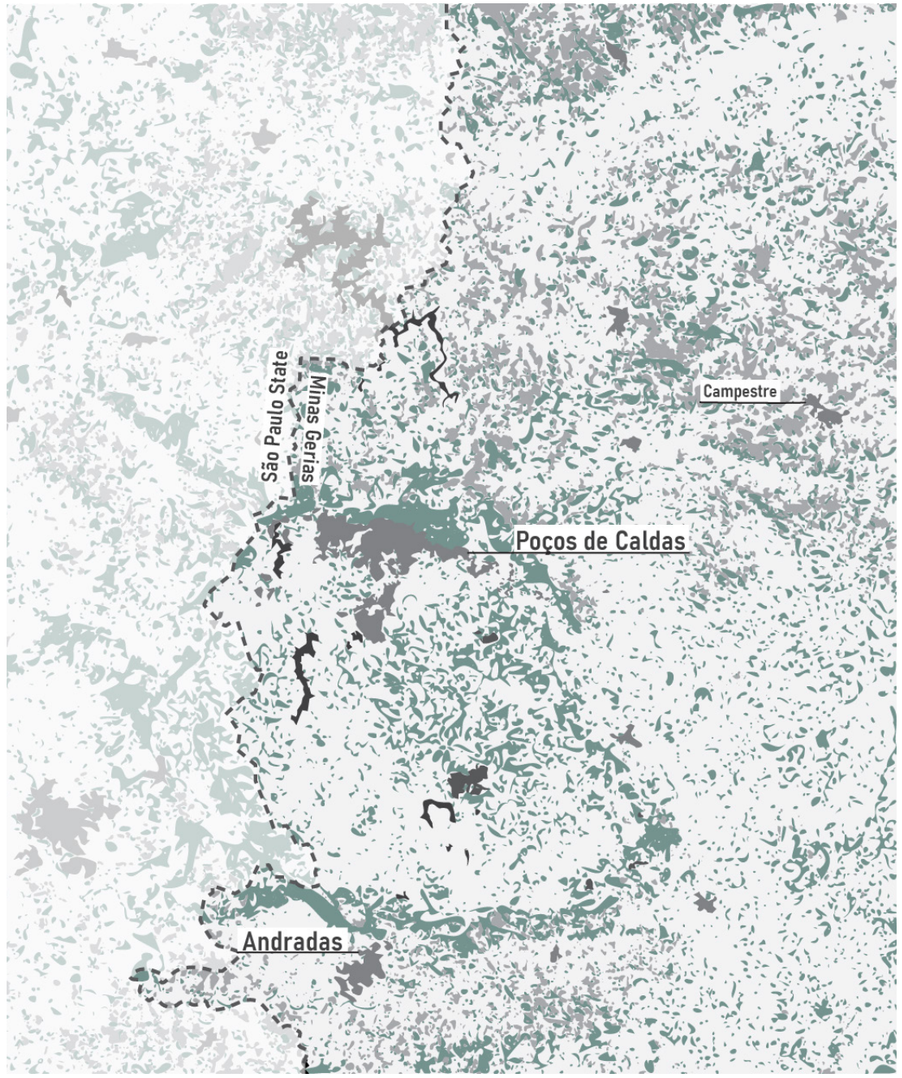
Fragmented Coffee Landscapes: Rainforest structure

Pieces of the Atlantic Rainforest are present everywhere in the region; however, it is hard to imagine that this landscape ever was a fully dense rainforest biome. This immense fragmentation of the ecological structure causes habitat fragmentation and a decrease in biodiversity, which contributes to the changed weather patterns already happening in the region.

The structure that remains, however, lies on top of the mountains. Poços de Caldas's main ecological structure follows the caldera structure, which is still connected. Commonly, the tops of mountains have the steepest slopes and are not suitable for agriculture; therefore, they have not been touched. Some of these mountains are also protected; when they have a 45-degree slope or more, they are protected by law (Projeto da Assessoria Especial Internacional do Ministério da Justiça e Segurança Pública, 2012)



Main green structure (by Author)

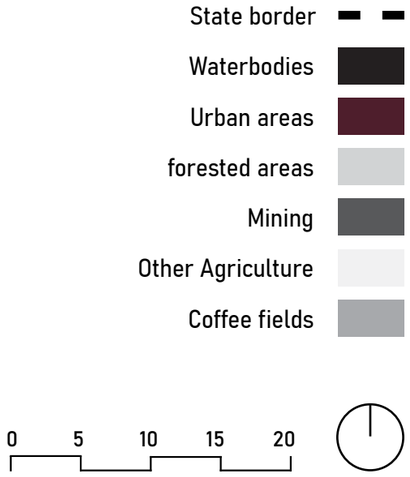


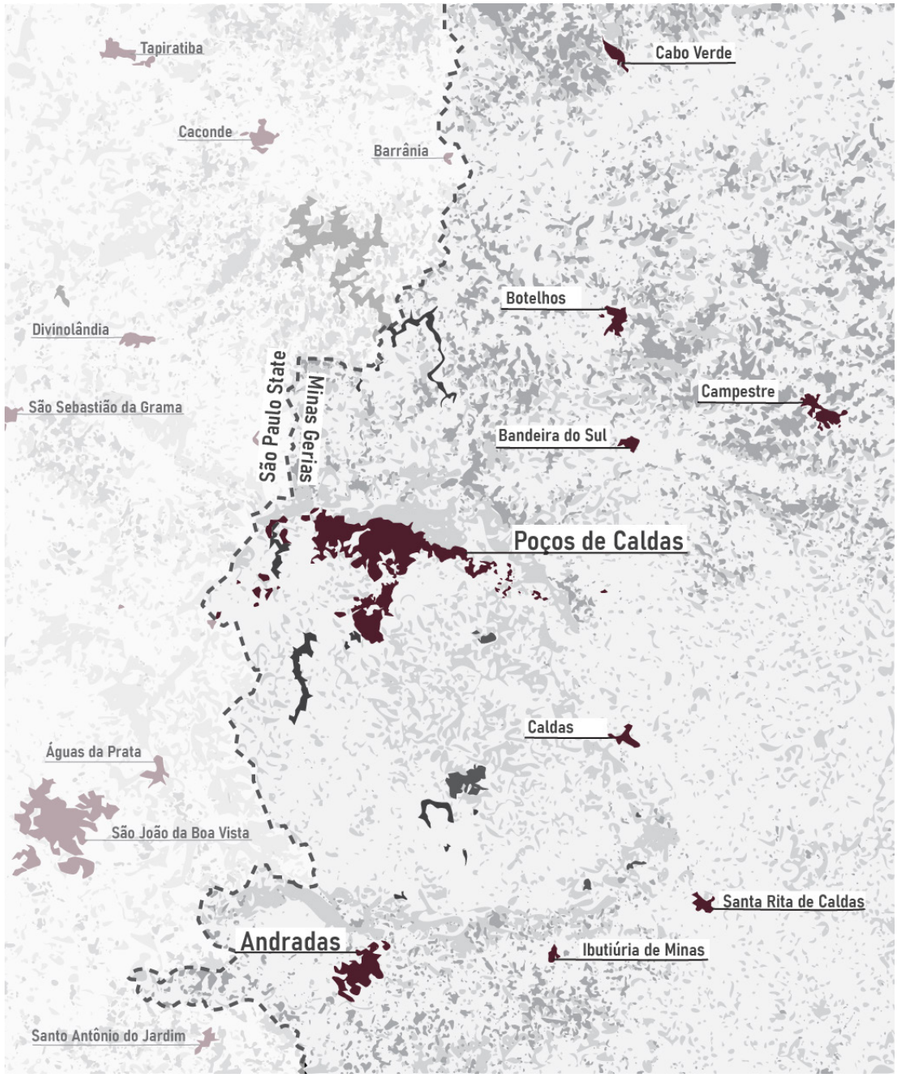
Land Cover Map of Brazil - Forested Areas
Based on data from MapBiomas Collection 7.0 (2021), accessed via QGIS plugin. Map created by the author using QGIS

Fragmented Coffee Landscapes: Urban areas

The Immediate Geographic Region of Poços de Caldas, includes eight municipalities: Andradas, Bandeira do Sul, Bothelhos, Caldas, Campestre, Ibitúra de Minas, Poços de Caldas and Santa Rita de Caldas. Poços de Caldas is the largest city, followed by Andradas.

Fieldwork was conducted around Andradas, Campestre for farmer interviews. Interviews with organisations behind coffee production, like exporters and associations were mostly in Poços de Caldas.

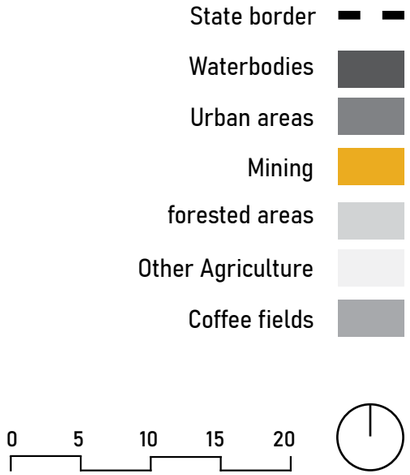


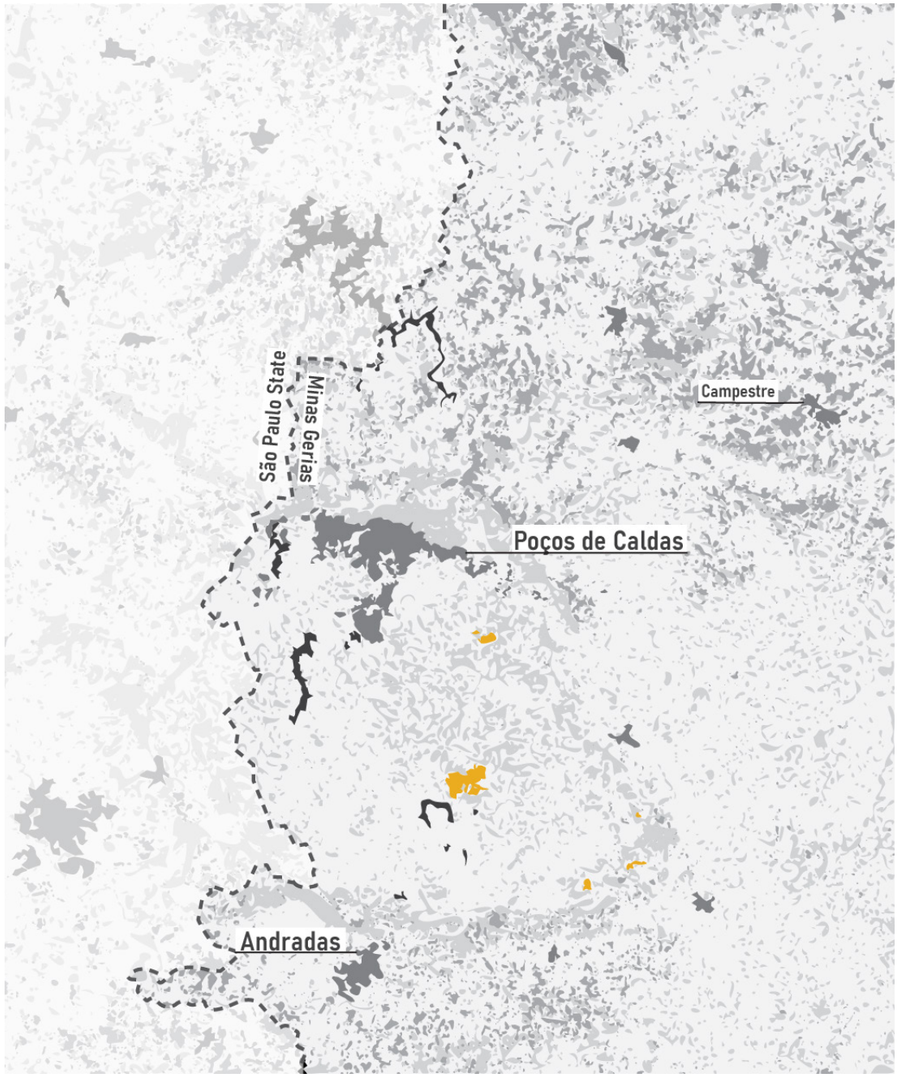


Land Cover Map of Brazil - Urban Areas
Based on data from MapBiomas Collection 7.0 (2021), accessed via QGIS plugin. Map created by the author using QGIS

Fragmented Coffee Landscapes: Mining

Mining is in important industry in the region. These mines are Bauxite mines, which is the primary resource for producing aluminium.





Land Cover Map of Brazil - Mining
Based on data from MapBiomas Collection 7.0 (2021), accessed via QGIS plugin. Map created by the author using QGIS

Fragmented Coffee Landscapes: Other Agriculture

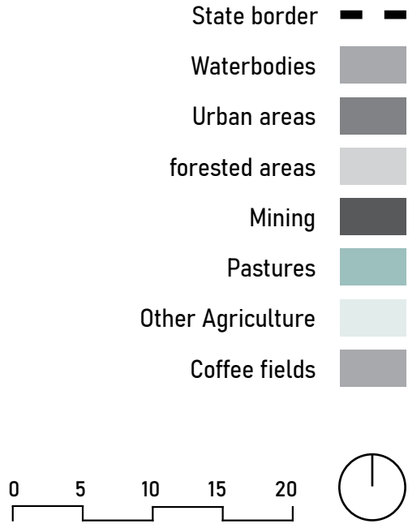
Even though landscapes in the region are highly formed by coffee agriculture, other forms of agriculture are also highly prominent, of which most prominiment pasturs.

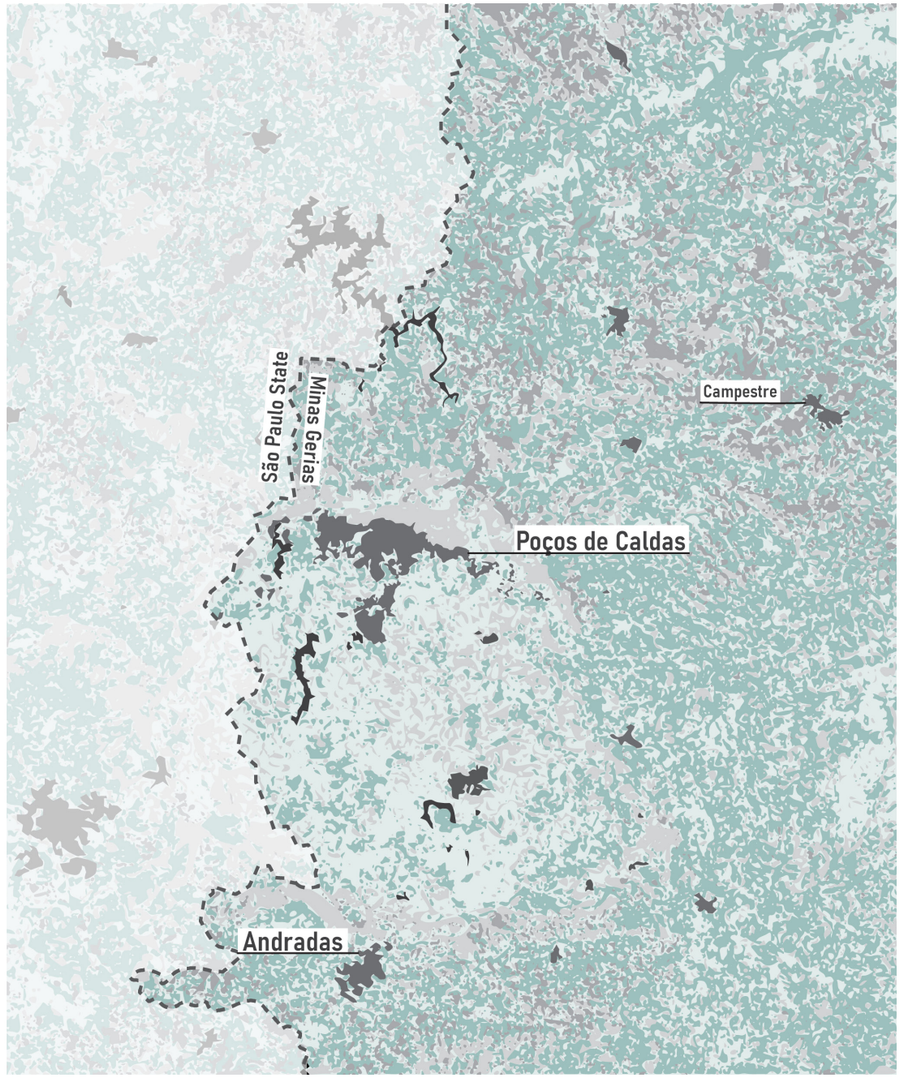
State border
Waterbodies
Urban areas
forested areas
Mining
Other Agriculture
Coffee fields

0 5 10 15 20

Land Cover Map of Brazil - Other Agriculture
Based on data from MapBiomas Collection 7.0 (2021), accessed via QGIS plugin. Map created by the author using QGIS

Fragmented Coffee Landscapes: Pastures





Land Cover Map of Brazil - Pastures
Based on data from MapBiomas Collection 7.0 (2021), accessed via QGIS plugin. Map created by the author using QGIS

Soil types

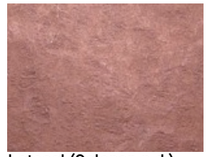
In the volcanic region, three main soil types were found, latosol (or oxisol), cambisol and argisol. Argisols are soils with high clay content, with a grayings or more commonly, bright red-orange colour. This soil is found in about twenty-four per cent of Brazil's surface. These soils are low to moderately fertile (Embrapa, n.d.)

Cambisols are solid that occur in the Southeastern region of Brazil and are developed from acidic rocks. It is characterised more by more brown-redish colours. These soils generally have a high natural fertility, although it differs per type of cambisol (Embrapa, n.d.).

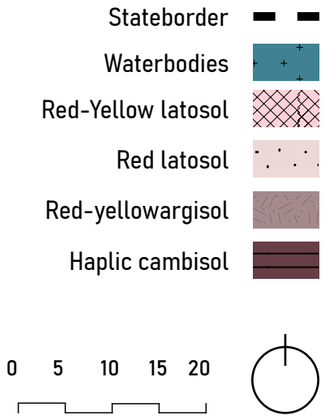
Latosols or oxisols are the most common soiltype found in Brazil. They are typical of tropical regions, with a reddish colour as well. These soils are highly developed and therefore low in fertility (Embrapa, n.d.).

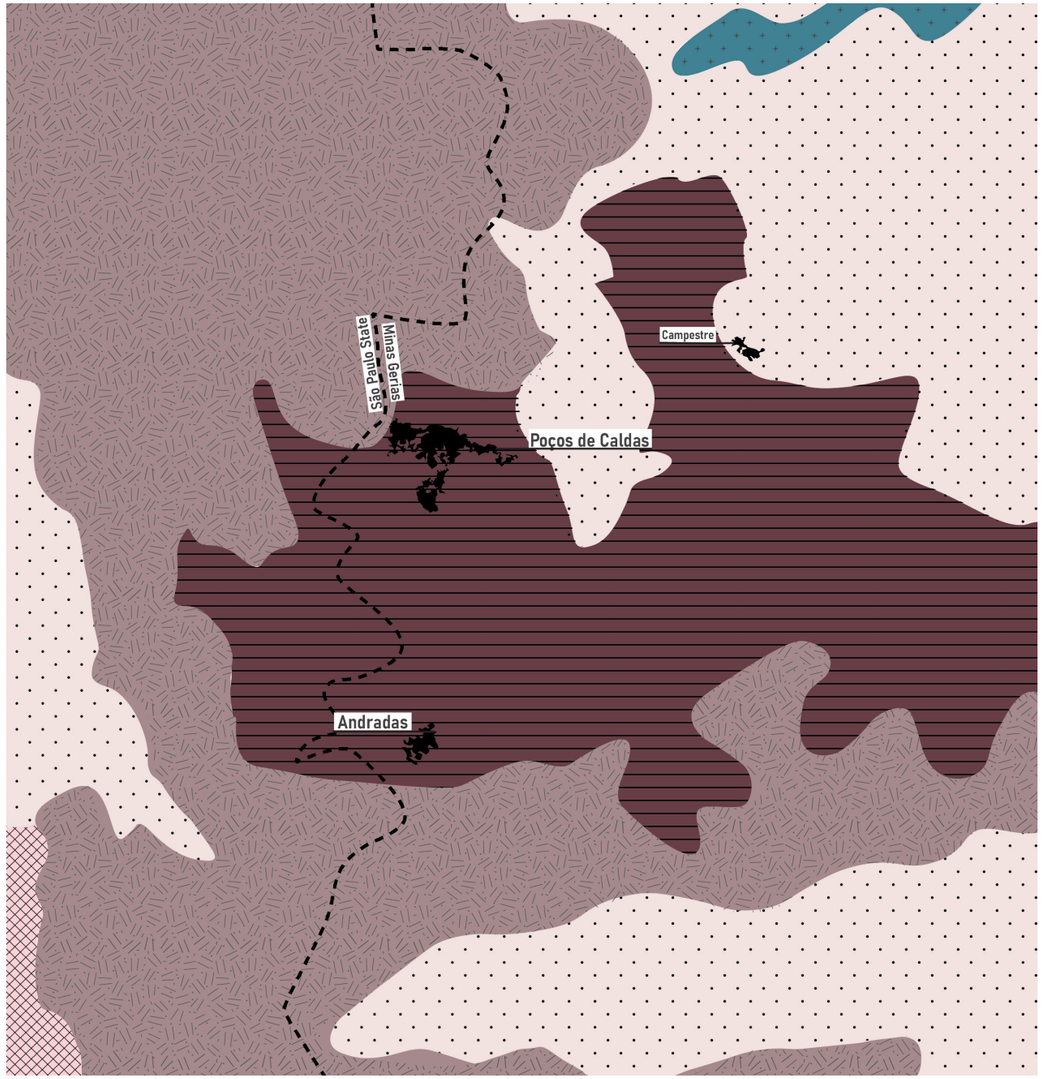
Argisol(nutrição de safras, 2024)

Haplic Cambisol (by Author)



Latosol (Celepar, n.d.)





Soil types
Based on data from (Instituto Brasileiro de Geografia e Estatística, n.d.) Accessed via ArcGIS online viewer

Environmental Challenges

The Case Study Region also faces these environmental challenges outlined previously in the problem field. All farmers in the fieldwork consistently mentioned differences in the weather patterns in the previous years. The most frequently mentioned issues were high temperatures, drought, and changed rain patterns. Situated within a rainforest biome, the region should typically experience a rainy season in the summer.

For the coffee plant, this rainy season is particularly important. It requires water at two critical stages, at flowering time and when the cherry starts to grow, both of which fall in summer. Previously, in December, January and February, there would be rainfall on most days, but nowadays these months are often dry. Besides that, unexpected rainfall occurs when the coffee needs a dry spell. For the coffee plant, this has significant consequences.

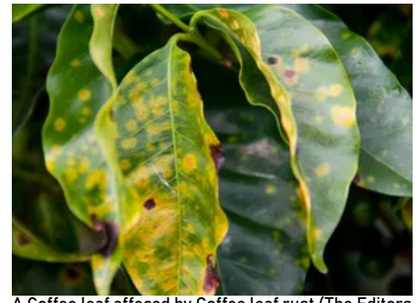
These changed rain patterns cause lower productivity in the coffee plant, sometimes with a productivity decrease of more than 10 bags per hectare per year. Additionally, beans are smaller and irregularly sized, branch growth is uneven, and sometimes plants have fruits and flowers simultaneously.
Rain patterns changed not only in frequency and timing but also in intensity. Nowadays, when it rains, showers are often short but intense. Slopes are more prone to erosion, which damages the soil by physically moving it and washing away nutrients. In addition, water infiltration in the soil becomes more difficult and the land becomes more prone to floods.

The increased temperatures, in turn, have considerable implications. Although Coffee trees need the sun, too much is not good either, contributing to lower productivity and shorter lifespan of the coffee tree. Soil quality is also significantly impacted, becoming increasingly dry and decreasing the amount of nutrients. Farmers mention that coffee has better resilience at higher altitudes and that plants on their farms' highest elevations are less affected. Climbing more, with the coffee fields, is generally not an option. Farms have often reached the top of the mountain already, or the tops are too steep and/or rocky to plant on.

Sunscreen for coffee plants on a young coffee tree (by author)

Consequences have been so drastic that a sunscreen for coffee plants has been developed, made from calcium and magnesium hydroxide (O. Costa & Revista Cultivar, 2022).

These altered weather conditions have also led to a rise in disease rates. "Broca" or coffee berry borer (Hypothenemus hampei) is a minor bug that penetrates the coffee cherry, laying eggs and feeding on the coffee seeds. Another widespread disease is coffee leaf rust, or in Portuguese, "ferrugem" (Hemileia vastatrix), A fungal disease that affects the coffee leaves and therefore the tree's health (The Editors of Encyclopaedia Britannica, 1998). Monocultural farms are a haven for disease to spread, and if nothing is done, productivity dramatically decreases. These diseases thrive in higher temperatures, climate change effects, and the monocultural cultivation methods are considerably increasing the risks of these diseases.



A Coffee leaf affeced by Coffee leaf rust (The Editors of Encyclopaedia Britannica, 1998)

Shows where the coffee berry borer entered the coffee cherry (by author)

Coffee beans affected by "Broca" or coffee berry borer (by author)

Analysis of the Region's Circularity: Environmental

CULTIVATION METHODS

Cultivation methods in Brazil, as mentioned before, are about 95 per cent sun-grown (Panhuysen & De Vries, 2023), which is also represented in this region. Generally, farms grow coffee as the only crop. On a few occasions, annual crops like beans or corn are grown as a cover crop across a fraction of the farm. Additionally, in between plots of coffee, and occasionally inside the plots, some old fruit trees provide limited shade for coffee plants and workers.

Polycultural farms exist but are not standard cultivation methods. They were not easy to find in the case study region and were not included in the interviews. There were, however, farms that experimented with adding more shade. When a coffee plant is placed in the shade, it is protected from too high temperatures and has a longer lifespan. Despite that, the size of the plant is smaller in shade, and it produces less coffee. One of the interviewees experimented with shade-grown coffee, but since productivity had declined, they determined it was better to return to conventional methods. Conclusively, when a choice has to be made between productivity with a sun-grown method or a healthier plant with shade-grown methods, productivity is the clear winner for coffee farmers.

A difference in size between coffee trees with coffee trees in the front of the picture receiving shadow from a tree outside of the image (By author)

Although coffee is the singular crop on most of the farms in the region, awareness of the importance of soil management is increasing. Farms have sometimes worked with biological material or cover cropping for years. However, farms have frequently adopted some soil management methods in the past few years. Diverse methods are applied. The first method is to use a type of biological material. This covers the soil and protects it from high temperatures. Occasionally, these mixtures include a curated set of ingredients, created for the coffee plant and its context specifically. Another standard method is applying a cover crop. This regenerative method of growing a crop between coffee trees improves soil health by protecting it from high temperatures and creating better moisture retention. It also increases biodiversity and crop yield (Cover Crops for Sustainable Crop Rotations - SARE, 2024). Some farmers choose to let natural plant growth go its way. In contrast, others prefer a preselected seed mix that can give extra value to the cover crop, like a plant that attracts pollinators or one that functions as a natural pest control for diseases that the coffee plant is susceptible to.

An example of soil managenent through biological material (By Author)

Covercropping with a pre comprised seed mixture (by Author)

EXTERNAL INPUTS

Farms in this region are still heavily reliant on inputs. Conventional farming methods, which have been used for a long time, require this input to increase. When a farm has a problem, like drought or disease, external inputs are the suggested solution. Besides that, big companies, like large-scale cooperatives, advertise a method where these inputs are advised to be used in a plan. Inputs will then be used at set intervals to prevent these problems from happening. Farmers who are heavily reliant on this external technical help will use pesticides regardless of looking at the issues happening on their farm, whether they are needed or not, degrading the soil unnecessarily.

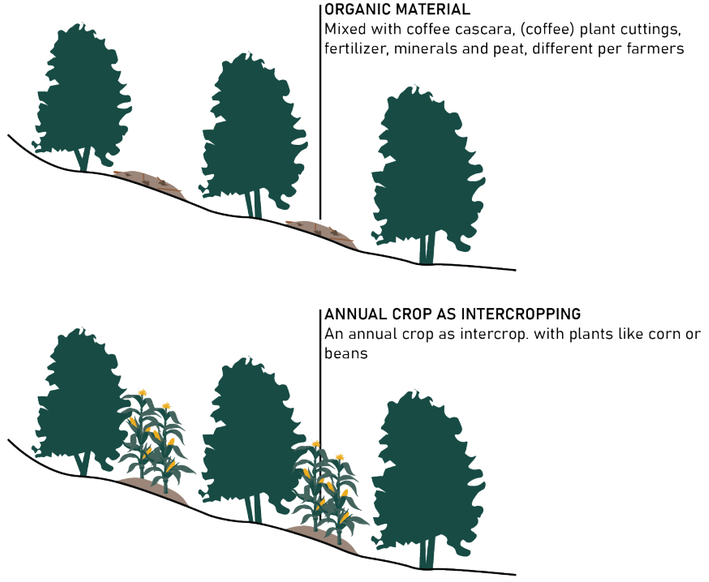
Agricultural engineers who offer this external help through big companies often follow an education funded by

companies interested in increasing outside inputs, like pesticide producers. This reveals a systemic problem in Brazil's agricultural system. Agricultural engineers go into the field with a biased view. Commonly, they do not understand how natural systems work.

With the increase in temperatures and diseases, many farmers opt to increase their inputs to deal with the issues since this is the conventional route, which offers short-term solutions to fight these pests and diseases. This further degrades the soil of its nutrients and has long-term effects on the environment.

SUPPORTING AND RESTORING

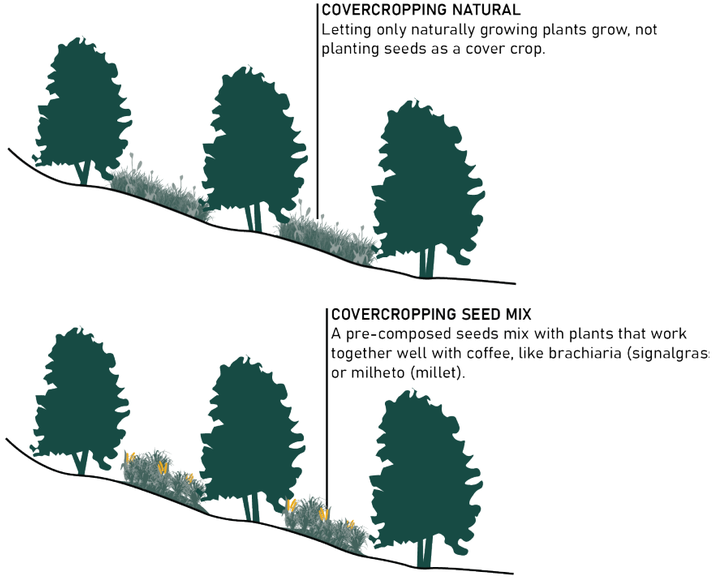
A new Brazilian law states that farms must have 20 per cent of the forest area on their property. This means farms must reforest when not up to that number (10 Years of the Brazilian Forest Code | BVRIO, 2023). Regardless, there are loopholes. Farms can obtain existing forest structures and not reforest anything (10 Years of the Brazilian Forest Code | BVRIO, 2023). There are more rules in play for the preservation of the ecological structure.



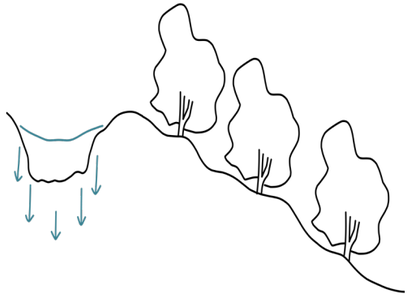
Watercourses have to be accompanied by buffers depending on the width of the waterway (Projeto da Assessoria Especial Internacional do Ministério da Justiça e Segurança Pública, 2012). Additionally, all plants have to be native to the Atlantic Rainforest, and farmers have to maintain forests on their property.

These rules have complications for farmers. The farmer must obtain the plants and plant them themselves. Some cooperatives offer the possibility of obtaining native plant species from their plant nursery, with native Atlantic forest plants. However, this is not yet at a scale where all farmers could benefit if they want. Besides that, multiple farmers stated in interviews that maintaining the forest, mainly in the first years after planting, is a hard task (F6-M3, F8-XL1). Externally, no one is aiding this maintenance, even though this is a whole new skill for farmers, which is very different from farming.

As mentioned previously, the coffeescapes of the Poços de Caldas are fragmented landscapes. The objective of ecological connectivity is lacking from policies and regulations, and therefore is not commonly a goal for farmers either.



Caçimba water chatchment system (by Author)



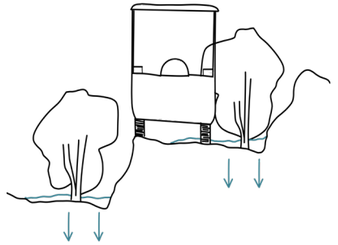
Caçimba water chatchment sysmem in section (by Author)

WATER

Currently, water is not heavily used in the coffee farming process in the case study region. Irrigation systems are not widely used in the case study region. None of the farms included in the field work use irrigation and depend on natural precipitation patterns. Occasionally, farms irrigate manually in periods of drought. Most farms are not interested in applying a systematic irrigation system; however, when interviewing farmers about possible measures they would take if the effects of climate change worsened, some farmers considered applying an irrigation system in the future.

While little to no water is used in the farming and harvesting steps, the processing steps require some water. Sorting machines use water after drying. In Brazil and in the case study region, the natural drying method is most common for processing coffee. However, occasional farms use the washed method. Besides that, water is also used to to dilutistribute inputs like pesticides.

The water sources are generally found on or close to farms. Farms use water from mountain streams and ancient water mines and wells, from which pipes have been laid towards the farm. These mines are likely caused by cracks and creases in the rocky mountainous terrain, forming springs at natural pressure points when the water exits and enters the surface layer. Usually, farms and surrounding communities that also use the source have to receive permits from the government to use this type of source. As mentioned, erosion and drought are common challenges, and there is a solution that some farmers use (F4-L1, F7-S2, F10-XL2). A “caçimba” or “bucket” is a hole dug at high elevations of a farm on the edge of a



Terracing system in section (by Author)

Terracing system(by Author)

coffee plot. These excavations catch rainwater at the top of the farms, preventing it from streaming down rapidly and causing erosion. Besides that, it allows for a slower and easier infiltration into the soil, increasing humidity, and improving the overall quality.

Another method currently applied is creating terracing in the soil (F10-XL2, F12-L3), mostly to create easier work environments. However, some farmers suggested that when building the terracing at a slight angle, water runs down more slowly and is stopped at every step, allowing for a slightly slower infiltration and decreasing the erosion risk.

Water infiltration systems can be effective for improving soil moisture and reducing runoff and risk of erosion, but their widespread use must be carefully balanced across the larger watersystem. If farms in upstream areas adopt these methods without limits, they may unintentionally reduce the flow of water to downstream regions, worsening water scarcity and drought conditions. To prevent such imbalances, clear regulations must be established, ensuring equitable access and long-term sustainability for all users in the local basin.

BIOLOGICAL MATERIALS

By-products of the farming process By-products of the farming process include cuttings from pruning the coffee tree and other trees on the farm. These by-products are reused on the farms, mixed with biological material. When these cuttings are cut into small pieces, they have the highest value, since nutrients can more easily access the soil; however, this is usually not always done. The cuttings are also used to produce energy for a machine that is used to dry the coffee cherries.

The same happens for the by-product of the coffee cherry, often called “cascara”. The coffee cherries are rich in potassium and antioxidants that can help the soil like a natural fertiliser (Iriondo-DeHond et al., 2020). Almost all farmers interviewed used the cascara and wood cuttings to fertilise the soil. However, nutrients from only coffee by-products are not enough to fertilise the soil thoroughly. Other plant by-products should also be added for complete nutrition (AE1).

TECHNICAL MATERIALS

Non-biological by-products on the farm include packaging from pesticide and fertiliser inputs. Pesticide packaging is required by law to be picked up from the producer by the producer or distributor of the pesticide. Cooperatives and sellers set up programs to pick up this packaging from the producer. For

Machine to produce energy from cascara and cuttings (by author)

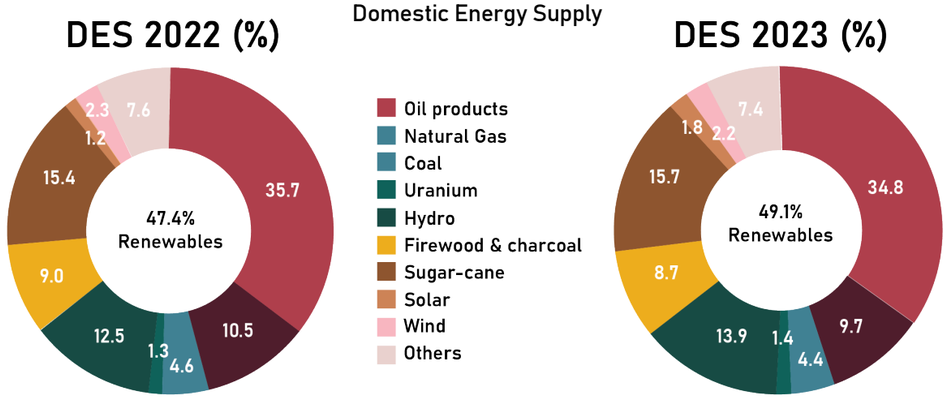
Coffee drying machine (by Author)

fertiliser packaging, similar programs depend on the municipality. Where this program does not exist, these packagings end up in a “ferro velho”, where waste and by-products are sold, and bought by people who are usually unemployed or not formally employed by the centres. Their scraps get sorted and sold to various parties, often recycling centres that further process the by-products.

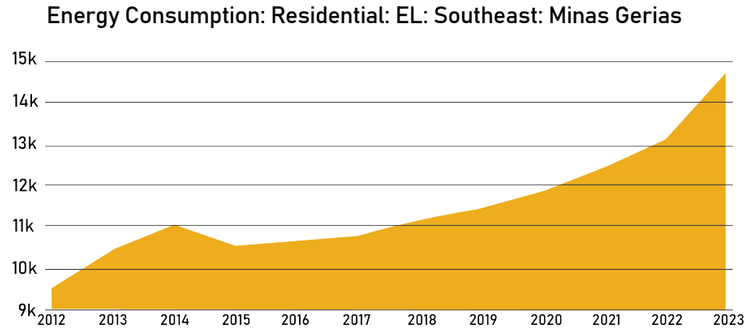
ENERGY

Brazil runs on a relatively renewable mix of energy carriers and sources. Due to its geographical landscape, in other words, its many rivers and potential energy, a large source is hydropower. By itself, it represents 13.9 per cent of the total energy production in Brazil in 2023 (Ministério de Minas e Energia & Brazilian government, 2023). Sugar-cane (15.7 per cent) and firewood (8.7 per cent) are the two major contributors of renewable energy, next to the aforementioned hydropower.

The residential energy consumption of Minas Gerais is reported to be 14679 GWh (14.7 TWh) in 2023 (CEICdata.com, 2025). Seeing the trend of increased consumption, it will very likely be even higher today. To put this into perspective, the region would consume on average 40 GWh per day. Minas Gerais itself has the Furnas Dam, located on the Grande River. The dam has an installed capacity of 1216 MW. If we compare the residential consumption to the highest potential of the Furnas Dam, then it would have to run



Domestic Energy Supply Brazil (Ministério de Minas e Energia & Brazilian government, 2023)



Energy consumption in Minas Gerais (Ministério de Minas e Energia & Brazilian government, 2023)

for 33.12 hours to meet the daily demand.
According to ANEEL, the Brazilian power sector regulator, 2023 would be the year they add 1.8GW of solar PV in Minas Gerais alone Williams (2023)(Brazil Forecasts 10 GW of New Installed Capacity in 2023, 90% From Renewables, 2023). This would have blown the production of the dam out of the water in one year. This highlights the very volatile development of energy projects, and by 2025, this data may be outdated again.

ENVIRONMENTAL CONCLUSION

There is no question that climate change is hitting the region and its coffee cultivation. While some solutions might offer some adaptation to the effects, a strategy to both adapt and mitigate the systemic environmental challenges based on coffee cultivation methods, dependency on outside inputs, and the policies and regulations that are supposed to deal with these issues is needed.

Analysis of the Region's Circularity: Economic

As mentioned earlier, the Brazilian system is an industrialised system that produces the most coffee in the world. Generally, there is a high focus on efficiency and quantity. It is driven by the market and the capitalistic system that we live in, and in these systems, productivity, prosperity and market integration are undeniably important.

Due to the sensitive nature of the information, farmers and other stakeholders were not asked about their income during interviews. Therefore, some assumptions will be made based on national results.

CURRENT INCOME

Due to the sensitive nature of the information, farmers and other stakeholders were not asked about their income during interviews. Therefore, previous results about income will be assumed to count for the region as well.

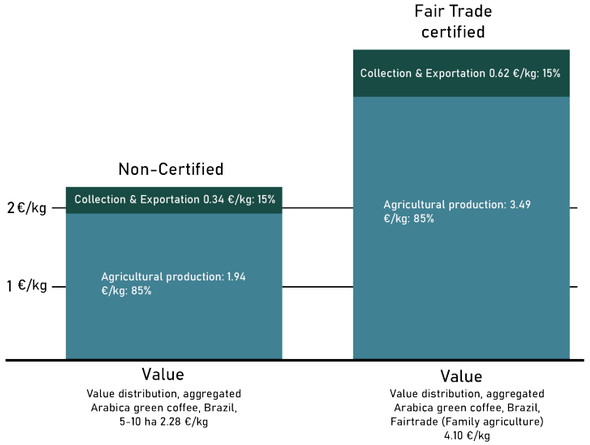
During fieldwork, multiple programs were encountered that would give premiums to coffee for speciality coffee grades or sustainability. Incomes might be slightly higher due to the region being a speciality coffee region, for which farmers sometimes get a premium added on top of the usual price. Therefore, since the region is focused on good quality coffee, farmers might have a slightly higher income than in other areas.

DIVERSIFYING

As mentioned, few farmers grow other crops, mainly for financial reasons. Intercropping or agroforestry systems would not be "worth it" for farmers since the productivity of the coffee plant would be lower.
During the fieldwork, farmers suggested that focusing on multiple crops would not be feasible, especially for smaller farms, due to a lack of resources, labour, and knowledge capacity.

Few farms had annual crops, but not for financial reasons. Crops were for self-consumption or consumption by cattle or neighbours. Although the production might not be for commercial selling, it might relieve the costs for farms for buying food and resources. Therefore, there might be some financial benefits.
Mid-size and larger farms generally had a processing location on their farm property. This was a concrete drying location since the natural processing method is most common in Brazil and in the case study region. Most farms that had this drying facility also had machines accompanying this step on the value chain, a drying machine,

a depulping machine, and at times, sorting machines. Farmers mentioned that selling their coffee without being processed would not be profitable enough. These farms would often help smaller neighbouring farms process this coffee for a price. Having these facilities on the farm adds much value for the farmers.
At times, medium farms owned a coffee roaster. They would roast only a small part themselves and still send most of the coffee to cooperatives and exporters. The bigger the farm, the more functions were part of their business. One farm roasted 80 per cent of its own coffee and has a café location as well, taking up more steps in the value chain.



Value Distribution (Moda et al., 2024)

INTEGRATION INTO THE VALUE CHAIN

Marketability of coffee is crucial. Their production value is determined by the ability to enter the market at a secure position and generate satisfactory returns. The current market is focused on quality and quantity, but not sustainability. While there is a suggestion of a growing demand and awareness around sustainable coffee production, the market demand does not match. Production of “sustainable coffee” seems to be higher than the demand (Moda et al., 2024). Evidence from the stakeholder interviews suggests that. When farms have tried to adapt to organic coffee growing, the coffee was not sold and stayed behind in storage for an irregular amount of time. Due to these practices, farms revert to more conventional methods, highlighting the significance of coffee’s marketability. Moreover, this also affects the premium pricing of these coffees, which decreases as a result. So, even though these certifications do offer a premium, the system is not as simple as it may appear. These batches of premium coffee end up being mixed with less sustainable coffee, resulting in returns that do not outweigh the cons (Moda et al., 2024).

What farmers do focus on is quality. As mentioned before, the region is focused on specialty coffee. Therefore, creating coffee with a grade above 80 points is important to farmers, since they might receive a premium price. Also, some sustainability programs from cooperatives or offer a premium for more sustainable coffee, but these programs are not yet scaled, and farmers suggest prices are not much higher. Often, these sustainability programs do not motivate farmers to increase their sustainable practices; they are already at the sustainability standard of a program before they join these programs.

An observation in marketing has been that both large farms and cooperatives use sustainable farming methods as a marketing tool and portray themselves as smallholder or family farms. However, this is not consistent with reality. They show only part of reality, like the part of the farm where they are reforesting, but not the large monocultural fields of coffee. This suggests that consumers care about this production method; however, it is hard to check whether these marketing strategies are trustworthy.

Many farmers in the case study region depend on cooperatives for market integration. Only one farm did not sell its coffee to a big cooperative, but was still connected for other benefits. The smaller the farm, the more reliant on cooperatives farms were. Farms can therefore depend on these actors for their income, especially in regions where they are the main exporting stakeholder. In the case study region, the most collaborated with cooperative is Cooxupé, which is also the largest coffee cooperative in the world.

This strong reliance on cooperatives, particularly Cooxupé, underscores their central role in facilitating market access and income generation for coffee producers in the region. However, such dependence, especially when concentrated around a single dominant cooperative, raises concerns about the potential of monopsony power. In a monopsony, where one buyer controls the market, farmers may face limited bargaining power over prices and conditions of a sale (Zavala & Princeton University and The World Bank, 2024). While cooperatives like Cooxupé offer support services and market connectivity, their dominant position within coffee economies highlights the need to examine market asymmetries, which are causing a lower price for farmers, so they can profit.

SELF SUFFICIENCY

Reliance on external outputs is very present and also costly for farmers. The bigger farms got, generally the more conventional methods were applied and the more organised the appearance of farms was. Even though field research did not give precise

results on the amounts of pesticide and fertiliser used, this suggests a higher application of external inputs. Large farms are more frequently stated to apply more external inputs as the effects of climate change rise. In the case study region, this was not different.

Dissimilarly, bigger farms had some small-scale circular projects, catching rainwater and producing solar energy. This projects were small and not yet at the scale where the actual inputs of the farm are covered, but it shows an awareness and slightly lower reliance on external networks.

PRODUCTIVITY

Productivity is one of the main factors that producers focus on. Farmers are always looking to increase their productivity. If measures decrease productivity, they will not be maintained and will return to conventional farming methods that have proven to be productive. This productivity is what farms rely on for their income; the more you produce, the more you can sell. Since coffee prices are not currently high, especially when there is no premium through certification or sustainability programs, these farmers rely on productivity for their income.

ECONOMIC CONCLUSION

This case demonstrates that in Brazil's coffee sector, including in the case study region, economic priorities remain central for both producers and cooperatives. Although specialty coffee presents opportunities for market differentiation, it does not represent the complete farmers' production, and the price premiums, whether for quality or sustainability, are often insufficient to compensate for the costs and risks involved. Most farmers continue to rely on maximising yields per hectare to secure a viable income, given persistently low prices. Although sustainability certifications can offer small price premiums, many farmers say these rewards are not enough to make up for the extra effort and costs, especially since the market demand for sustainable or organic coffee is still limited.

This highlights a challenge: without an economic incentive, producers find the barrier to a just transition too high. To make sustainability a realistic pathway for farmers, market structures must improve to reward environmental and social innovation, alongside productivity and quality.

Analysis of the Region's Circularity: Social

KNOWLEDGE ACCESSIBILITY

Farmers generally had good access to courses through cooperatives, mostly external cooperatives and associations. As mentioned, these were often focused on technologies and mechanisation and, at times, non-farming-related coffee knowledge.
Some farmers mentioned courses about cultivation methods and transitioning to more sustainable practices, but less frequently (F7-S2). The most frequently mentioned topic was soil management, as this was an upcoming method in the region.

There was no notable difference in the region in the availability of courses, when comparing the different farmer types. However, there was a notable difference in the willingness to follow courses. Smaller and mid-scale farms were inclined to follow courses more, while larger farms (F8-XL1) were aware of their existence but did not intend to follow a course.
One of the main programs mentioned was SENAR, an organisation that collaborates with the CNA, the federation of agriculture in Brazil (Brazilian farmers, 2023). They help turn policies into practice, focusing on technology.

PERMANENT OR SEASONAL WORK

A mixture of seasonal and permanent work is used throughout the region. Many farms have a permanent hire throughout the year (e.g. F7-S3, F8–XL1, F10-XL2), but a lot also hire seasonal help during the harvesting season. Finding locals for this seasonal work is a challenge, due to a large labour shortage, according to a lot of farmers, they hire people who come from the North of Minas Gerais (F3-XS1, F7-S2, F4-L1, F10-XL2).

A system that some farmers used helped: a sharecropping system, where farmers give away a share of their profit to the employees. When asked about labour shortage, these farms (F9-L2, F12-L3) had no issue finding labour. For the employees, this system seems to be more profitable and gives them a fairer distribution of the profit. These farmers, however, did not seem to be completely dependent on their coffee farms for an income; these people might have a higher capacity and more profit to give away. While some smaller farmers, with lower income, cannot give away half their profit to an employee.

FORMAL OR INFORMAL WORK

The formality of work agreements often depends heavily on the type of work and whether it is permanent or seasonal. During the fieldwork, the sensitive nature of the information did not allow asking whether agreements with employees are formal or informal. In family farms, which are very common in the case study region, it can be assumed that many of the contracts are not formal.

COMMUNITY

Having extra help from the community could help, but mainly during the harvesting season. However, since many people produce coffee in these communities, they all harvest it at the same time, and this community is working on their harvest (F5-M2).

Shadecover through trees for breaktime (by author)

Undeniably, many external inputs, like pesticides and fertilisers, were used. These affect soil and water quality, which has health consequences for surrounding communities, also in the case study region. Since larger producers use more conventional methods, these communities are more affected.

WORKING CONDITIONS

Since the fieldwork was not Since the fieldwork was not conducted during harvesting season, the workers' conditions were not very well visible. Some conditions were slightly visible. Since farms are sun-grown, workers often work in the full sun. Some farms had bigger trees once in a while, or, at times, shade cover constructions for taking breaks (F4-L1, F10-XL2).

For harvesting conditions, the new terracing technique mentioned before was also an upcoming trend. Farmers mentioned that it was not only good for some water retention, and efficiency, but also for easing the harvesting methods. (F12-L3) It makes the terrain more even, with less obstruction making the conditions better for the harvest workers.

Shadecover for breaktime (by author)

Agrochemical input distribution is sometimes done by drone, taking out human labour and danger (F4-L1). Regardless, very few fields had clear signs of whether plants had been recently sprayed. Entering a field that was just sprayed with chemicals could be toxic. In a new certification, Certifica Minas, rules were made for permission to enter the property after spraying these inputs. Farms with this latest certification did have this signing, in compliance with the certification (F7-S2).

Accommodation conditions, likewise, were not visible. However, bad working conditions are still happening, even in neighbouring municipalities like Machado (Ministério do Trabalho e Emprego, 2024). So, it is impossible to conclude that farms in this region do not have bad working conditions; it cannot be ruled out.

INEQUALITIES

An apparent underrepresentation of female owners is visible in the case study region. Although many of the people interviewed were female, often the farms were still owned by their fathers. It was not clear if they were the ones inheriting the farms from their fathers; however, they were actively working in the business (F4-L1, F9-L2). Ultimately, a quarter of the farms visited were owned by women. One farmer (F12-L3) had participated in a program set up for female owners, making coffee only from female-owned properties.

Since the fieldwork was not conducted during harvesting season, other conditions were not identified and inequalities that happened during that time of the year were not visible.

GOVERNMENTAL SUPPORT AND POWER

Subsidies or funding were not commonly mentioned during the fieldwork. Subsidies, where farms get money to invest without paying anything back, were not mentioned once.

Interviewees did mention funds to buy machinery, technology or inputs (F2-M1, F3-XS1, F4-L1). These, however, were loans and had to be paid back. There was no indication for support for sustainability or circularity programs.

In terms of governance and policy, farmers appeared to be largely disconnected from participatory decision-making processes, municipal, regional, or national. There was no indication that they were actively involved in influencing agricultural policies or strategies.

TRANSPARENCY

Transparency is not easily visible, but what is clear is that farms in the region are very dependent on cooperatives and exporters. Every farm, from small to large farms (only excluding XL farms) sells coffee through these stakeholders, and is dependent on them for reprocessing and warehousing. Direct-trade collaborations, where farmers are directly in contact with roasters, often on another continent, are not common.

Lots of coffee ends up getting mixed at a cooperative or exporter. Even though these actors may have a good logistical, traceable system before mixing, this does not mean that information about the origin is brought to the customer (C1). Even though exporters are already a middleman, they are still dependent on others too. They buy their coffees directly at the farm, but also through other traders (E1). Through these extra steps and trough the mixing process, information gets lost and untraceable.

SOCIAL CONCLUSION

This analysis highlights the social challenges that farmers face in the case study region. The labour conditions can be dangerous due to a lack of systematic protection against agrochemicals and bad working conditions, including a lack of basic accommodation. For the transition to a circular production system, small and medium-sized farms have to be proactive and overcome obstacles like the lack of external support or uninclusive governance. Overall, these issues show a need to strengthen the capacity of farmers through more accessible resources and inclusive governance that promotes circular practices rather than conventional ones.

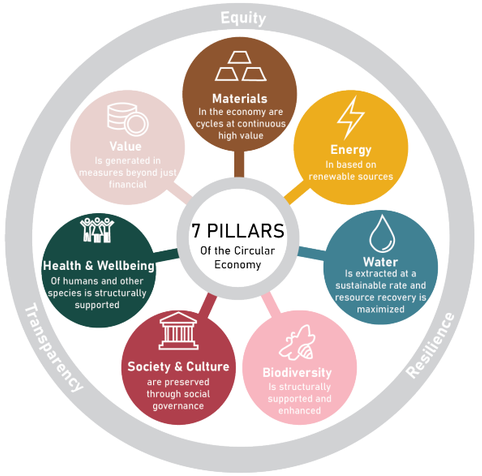
Multi-Criteria Analysis

This multi-criteria analysis gives insight into the diversity of coffee farms in Brazil. It focuses on the differences for a broad circular spectrum, including all of Metabolic's seven pillars of circular economy (2017), including the values of transparency, equity, and resilience, and is adapted to fit the current coffee industry and its challenges.

The criteria are set up as indicators to assess the status quo of circularity within coffee farms and are divided into three main topics: environmental, economic, and social. Weighings define the necessity for these topics within the transition towards a circular future, also taking into account the farmers' perspective through interview results.

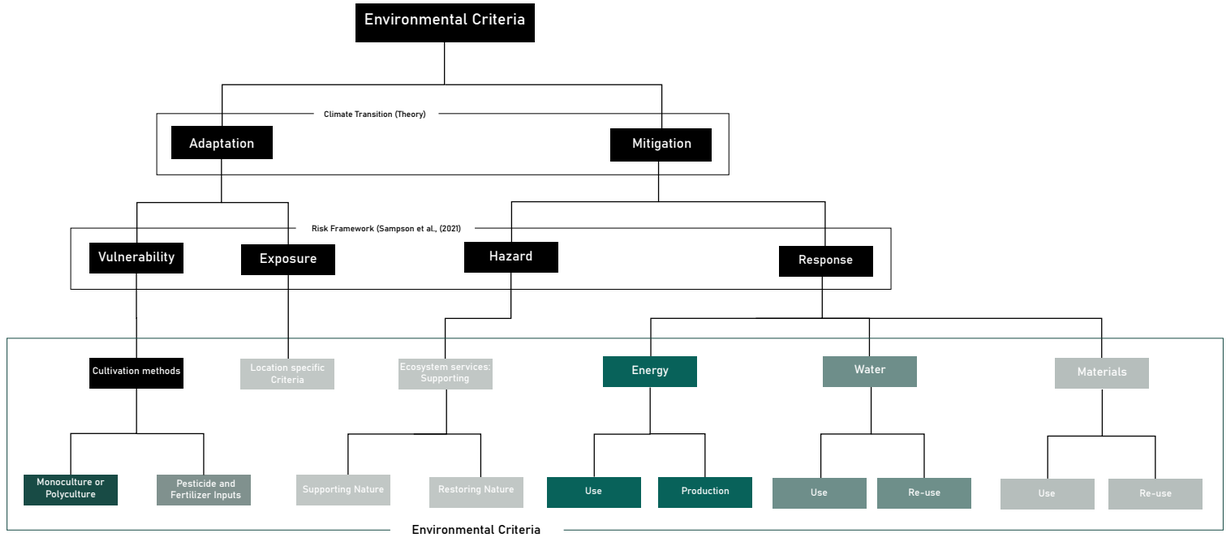
The indicators are evaluated through both a literature review and interview results. Because literature reflects on a wider area, often a national-level area, while interview data is only present for the case study region, the multi-criteria analysis is focused on the farm archetypes in the case study region. Consequently, some criteria are described nationally, assuming these findings represent the case study area.

The analysis will start by explaining the criteria's definition and weighting, after which results per topic will be filled in.



The seven pillars of circular economy (Metabolic, 2017)

Criteria: Environmental

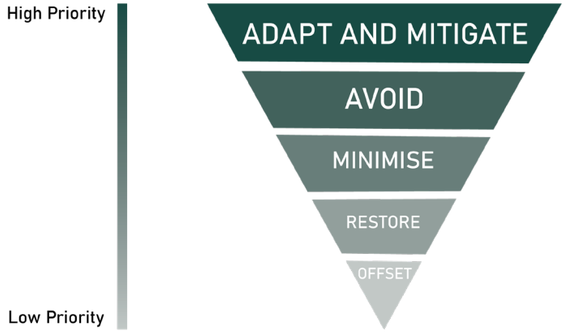


CRITERIA

The environmental criteria of the multi-criteria analysis are based on the theory of mitigation and adaptation of the effects of climate change. The impact of climate change is already felt by coffee farmers throughout Brazil, for example, through high temperatures affecting the coffee plant. Adapting to the effects of climate change can be done by reducing the sensitivity or the exposure to a climate hazard to the coffee system. The vulnerability and, as such, the sensitivity of the coffee production lies with cultivation methods. Using a sun-grown, monocultural method and applying pesticides and fertilisers as inputs make the system susceptible to high temperatures and diseases and decrease soil health. This, in turn, increases the sensitivity of the plant. Exposure to these effects is also caused by the context of a coffee farm when farms are located in lower elevations, in areas further away from buffering ecosystems, or in a location often hit by extreme weather events, the exposure to a climate hazard increases.

Though adaptation is essential, mitigation of the causes of climate change is also necessary. The chance that climate hazards can decrease lies in supporting the foundational systems of ecosystems. Systems like soil formation, nutrient cycling, biodiversity, and water cycle regulation are essential to ecosystems' existence. Therefore, these cycles should be supported and restored as much as possible.

The response pillar added by Simpson et al. in 2021 accounts for the human response to climate risk. In these criteria, the three physical flows of the seven circular pillars by Metabolic (2017) are water, energy, and material, representing the material flows created by human activity. The current use of these flows will determine the dependency and impact currently made on the environment, and kn owing the current re-use practices of these flows is essential in determining the level of physical circular practices used by producers.



Mitigation hierarchy adapated from (Nordic Council of Ministers et al., 2023)

WEIGHING

The weighting of the environmental The weighing of the environmental criteria in this analysis is grounded in the theory of the mitigation hierarchy, adapted to reflect the specific environmental challenges of the Brazilian coffee industry. Traditionally, the hierarchy follows a sequence of actions ranked from most to least desirable: avoid, minimise, restore, and offset. This framework emphasises that preventative measures should be prioritised, as they tend to have more lasting and cost-effective impacts compared to reactive strategies (Nordic Council of Ministers et al., 2023).

However, in the context of climate change and the Brazilian coffee sector, an additional pillar has been integrated into the hierarchy: measures that contribute to both mitigation and adaptation. These synergetic strategies are prioritised, as they offer integrative solutions that address current vulnerabilities and long-term sustainability.

Accordingly, mitigation and adaptation are placed at the top of the hierarchy. They represent innovative and integrative responses to climate change, delivering both immediate and enduring benefits. Following this, avoidance is given high priority, based on the principle that preventing environmental harm is more effective than reversing it later.

An example of this in the coffee system is the reliance on external chemical inputs such as fertilisers and pesticides. Avoiding their use would drastically reduce negative impacts on soil health, biodiversity, and surrounding ecosystems. Similarly, water use practices, such as minimising irrigation through

rainwater harvesting or enhancing soil infiltration, can reduce pressure on local water systems, which are critical to the ecosystem and climate resilience.

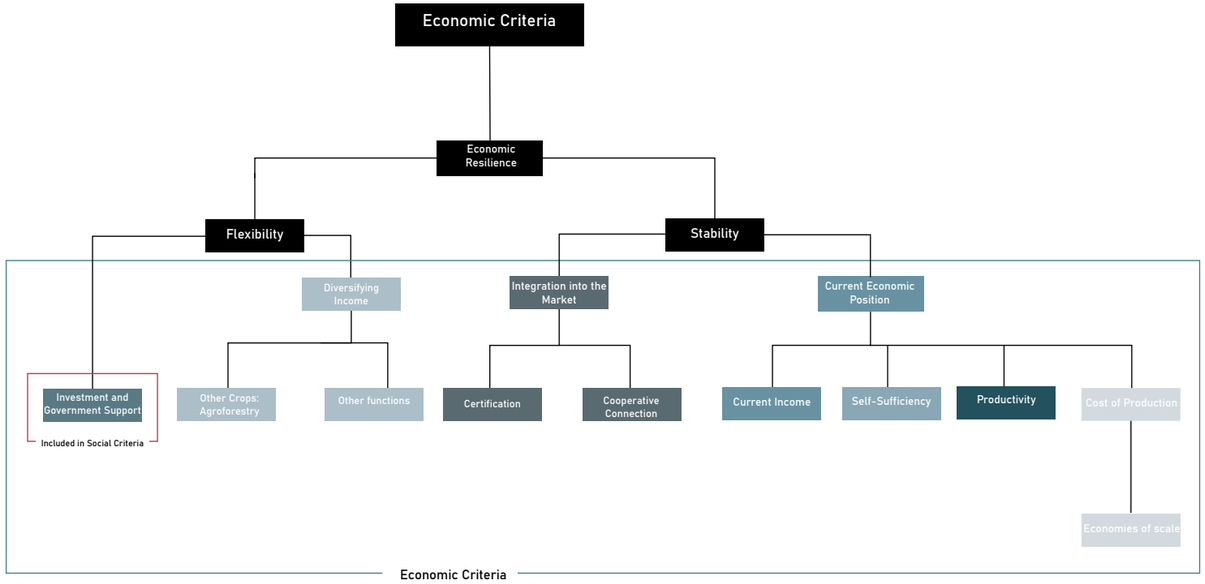
The next tier in the hierarchy is minimisation, which becomes necessary when complete avoidance is not feasible. This is particularly relevant for energy use in coffee production. While eliminating energy use entirely is unrealistic, minimising consumption through energy-efficient technologies and shifting to renewable energy sources can significantly reduce environmental impacts. Where residual emissions remain, offsetting renewable technologies should be considered as a complementary strategy.

In the traditional mitigation hierarchy, restoration follows minimisation. However, in this adapted model, restoration of the ecosystem is given elevated importance due to the Brazilian context, especially in ecologically sensitive areas such as the Atlantic Forest biome, where extensive degradation and fragmentation are a big issue. Restoring these ecosystems not only helps adapt against the effects of climate change but also strengthens mitigation capacity by improving ecosystem services that support and protect the ecosystem.

Lastly, materials such as the packaging of agricultural inputs are addressed. While complete avoidance may not be feasible in the short term, especially given current production systems, efforts to reduce and manage material use are essential. The restoration of material flows, for instance, through reuse or recycling, can significantly reduce waste and environmental impact, making it an important step above offsetting in the environmental multi-criteria analysis.

Criterion	Weighing (1-5)	Multiplier
Monoculture or Polyculture	5	1.5
Ecosystem services: Supporting and restoring	5	1.5
Pesticide and Fertilizer Inputs	4	1.4
Water	4	1.4
Energy	3	1.3
Materials	2	1.2

Criteria: Economic



CRITERIA

Though the economy is not one of the main pillars in this project, it is interlinked with social and environmental topics and could, therefore, not be left out of the criteria. Economic resilience is the basis of these criteria, covering the past and future.

Economic resilience is divided into two sub-pillars, stability and flexibility. Resilience in farming systems means that farms need the ability and the capacity to keep doing what they are supposed to do (Capoani et al., 2025). In this case, that is coffee production. However, that is not the only thing. Providing for the livelihoods and communities surrounding these coffee production systems is just as important. Economic resilience includes stability. Stability means having the ability to deal with shocks and stresses in the short term, like being able to keep the current function of the farm if the market changes or a crisis hits. A good current

economic position is an important factor, including income, productivity, and production costs. Extra stability in the cost of production can be caused by effects like economies of scale, such as when farms can buy in bigger quantities and therefore get a price reduction. Besides, self-sufficiency can cause a more stable income through a lower dependency on external inputs and systems.

Besides the current economic position, good market integration is essential. High productivity will not mean anything if a product cannot reach the market. Marketability can improve through connection to a cooperative or certification.

Flexibility means adapting to changes in the long term, and being able to transform when a system needs changing (Capoani et al., 2025). This could be done through investing in new technologies and methods, or altering a cultivation method whenever the effects of climate change are shown. Flexibility is therefore also linked to the current income and the capacity to save and invest. Additionally, farmers can build their flexibility by diversifying their income streams through growing other crops or having extra functions on the farm, like extra steps in the coffee value chain or functions that serve the community.

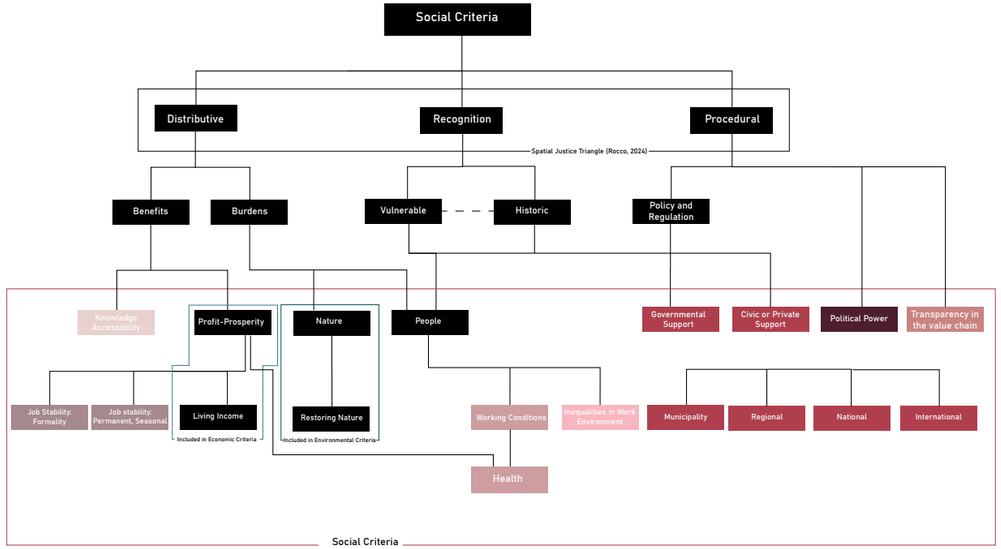
WEIGHING

Criterion	Weighing (1-5)	Multiplier
Integration into the Market	5	1.5
Productivity	4	1.4
Diversifying Income	4	1.4
Self-Sufficiency	4	1.4
Current Income	3	1.3
Cost of Production	2	1.2

The economic criteria are weighted based on their critical importance to enabling the transition to a circular economy.
The highest-scoring criterion is market integration, which includes reliance on cooperatives and certifications that enhance product marketability. This aspect is crucial: even if farmers are willing to adopt sustainable practices, the transition cannot succeed without a viable market for their products. Farmers must earn a living wage from their production. One example observed during fieldwork illustrates this clearly: a farmer piloted organic coffee production, but due to a lack of market demand, the coffee did not sell. As a result, the farmer returned to conventional farming methods (F10-XL2).
Productivity is also heavily weighted, as it was identified as a key driver or barrier to change. For farmers, productivity directly impacts income. If transitioning to more sustainable methods results in lower productivity, farmers are less likely to make that change (F2-M1). Diversification and self-sufficiency are important economic advantages of circular farming, as they provide stability and resilience.

A farmer's current income serves as a baseline of their capacity to invest in change. If the income is too low, investment becomes impossible. While the cost of production is a relevant factor in improving income, it is not the sole concern. If higher production costs lead to more stable and consistent outputs, this can justify the additional expense.

Criteria: Social



CRITERIA

The social criteria are derived from the spatial justice triangle (Rocco, 2024), as outlined in the conceptual framework chapter. Under the pillar of distributive justice, these criteria evaluate whether the benefits and burdens within the coffee system are shared equitably. Benefits include fair access to knowledge about new technologies, equitable distribution of profits across archetypes, and a balanced share along the value chain. Alongside benefits, the assessment also considers burdens. For example, whether certain archetypes disproportionately impact the natural environment, potentially harming ecosystems and unfairly affecting others. Finally, the analysis examines social inequalities within and across archetypes, such as inadequate working conditions or other forms of systemic disparity in the work environment.

Recognition justice focuses on potential inequalities within the workplace; it assesses whether certain groups within the archetypes face particular vulnerabilities, whether due to historical marginalisation or systemic challenges.

Ultimately, the procedural justice pillar addresses whether decisions in governance systems are being made fairly. The first thing to consider is to what extent governmental, civic and private support is justly divided over the archetypes. However, linked to recognitional justice, justness does not necessarily mean equality; vulnerable groups might need more support to have the capacity to deal with the challenges they face.

The level of power held by each archetype can also vary significantly. This analysis will assess whether groups are adequately represented in participatory processes within governments or companies, or if monopsonies among exporters disempower them. The final, yet crucial, criterion is transparency. An assessment will conclude whether there is a difference between the level of transparency throughout farm types or whether they are similar.

WEIGHING

The two highest-scoring criteria are rooted in systemic issues within the coffee production industry. These fundamental problems relate to human rights and call for zero-tolerance policies, Therefore, they are assigned the highest weight in this multi-criteria analysis.
Next are three criteria essential for enabling a just transition toward a circular economy. Achieving a circular economy is not feasible without access to knowledge, external support through policy and regulation, and a transparent value chain.

Criterion	Weighing (1-5)	Multiplier
Inequalities in Work Environment	5	1.5
Working Conditions	5	1.5
Transparency in the value chain	4	1.4
Knowledge Accessibility	4	1.4
External Support	4	1.4
Formal or Informal	4	1.4
Permanent or Seasonal	3	1.3
Political Power	3	1.3

While informal contracts and seasonal work are interlinked, the lack of formal employment structures represents a more fundamental challenge. Seasonal work, particularly during harvesting season, is not inherently problematic, provided working conditions are fair and wages are properly paid. However, the opportunity for stable, permanent employment naturally offers greater long-term security for workers.

Political power received the lowest score among the criteria. While greater inclusivity in decision-making is valuable, it is not as essential for the transition as long as government support is present through effective policies and regulations.

Multi Criteria Analysis: Environmental

CRITERIA	MULTIPLIER	ARCHETYPE				
MONOCULTURE OR POLYCULTURE	1.5	XS	S	M	L	XL
The farm fully implements intensive agroforestry methods, integrating diverse crops, trees, and natural ecosystem functions.						
The farm uses extensive agroforestry methods, incorporating trees and diverse plants, but with lower intensity and integration than intensive agroforestry.		2				
The farm practices polyculture, growing multiple crop types together to enhance biodiversity and soil health.			3			
The farm applies polyculture techniques such as intercropping, shade planting, and cover cropping, but only introduces one additional crop type to the system.				4	4	
The farm relies on monoculture, cultivating a single crop type with minimal diversification or integration of natural processes.						5
SCORING	1.5	3	4.5	6	6	7.5
PESTICIDE AND FERTILISER USE	1.4	XS	S	M	L	XL
There is no use of pesticides or chemical fertilizers on farm.						
There is minimal use of pesticides, with a strong reliance on natural fertilizers and alternative pest control methods.						
There is moderate combining both natural and chemical fertilizers, with limited and controlled pesticide use.		3	3			
There is a high use of pesticides and chemical fertilizers, though some natural alternatives are also integrated.				4	4	
There is a high use of pesticides and chemical fertilizers.						5
SCORING	1.4	4.2	4.2	5.6	5.6	7
SUPPORTING AND RESTORING NATURE	1.5	XS	S	M	L	XL
The farm actively restores and supports nature, engaging in reforestation, habitat creation, and biodiversity enhancement; it plays a key role in strengthening local ecosystems and natural processes.						
The farm contributes to the restoration of nature, integrating some ecological practices (e.g. hedgerows, native species planting) that support biodiversity and soil regeneration.			2	2		
The farm maintains existing natural features but does not actively contribute to restoring or enhancing surrounding ecosystems.		3			3	
The farm limits natural regeneration, with practices that disturb local habitats or reduce ecosystem complexity, offering little ecological support.						4
The farm actively degrades surrounding nature, removing habitats, reducing biodiversity, and disrupting natural processes, with no effort to support ecosystem services.						
SCORING	1.5	4.5	3	3	4.5	6
ENERGY USE AND PRODUCTION	1.3	XS	S	M	L	XL
The farm runs almost entirely on renewable energy, with efficient systems minimizing fossil fuel use. It may even generate excess renewable energy, reducing reliance on external energy sources.						
The farm primarily relies on renewable energy, such as solar, wind, or biogas, but still depends on non-renewable sources for certain operations.						
The farm uses a mix of renewable and non-renewable energy, without a clear strategy for reducing fossil fuel dependence or improving energy efficiency.		3	3	3		
The farm depends mostly on non-renewable energy, with minimal investment in renewables or energy efficiency measures.					4	
The farm relies entirely on fossil fuels or other non-renewable energy sources, making no effort to transition toward sustainable energy use or reduce its environmental impact.						5
SCORING	1.3	3.9	3.9	3.9	5.2	6.5

MONOCULTURE VS. POLYCULTURE

Farm size clearly influences cultivation methods. Larger farms tend to adopt more conventional, mechanised systems that favour monoculture, since these layouts facilitate efficiency and mechanised harvesting. In contrast, smaller farms often exhibit more diverse and irregular planting patterns, partly due to terrain constraints incompatible with large-scale machinery. These layouts, at times unintentionally, allow for integration of natural structures, increasing the biodiversity and decreasing the farm's impact on the natural environment.

PESTICIDE AND FERTILISER USE

The reliance on external chemical inputs, such as pesticides and fertilisers, increases with farm size. Large-scale monocultural systems typically depend on regular and preventive applications based on predefined fertilisation schedules. This differs from smaller farms, which often apply inputs guided by need rather than a schedule. Furthermore, biological alternatives are more prevalent among smaller farms, especially those holding certifications such as Fairtrade (F1-S1, F2-M1, F3-XS1), which promote ecological approaches and have stricter input regulation.

NATURE CONSERVATION AND RESTORATION

In the Atlantic Rainforest, which is an ecologically sensitive biome, coffee agriculture has contributed to ecosystem fragmentation. However, responses to this issue vary significantly by farm size. Smallholders often lack the financial, technical, and labour resources to implement active restoration strategies (F11-XS2). Medium-sized farms engage more in reforestation using native species (F6-M3, F7-S2). In contrast, larger farms (F8-XL1, F10-XL2) tend to meet the legal requirements of Brazil's Forest Code (10 Years of the Brazilian Forest Code | BVRIO, 2023) by acquiring land to offset deforestation, rather than engaging in their own reforestation. This approach meets the formal obligations but does not contribute meaningfully to ecological recovery.

ENERGY USE AND PRODUCTION

Large farms consume notably more energy due to their reliance on mechanisation, including harvesting, irrigation, and land management. However, energy-intensive irrigation systems are especially prevalent in large-scale operations in regions such as the Cerrado and Triângulo Mineiro, where drought conditions make them essential for viable production. In the case study region, these irrigation systems are not broadly used, especially in smaller farms, due to the mountainous locations. Across all farm types, the use of renewable energy remains rare.

Multi Criteria Analysis: Environmental

CRITERIA	MULTIPLIER	ARCHETYPE				
WATER USE AND RE-USE	1.4	XS	S	M	L	XL
The farm optimizes water use and actively treats and reuses water, implementing rainwater harvesting, wastewater treatment, and efficient irrigation techniques, minimizing waste and environmental impact.						
The farm primarily relies on sustainable water sources and uses some water-saving or recycling measures, but there is still some reliance on external water supplies.		2	2			
The farm uses a mix of efficient and inefficient water practices, with some water conservation efforts but no systematic treatment or reuse strategies.				3	3	
The farm relies heavily on external water sources with inefficient use, limited conservation measures, and minimal wastewater treatment or reuse.						
The farm has unsustainable water use, extracting large amounts from local sources without treatment or reuse, contributing to depletion, pollution, or water scarcity issues.						5
SCORING	1.4	2.8	2.8	4.2	4.2	7
MATERIALS: BIOLOGICAL & TECHNICAL	1.2	XS	S	M	L	XL
The farm effectively manages all of its waste, using composting or organic fertilizers with all reuse happening locally.						
The farm effectively manages most of its waste, using composting or organic fertilizers with some reuse happening locally, but a portion still requires external processing or disposal.		2	2	2	2	
The farm has a mix of waste management practices, with some organic waste being repurposed, but much of it still leaving the system or requiring long supply chain loops for processing.						3
The farm has inefficient biological waste management, with most waste being discarded, burned, or left untreated, and little effort to keep materials within a short-loop system.						
The farm does not manage biological waste sustainably, leading to pollution, methane emissions, or nutrient loss, with no attempt to reuse or close material loops, resulting in long, inefficient waste cycles.						
SCORING	1.2	2.4	2.4	2.4	2.4	3.6
SCORING TOTAL		20.8	20.8	25.1	27.9	37.6

Results

Archetype	XS	S	M	L	XL
Scoring Total	20.8	20.8	25.1	27.9	37.6
Weighing Land-Use	1.1	1.2	1.3	1.4	1.5
MCA Environmental Result	22.88	24.96	32.63	39.06	56.4

WATER USE AND REUSE

Large-scale farms in dry regions, like Cerrado, rely heavily on irrigation (Global coffee platform [GCP], 2023) (Moda et al., 2024), significantly increasing their water footprint. In these areas coffee production would not be feasible without irrigation systems. Rainwater harvesting and reuse practices are also uncommon. However, Some medium-sized farms (e.g., Farms 4 and 7) have adopted traditional infiltration systems to improve groundwater infiltration.

BIOLOGICAL AND TECHNICAL MATERIALS

Fieldwork suggested that farms reuse most biological material produced during farming, harvesting and processing. These products were reused as organic material on the soil, usually on the farms themselves. The more industrial farms (F10-XL2) did not return it to their soil, but sold it to other farms, increasing the length of the loop, but still reusing it.

Consequently, smaller and medium-sized farms are likely to be more prone to recycling organic materials, such as pruning waste or compost, returning them to the soil to enhance fertility and reduce waste, however, only with minimal treatment. This contrasts with larger farms, where such practices are less common and more industrially managed.

FINAL ENVRIONMENTAL ASSESSMENT

Since more land will be affected depending on the farm size, especially regarding the physical nature of the environmental criteria, an extra multiplier has been added over the final scoring.

Because larger farms operate on significantly more land and use more intensive and conventional methods, including mechanisation, chemical inputs, and monoculture, they inherently have a greater environmental impact. This is especially evident in their contributions to land degradation, biodiversity loss, and resource consumption. Although farms of all sizes contribute to ecological pressures, the scale and intensity of large farms amplify their overall footprint.

Multi Criteria Analysis: Economic

CRITERIA	MULTIPLIER	ARCHETYPE				
CURRENT INCOME	1.4	XS	S	M	L	XL
Coffee farmers earn more than the average amount that coffee farmers earn with only coffee (23,79€/month) with only coffee farming					1	1
Coffee farmers earn more than the average amount that coffee farmers earn with coffee and other income streams combined (23,79€/month)						
Farmers earn more than 10,000 Brazilian Real per month				3		
Farmers earn n living incomejust enough to make a living income (with only coffee)			4			
Farmers do not earn a living with only coffee (Between the cost of living range)		5				
SCORING	1.4	7	5.6	4.2	1.4	1.4
COST OF PRODUCTION	1.2	XS	S	M	L	XL
The farm has very low production costs, using efficient, circular strategies such as on-farm input production, waste recycling, and low reliance on external resources.						
The farm has relatively low production costs, with some reliance on external inputs but overall efficient resource use and cost management.				2		
The farm has a moderate cost of production, balancing external inputs and self-produced resources, with costs fluctuating based on market conditions.			3		3	
The farm has high production costs, depending significantly on external inputs such as fertilizers, pesticides, and energy, increasing financial risks.		4				4
The farm has very high production costs, relying heavily on costly inputs, mechanisation, and resource-intensive practices, making it vulnerable to price fluctuations and financial instability.						
SCORING	1.2	4.8	3.6	2.4	3.6	4.8
DIVERSIFICATION OF INCOME	1.4	XS	S	M	L	XL
The farm has high income flexibility, generating revenue from multiple sources, such as integrating other stages of the coffee value chain or growing additional crops for year-round sales						1
The farm has diverse income streams, with some added value in the coffee chain or a mix of additional crops, but still relies primarily on a few key activities.						
The farm has a moderate level of income flexibility, with some seasonal variation in income sources but without significant diversification in function.				3	3	
The farm has limited income flexibility, depending mostly on a single primary product, with only minor additional revenue sources or seasonal adjustments		4	4			
The farm has no income flexibility, relying entirely on a single crop or product without additional income streams, making it highly vulnerable to market fluctuations.						
SCORING	1.4	5.6	5.6	4.2	4.2	1.4

CURRENT INCOME

The current income of farmers is very diverse among farmer archetypes. The smallest archetype (XS) includes a group that does not earn enough to earn a living income to pay the cost of living (Global Coffee Platform [GCP], 2023). The bigger a farm gets, the more it generally earns. The L and XL archetypes earn more than the general income with only coffee farming (Global Coffee Platform [GCP], 2023).

COST OF PRODUCTION

The cost of production depends on multiple variables, like the cost of living in the region and the production cost per hectare. Generally, farms with more than 10 ha are found to have a higher cost of living (Global Coffee Platform [GCP], 2023). However, the smallest farms (archetype XS) have been found to be the least efficient, driving up the cost of production per hectare.

Due to a large amount of inputs, the largest farms have a high production cost. Therefore, both large and small farms are paying more for their production. The middle farmers are in a place where they are less dependent on external outputs but also have a higher efficiency and lower production costs than both small and big farms.

DIVERSIFICATION OF INCOME

Farms in the region generally do not grow crops other than coffee on the farm and are fully sun-grown using conventional methods. Bigger farms have a higher diversification score, since they typically have more functions to further process the coffee (F10-XL2), (F9-L2). They have a high income flexibility to invest in their future. Mid-size farms generally process their own coffee but have no other functions. At times, both mid-sized and large farms have annual crops growing in a small part of their farms (F8-XL1, F4-L1). The smallest farm size often does not have the space to process its coffee, but is reliant on some external income streams and external aid just to earn a living income (Global Coffee Platform [GCP], 2023). These farms do not have the capacity to experiment with extra crops.

Multi Criteria Analysis: Economic

CRITERIA	MULTIPLIER	ARCHETYPE				
INTEGRATION INTO THE VALUE CHAIN	1.5	XS	S	M	L	XL
Farms have multiple certifications or have a strong organisational and business structure, without dependancy on cooperatives or certification.						1
Farms are linked to cooperatives, but not dependant on them for their integration into the value chain.					2	
Farms are linked to a cooperatives and have a certification, dependency on external organisation is moderate			3	3		
Farms either are linked to a traders or cooperatives or have at least one certification., but are highly dependant on them getting an ingration into the value chain		4				
Farms are not integrated into the supply chain, E.G. they ar e not connected to any cooperatives and traders and have no certifications.						
SCORING	1.5	6	4.5	4.5	3	1.5
SELF SUFFICIENCY	1.4	XS	S	M	L	XL
The farm is highly self-sufficient, producing most of its own inputs (e.g., seeds, fertilizers, animal feed) and relying minimally on external resources						
The farm is mostly self-sufficient, generating many of its own inputs but still depending on some external resources for key production needs						
The farm has a moderate level of self-sufficiency, producing some inputs while still requiring a significant amount of external supplies						
The farm has low self-sufficiency, depending primarily on external inputs for production, with limited internal resource generation		4	4	4		
The farm is highly dependent on external inputs, relying almost entirely on purchased resources such as fertilizers, seeds, and feed, making it vulnerable to supply chain disruptions.					5	5
SCORING	1.4	5.6	5.6	5.6	7	7
PRODUCTIVITY	1.4	XS	S	M	L	XL
Farms achieves highest productivity, consistently achieving high yields.			1			
Farms achieves high above-average productivity, consistently producing above the average.					2	
Farms achieves moderate productivity, producing average productivity consistently or produces high amounts with major inconsistencies.		3				3
Farms achieves low productivity, or has inconsistencies in producing around average procuction.						
Farms achieves low productivity, below average.				5		
SCORING	1.4	4.2	1.4	7	2.8	4.2
ECONOMIC TOTAL		33.2	26.3	27.9	22	20.3

INTEGRATION INTO THE VALUE CHAIN

The bigger a farm gets, the more organised its organisational structure becomes, doing more for themselves and not being dependent on cooperatives. These large farms (F10-XL2) often have many certifications, since they have a high capacity due to more employees for administration and bureaucratic processes.

Small farms are heavily reliant on cooperatives for their exports. They have access to the market through these cooperatives and bargaining power is lacking. Some farms have a certification that gives them a slight premium on their coffee and increases its marketability.

SELF-SUFFICIENCY

All farms in the case study are still reliant on external inputs. Pesticides and fertilisers are the most intensely used on large farms (F8-XL1). The farm does not generate or reuse energy, water, or other materials.

PRODUCTIVITY

The Global Coffee Platform [GCP] (2023) found a direct correlation between the size of the farm and its productivity. The average productivity of all farms was about 35 bags of coffee per hectare, but archetype S had the highest productivity rate of all farmer types, with around 43 bags per hectare. A clear distinction in productivity was found in the farm sizes; however, no clear trend following the size of the farms was found (Global Coffee Platform [GCP], 2023).

FINAL ECONOMIC ASSESSMENT

The economic structure of coffee farms varies significantly based on farm size. While larger farms earn higher incomes and are better integrated into the value chain, they also face higher production costs and dependency on external inputs. Mid-sized farms have found a balance, showing lower production costs and moderate income diversification. In contrast, the smallest farms struggle with low income, inefficiency, and limited access to processing and market power, often relying on cooperatives and external aid. Ultimately, much of the farms' success and ability to transition depends on their economic capacity, and the smallest farms have undeniably emerged as the most vulnerable economic archetype.

Multi Criteria Analysis: Social

CRITERIA	MULTIPLIER	ARCHETYPE				
KNOWLEGDE ACCESSIBILITY	1.4	XS	S	M	L	XL
The farm actively promotes knowledge-sharing, training workers and farmers in sustainable practices, innovation, and circular strategies while integrating traditional and scientific knowledge.						
The farm prioritizes knowledge development, offering training opportunities and fostering learning, but access to information may still be somewhat limited.					2	2
The farm has a moderate level of knowledge access, with some training and skill development, but learning opportunities are not consistently available.			3	3		
The farm has limited knowledge-sharing, with minimal training or capacity-building opportunities, leading to gaps in best practices and innovation adoption.		4				
The farm has very restricted knowledge access, with no structured training, little to no skill development, and a lack of information-sharing among workers and farmers.						
SCORING	1.4	5.6	4.2	4.2	2.8	2.8
PERMANENT OR SEASONAL	1.3	XS	S	M	L	XL
The farm provides highly stable, year-round employment, offering permanent work opportunities with consistent income and tasks throughout the year. Labour is done mostly						
The farm offers mostly stable employment, with a core group of permanent workers and some seasonal fluctuations in workload.					2	2
The farm has a mix of permanent and seasonal work, where some employees have year-round jobs, but a significant portion of labor needs vary by season				3		
The farm relies primarily on seasonal labor, with only a small number of permanent workers and most tasks concentrated in peak seasons.		4	4			
The farm has highly unstable, entirely seasonal work, providing employment only during specific periods, leading to financial and job insecurity for workers.						
SCORING	1.3	5.2	5.2	3.9	2.6	2.6
WORKING CONDITIONS	1.5	XS	S	M	L	XL
The farm provides excellent working conditions, ensuring fair wages, safe working environments, reasonable hours, social protections, and strong labor rights enforcement.						
The farm offers good working conditions, with fair wages and generally safe environments, though some minor labor challenges may still exist.						
The farm has acceptable working conditions, meeting basic labor standards, but with some inconsistencies in wages, safety, or worker protections.		3	3	3		
The farm has challenging working conditions, with low wages, long hours, or unsafe environments, though some efforts may be made to improve them.					4	4
The farm has poor working conditions, with exploitative labor practices, unsafe environments, low wages, and little to no worker protections in place.						
SCORING	1.5	4.5	4.5	4.5	6	6
FORMAL OR INFORMAL	1.4	XS	S	M	L	XL
The farm relies only on formal labour.						
The farm relies primarily on formal labour, hiring only informal people with personal relationships.						
The farm hires a mix of formal and informal labour.		3	3	3	3	3
The farm relies primarily on informal labor, which is not a family or personal relationship.						
The farm relies only on informal labor, which is not a family or personal relationship.						
SCORING	1.4	4.2	4.2	4.2	4.2	4.2

KNOWLEDGE ACCESSIBILITY

knowledge accessibility is lower among smallholder farms (Aldi South Group, 2021). During fieldwork however, most farms mentioned a high availability of coursed through programs like SENAR, a governmental program from the agricultural ministry (e.g., farm 4, 5 & 6). In spite of that, focused were often focused on new technologies, rather than transitioning towards a more circular system.

PERMANENT OR SEASONAL WORK

Due to the level of mechanisation in bigger farms, there is a lower dependency on seasonal labour (Moda et al., 2024). The possibility of buying machines for mechanised harvest is estimated to reduce the amount of hired labour by 62% (Moda et al., 2024), and workers tend to be more permanent than social.

FORMAL OR INFORMAL

Informality is widespread in the Brazilian coffee sector (Aldi South Group, 2021), especially among smallholder farms. However, an important thing to mention is that while smallholder farmers are more reliant on seasonal and informal work (Moda et al., 2024), more often these relationships are more personal or family related (Aldi South Group, 2021), which offers more flexibility and fewer issues with informality. However, there are, of course, no guarantees with informal working agreements, leaving the door open for error and bad working conditions.

In contrast, informality can lead to exploitation on larger farms, especially during harvesting seasons. Workers paid by unit instead of per hour, especially micro workers, are particularly vulnerable in these times (Aldi South Group, 2021).

WORKING CONDITIONS

Working conditions include multiple of the most pressing topics in the Brazilian coffee industry. A big problem relates to the application of agrochemical inputs. Among smallholder farms, there is a lack of awareness on how to handle it, but the risks are great for workers, farmers, their families and surrounding communities (Aldi South Group, 2021). Even though there are laws in place, there is too little oversight checking whether laws are enforced (Aldi South Group, 2021).
Also, there are large health risks associated with large farms. Here, people often work more directly with applying these toxic inputs (Aldi South Group, 2021).
Accommodation is also a pressing problem on larger farms. Housing units are often poor and do not conform to human rights, with there not being gender segregated

Multi Criteria Analysis: Social

CRITERIA	MULTIPLIER	ARCHETYPE				
INEQUALITIES IN WORK ENVRIONMENT	1.5	XS	S	M	L	XL
The farm actively promotes equity, ensuring fair wages, and equal opportunities for all workers, including minorities and marginalized groups.						
The farm recognizes and addresses inequalities, offering fair wages and opportunities, with some policies supporting vulnerable groups, though disparities may still exist.						
The farm has a neutral approach, with no active discrimination but also no targeted efforts to reduce inequalities or support minority workers.		3	3	3		
The farm has significant inequalities in the work environment, with marginalized groups present facing lower wages, or limited opportunities.					4	4
The farm has severe inequalities, with a high number of vulnerable workers experiencing discrimination, unsafe conditions, and exploitation, and no policies in place to improve fairness.						
SCORING	1.5	4.5	4.5	4.5	5.6	5.6
CRITERIA	MULTIPLIER	ARCHETYPE				
EXTERNAL SUPPORT	1.4	XS	S	M	L	XL
Is currently very supported through policies, subsidies etc. civic and public & private to make the just transition towards a circular economy.						1
Is largely supported through policies, subisidies privately and governmentally to transition to more sustainable and just practices					2	
Is somewhat supported by governmental, so some investments towards more sustainable and just practices can be made				3		
Is barely supported through government, civic or private programs to transition to more sustainable and just practices		4	4			
Is not supported through government, civic or private programs to make transitions to sustainable or just practices.						
SCORING	1.4	5.6	5.6	4.2	2.8	1.4
(POLITICAL) POWER	1.3	XS	S	M	L	XL
Has a lot of power in the government through farmers' table, monopsony, participatory processes etc.						1
Has a significant amount of power in the government through farmers' table, monopsony, participatory processes etc.					2	
Has some say through participatory processes.				3		
Has little say in politics, is sometimes invited to paticipate in participatory processes.			4			
Has no say in decision making processes, is left out of participatory processes.		5				
SCORING	1.3	6.5	5.2	3.9	2.6	1.3
TRANSPARENCY IN THE VALUE CHAIN	1.4	XS	S	M	L	XL
The farm or cooperative to which farm is connected is fully transparent, openly sharing detailed information about sourcing, production practices, labour conditions etc.						
Farm or cooperative is mostly transparant, sharing most information openly on sourcing, prodcution practices, labour conditions etc.						
The farm or cooperative is moderately transparant, but some key information is missing, to trace all production processes				3	3	3
Farm or cooperative share barely anything about sourcing, production practice and labour conditions etc.		4	4			
Farm or cooperative share nothing about their sourcing, production practive, labour conditions etc.						
SCORING	1.4	5.6	5.6	4.2	4.2	4.2
SOCIAL TOTAL		41.7	39	33.6	30.8	23.9

housing units, increasing he safety of female workers, having little accessibility to good quality drinking water and toilets (Ferroni et al., 2021)(Aldi South Group, 2021).
Occasionally, on large farms, there have been reports of debt bondage (Ferroni et al., 2021; Aldi South Group, 2021), leaving a condition of forced labour.

INEQUALITIES AND DISCRIMINATION IN THE WORKPLACE

Brazil's coffee sector is marked by deep-rooted inequalities, particularly around gender, labour conditions and historical disadvantage. Though women's roles in coffee production are increasing (Aldi South Group, 2021), they remain underpaid, underrepresented, and overexposed to risk across both smallholder and large-scale farms.
On smallholder farms, traditional norms limit women's access to land, decision-making, and income. Women's work is more often informal and unpaid than men's (Aldi South Group, 2021). The absence of formal contracts or grievance mechanisms exacerbates vulnerabilities.

Larger farms, while more structured, also face serious issues. Women are often excluded from permanent roles, earn less, and lack access to pensions or childcare. During harvest seasons, poor housing conditions, including the lack of gender-segregated accommodation, create risks of gender-based violence.
More inequalities are present, rural workers get paid little and systemic challenges are still running throughout the coffee work environment, based on deep-rooted problems that have been there since slave labour times. There is, however, little data on what type of farms this is most present.

EXTERNAL SUPPORT

governmental support is available as well. Especially small farmers depend on it for Governmental support is also available. Small farmers, in particular, depend on it for a living income (Global Coffee Platform [GCP], 2023).
Premiums also come from external projects and certifications, like Fairtrade, which are mostly available for smallholder farmers. However, these premiums have gone down due to the lack of market for this type of coffee (Moda et al., 2024), and often, coffee disappears into the commodity batches, leaving a lower return at the end.

Small farms are dependent on external support for making a living income, they are not able to invest this aid into cirular practices. Subsidies and funding are available for the smaller farmer groups. However, these are often loans, and they are often focused on technical advancements and mechanisation rather than improving sustainability.

Accessibility to this support should also be taken into account. For smaller farmers, who have less capacity in their labour force, a bureaucratic procedure to ask for support might be out of reach, whether they are eligible or not.

	Area Stratum					
	0-5 ha	5-10 ha	10-20 ha	20-50 ha	50-100 ha	Total
Annual Actual Income						
Total (%)	100.0	100.0	100.0	100.0	100.0	100.0
1 Coffee (%)	30.0	61.8	83.3	79.7	90.7	**82.7**
2 Other products (%)	30.0	1.0	-6.8	5.9	-2.3	**1.5**
3 Insurance (%)	0.0	0.0	0.0	0.5	1.9	**1.1**
4 Other rural properties (%)	1.8	0.0	0.0	0.3	0.1	**0.2**
5 Outside work (%)	0.7	12.3	6.5	4.7	3.7	**4.6**
6 Services and rents (%)	16.8	14.1	12.6	6.2	4.8	**6.8**
7 Aid (%)	20.7	10.9	4.4	2.8	1.2	**3.1**
Sample frequency (n)	6	8	7	29	14	64

Income of farmer types (aid: pensions, retirement and governmental aid) (Global coffee platform [GCP], 2023)

Large agribusiness still get the highest funding of famers groups in Brazil (Fernandes, 2024). This suggests that in the coffee indsutry this is also the case, and that archetype XL gets higher fundings than small farmrs.

POWER

The labour law reforms from 2017 weakened the position of workers' unions, benefitting employers who were no longer forced to pay the dues (Camargo, 2023). This reform, however, drastically weakened the enforcement of labour laws, lowering the collective action power they had before (Ferroni et al., 2021). This has tremendous effects on workers and farmers.

Smallholder farmers face alack of bargaining power in supply chains dominated by a few powerful supermarkets, importers and cooperatives. This monopsony dynamic means that prices and, therefore, conditions on farms, are often dictated by actors far removed from the production site (Zavala & Princeton University and The World Bank, 2024). Large farms have slightly more leverage but still suffer under the power of market dynamics controlled by major corporate buyers (Ferroni et al., 2021). Industrial farms and agribusiness have much higher market power and, at times, have direct access to participation in government processes. Bancada Ruralista or the farmers' table strongly supports them and has significant political influence to promote policies that weaken environmental protections, increase pesticide use, and resist land reform. These policies benefit large farms by facilitating land expansion and reducing oversight, often at the expense of smallholder farmers and Indigenous communities (De Santi, 2024; Fernandes, 2024). Despite promises to reduce deforestation and implement environmental policies, the Brazilian government still directs most of their resources to the large landowners, rather than to family farming (Fernandes, 2024). Smallholder farmers remain vulnerable and reliant on cooperatives and external income while facing challenges such as limited market access. This concentration of power enforces inequality and environmental degradation. While these sources do not specifically address coffee farming, agribusiness is also present in this sector, and it is reasonable to assume that similar power dynamics apply.

TRANSPARENCY

The complexity of coffee supply chains, including practices like the blending of coffee beans, makes it difficult to accurately trace the origin of coffee. Even large companies often buy through importers, limiting their direct oversight. While some transparency initiatives exist, the traceability of coffee remains poor, weakening accountability for the present problems. This lack of traceability also leads to a lack of data, whether small or large farms are more affected. However fieldwork, shows that smaller farms are more dependant on cooperatives, that tend to blend coffees a lot.

FINAL SOCIAL ASSESSMENT

The differences between smallholder and large-scale farms in Brazil's coffee sector reveal a landscape with systemic inequalities and varying capacities. Smallholder farms generally face lower knowledge accessibility, limited market power, and dependence on external aid and informal labour structures. Despite this, their labour relationships are often more personal and flexible. However, they lack formality. Conversely, larger farms benefit from higher mechanisation, reducing their reliance on seasonal labour and enabling more formal employment. Still, they often expose workers to worse working conditions, including poor housing.

While both large and small farm types contend with serious labour and environmental issues, large farms tend to have more political influence and better access to external support, with higher government power. Smallholders struggle with bureaucracy, informality, and vulnerability in a system dominated by large market powers. As a result, small farmers struggle more to meet the social criteria.

Multi Criteria Analysis: Results

CRITERIA		ARCHETYPES				
ENVIRONMENTAL	WEIGHT	XS	S	M	L	XL
MONOCULTURE OR POLYCULTURE	1.5	3	4.5	6	6	7.5
PESTICIDE AND FERTILIZER USE	1.4	4.2	4.2	5.6	5.6	7
SUPPORTING AND RESTORING NATURE	1.5	4.5	3	3	4.5	6
ENERGY USE AND PRODUCTION	1.3	3.9	3.9	3.9	5.2	6.5
MATERIALS: BIOLOGICAL & TECHNICAL	1.4	2.8	2.8	4.2	4.2	7
WATER USE AND REUSE	1.2	2.4	2.4	2.4	2.4	3.6
ENVRIONMENTAL TOTAL		20.8	20.8	25.1	27.9	37.6
LAND SIZE MULTIPLIER		1.1	1.2	1.3	1.4	1.5
ENVIRONMENTAL RESULTS		22.88	24.96	32.63	39.08	56.4
ECONOMIC		XS	S	M	L	XL
CURRENT INCOME	1.4	7	5.6	4.2	1.4	1.4
COST OF PRODCUTION	1.2	4.8	3.6	2.4	3.6	4.8
DIVERSIFICATION OF INCOME	1.4	5.6	5.6	4.2	4.2	1.4
INTEGRATION INTO THE VALUE CHAIN	1.5	6	4.5	4.5	3	1.5
SELF SUFFICIENCY	1.4	5.6	5.6	5.6	7	7
PRODUCTIVITY	1.4	4.2	1.4	7	2.8	4.2
ECONOMIC TOTAL		33.2	26.3	27.9	22	20.3
SOCIAL		XS	S	M	L	XL
KNOWLEGDE ACCESSIBILITY	1.4	5.6	4.2	4.2	2.8	2.8
PERMANENT OR SEASONAL	1.3	5.2	5.2	3.9	2.6	2.6
WORKING CONDITIONS	1.5	4.5	4.5	4.5	6	6
fORMAL OR INFORMAL	1.4	4.2	4.2	4.2	4.2	4.2
INEQUALITIES IN WORK ENVIRONMENT	1.5	4.5	4.5	4.5	5.6	5.6
EXTERNAL SUPPORT	1.4	5.6	5.6	4.2	2.8	1.4
(POLITICAL) POWER	1.3	6.5	5.2	3.9	2.6	1.3
TRANSPARENCY IN THE VALUE CHAIN	1.4	5.6	5.6	4.2	4.2	4.2
SOCIAL TOTAL		41.7	39	33.6	30.8	23.9
TOTAL IMPACT ANALYSIS		97.78	90.26	94.13	91.88	100.6

RESULTS EXCLUDING WEIGHING

ARCHETYPE	XS	S	M	L	XL
ENVIRONMENTAL RESULTS	15	15	18	20	21
ENVIRONMENTAL RESULTS INCL. LAND USE WEIGHING	16.5	18	23.4	28	31.5
ECONOMIC RESULTS	24	19	20	16	15
SOCIAL RESULTS	30	28	24	22	20
TOTAL IMPACT ANALYSIS EXCL. LAND USE WEIGHING	69	62	62	58	56
TOTAL IMPACT ANALYSIS INCL. LAND USE WEIGHING	70.5	65	67.4	66	66.5
CHANGE WEIGHING VS. NO WEIGHING	28.78	28.26	32.13	33.88	44.6

CONCLUSION

This multi-criteria analysis assesses the sector's current state and identifies where and with what type of farm, the implementation of circular practices could have the most tremendous impact. The results show apparent differences across farm size archetypes in the case study region, highlighting that larger farms (particularly Archetype XL, scoring 100.6) currently contribute most to environmental degradation. Their high impact reflects the concentration of problems, such as monoculture, heavy chemical input use, and labour issues, making them the most urgent targets for impactful circular transitions.

However, the analysis also shows that the impact differs across all criteria. For instance, smallholder farms (Archetype XS scoring 97.78, and Archetype S: 90.26) face more acute social and economic challenges, such as informality, low income, and limited access to markets or resources. While their environmental footprint is smaller, targeted circular interventions could improve livelihoods and build resilience in vulnerable communities. Mid-sized farms (Archetype M scoring 94.13, Archetype L scoring 91.88) fall in between. They face both environmental and socio-economic issues, though less extreme. These farms may benefit from circular practices that increase efficiency and close resource loops, having a higher capacity than smallholder farms.

When examining the unweighted results, the outcomes per category do not change much. While there are smaller differences between the archetypes, the same archetype has the most potential impact with improvements in each category. However, the final unweighted outcome is completely different from the final weighted outcome. The weights, including the land use weight, highlight an extra pressure on the environmental criteria.

Ultimately, the analysis reveals that the highest overall impact from circular interventions would occur on the largest farms due to the scale and severity of current problems, which consist largely of environmental problems. However, it also reinforces that effective change needs custom-made interventions: addressing environmental overreach on large farms, improving economic and social resilience on small farms, and supporting mid-sized farms to strengthen sustainable practices. Rather than giving one solution for all farmers, this analysis demonstrates the need for adapted strategies that consider the unique differences of each farm type.

Stakeholder Analysis

Having a good overview of the stakeholders in the coffee industry is essential for understanding the interests, power dynamics and interdependencies that have to be understood before transition is possible. This analysis aims to identify and evaluate these dynamics between farmers, cooperatives, associations, and other actors, as well as at the influence they have. This analysis can guide decision-making to transform the coffee sector strategically.

COOPERATIVES

The main cooperatives in the region are large organisations with thousands of farms connected to them. Even though these organisations might have started out as small cooperatives run by farmers, they have grown to be powerful businesses within the world of coffee.

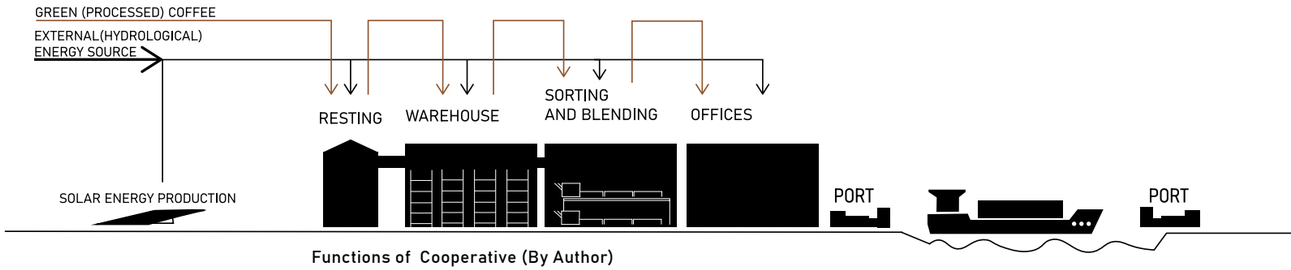
These stakeholders hold great influence and power over the transition, but they also depend on the big coffee companies they sell to.

Farmers in the region heavily depend on cooperatives for specific functions that they can usually not complete themselves. These functions include the reprocessing stage, which requires heavy and expensive machinery that farmers cannot afford, storing the coffee in their warehouses, and exporting. Besides that, cooperatives offer courses(C1), sometimes technical guidance (C2) and events for farmers to meet (C1).

Besides that, a cooperative helps a farmer maintain stability. Farmers can always have guaranteed sales at this cooperative; however, the prices they sell at have to be competitive with those of the largest coffee companies in the world (C1). Therefore, farmers are not offered high prices for their coffee.

Sustainability is a growing theme within cooperatives; sustainable development goals are heavily marketed, and teams working on sustainability are expanding. However, there have not been clear plans for what this sustainable development should look like. Some cooperatives set up sustainability programs, but until now, they are small-scale and non-compulsory, possibly applying to farms that already fulfil these requirements.

There is a need for clear objectives regarding circular, ecological and fair practices. With the number of farmers connected to these large-scale



Functions of Cooperative (By Author)

cooperatives, the cooperatives could be leaders in this transition. They can make a difference with ambitious goals and good guidance and support.

GOVERNMENTS

Government institutions and labour unions are influential stakeholders, though their roles have evolved over time. The Brazilian government shapes the industry through agricultural policy, rural development programs, and labour enforcement. Agencies like the Ministry of Agriculture and programs like SENAR support farmers in innovation. In these programs, there is still a focus on technical advancement and productivity.

Unions

Labour unions are crucial in advocating for workers' rights in rural sectors, have seen a notable decline in influence over recent decades. Reforms to Brazil's labour laws in 2017, coupled with the rise of informal labour and weakening collective bargaining mechanisms, have reduced union power (Camargo, 2023), particularly in rural areas where unionisation rates are already low (Ferroni et al., 2021). As a result, many coffee workers, especially seasonal workers, remain vulnerable to exploitation, with limited recourse or representation.

ASSOCIATIONS

Associations exist in many varieties. They can be an organisation run for farmers by farmers, or an external company offering support in branding and marketing (A1). While these organisations are generally smaller than cooperatives, they also have more specific goals. Associations are more there for farmers' capacity building in tasks they struggle to do alone. However, the impact of these associations can vary widely. Local associations can play a crucial role in, for example, strengthening communities and

building their capacity.

During the interviews, an example of an association had a lot of benefits. Through this association, F1-S1, F2-M1, and F3-M3 and more farms are connected, and they get a lively community centre, with community events, mental and physical health programs, technical support, and more.

Nevertheless, there are risks. Associations could become extra actors, increasing the length of the value chain and reducing farmers' profits. As long as they remain focused on building farmers' capacity and do not become another party focused on money, they can be valuable partners for farmers.

CERTIFICATIONS

The certifications most found in the region are Fairtrade, Rainforest Alliance, and Certifica Minas. All offering These certifications offer a premium and help producers enter new markets, but as discussed previously, problems arise with the marketability of this coffee. Farmers who invest in certifying their farms do not.

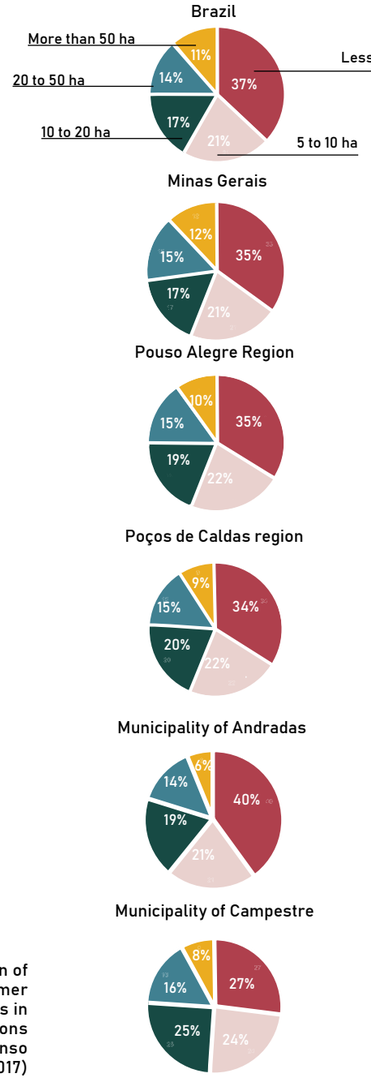
If certification wants to make a systemic impact, there is an undeniable need to increase the commercial potential for these certified coffees.

EXPORTERS

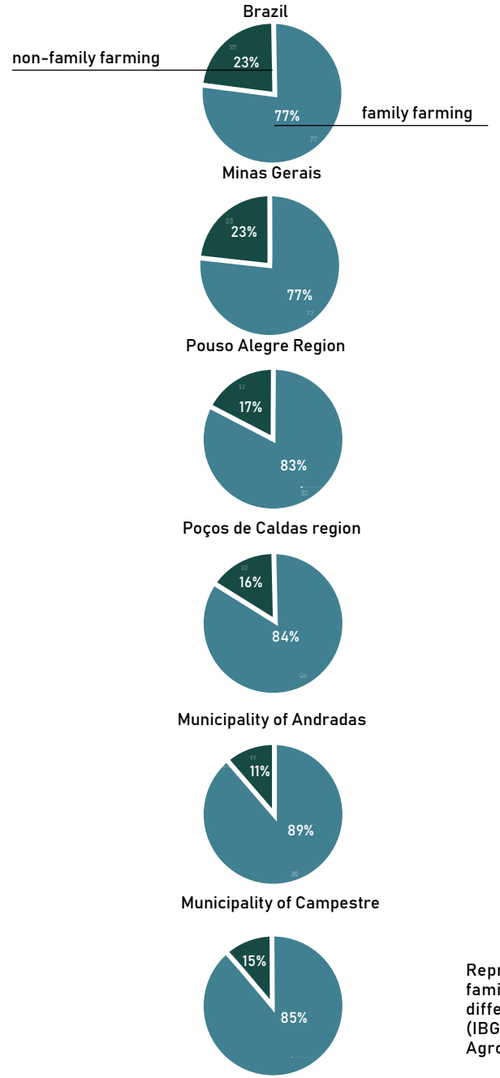
Exporters take over a specific part of the value chain. They do the stages of reprocessing, including quality control, and then storing. After they export and sometimes blend coffees (E1). These stakeholders still work with intermediary parties like suppliers, which can make the chain longer.

FARMERS: ARCHETYPE REPRESENTATION

To place the region in context with the rest of Brazil, the number of farms is compared. As previously noted, the largest group of farmers in Brazil operates on less than five hectares of land; however, despite their numbers, they produce the smallest share of the country's coffee. On the contrary, the group with the highest quantity of land is the smallest group of farmers, but also produces the most coffee.
The numbers within Minas Gerais, where most of the country's coffee is produced, are representative of the rest of the country. When zooming in, however, the numbers change slightly. Mid-size farms are slightly more represented in the case study region, the immediate region of Poços de Caldas. Although overall, the XL farms are less represented, the differences between municipalities in the number of XS farms are substantial (IBGE - Censo Agro 2017, 2017).



Representation of Brazilian farmer archeypes in different regions (IBGE - Censo Agro 2017, 2017)



Representation of family farmers in different regions (IBGE - Censo Agro 2017, 2017)

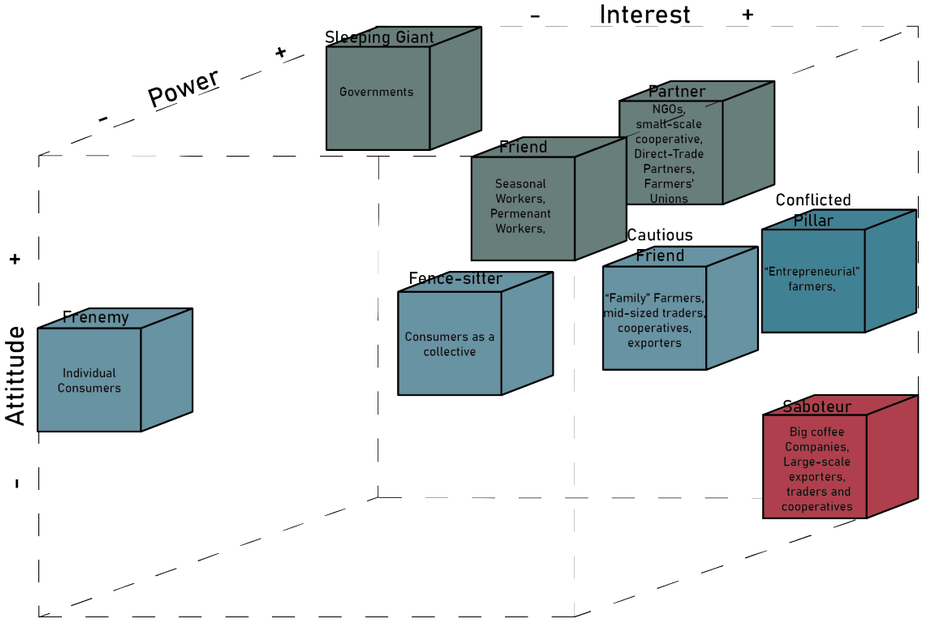
FAMILY FARMING

When comparing numbers representing family farming, there is a bigger difference. Again, Minas Gerais has representative numbers nearly identical to the national numbers. Nevertheless, when zooming in, numbers for family farming keep increasing.

Family farming is defined by various factors (Conafer, 2018). Firstly, farms cannot be bigger than four fiscal units. This size depends on the municipality and can be around five to thirty hectares per unit. The second criterion says most of the labour has to be done by the family, and thirdly, there is a minimum percentage, and the majority of the farm income has to be earned on the property or within the enterprise (Conafer, 2018).

Within the Pouso Alegre region, and zoomed in from there, the number of family farmers increased. This underpins the previous numbers, concluding that the large farms are less represented in the case study region. Besides that, it suggests coffee farming is the primary source of income for these farmers and lastly, hiring labour from outside the family is done less than in other parts of the country.

The differences in farm sizes can be seen in this more local context. Farm types lie closer together in the case study region than in the national context. These regional dynamics have caused the project to continue in the following steps, with three rather than five types of farms, Case study farm type S, case study farm type m and case study farm type L. Recommendations would otherwise be too closely together.



Power-Interest-Attitude Matrix (by author)

CONCLUSION

This analysis concludes in this power, interest, attitude matrix, showing the influence stakeholders have to change things in the time of transition, the personal interest they have in improving the industry and if they have a positive or negative opinion about the change.

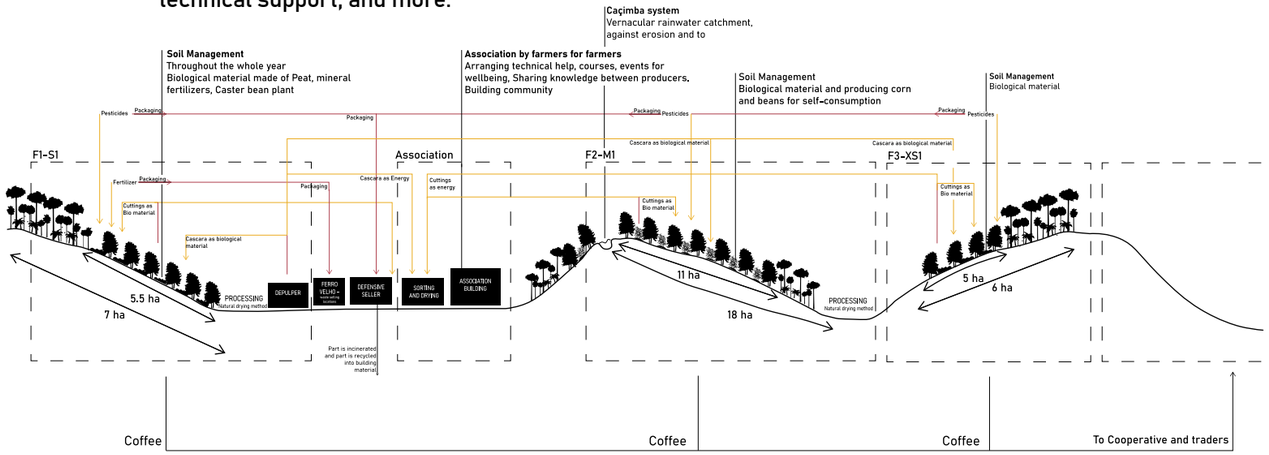
One important stakeholder not to forget is the consumer. Individually, they might not have power, but as mentioned before, marketability is an important challenge, and as a group, consumers have the buying power.

It becomes clear that an integrated approach is necessary that includes all stakeholders, builds up smaller farmers and workers, and convinces consumers, with the right policies and regulations from the government to achieve systemic and impactful change.

Case Study Farmer Type S

Small coffee farmers in the region typically have 0 to 10 hectares, and these types are localised in the most mountainous terrain. These smaller farms are integrated in nature but use sun-grown methods. Often, they are surrounded by multiple other coffee farms. These farms will use hand machines for harvesting, but manual labour where the surface types are too steep or rocky. These farms use their cuttings and cascara on the soil and as energy during processing. No biological material goes to waste. However, it could be treated to increase its profitability. These farms use biological materials on the soil to protect it, and, at times, use covercropping methods.

A common thing in this region is that smallholder farms officially owned by one family member are very tied to other smallholder farms from the same region. They will process their coffee in the same location, for example. Otherwise, when small farmers do not have their own processing site, they can use, for example, that of their neighbours. Coffee always arrives at the cooperative green and processed, ready for the second round of processing. These farmers are very dependent on their cooperative relationship for further reprocessing, as well as the storing and exporting of their coffee. The relationship to an association is very mixed and depends on the municipality and specific location, but when it does happen, like in this example, it has a lot of benefits. Through this association, F1-S1, F2-M1, and F3-M3 are connected, and they get a lively community centre, with community events, mental and physical health programs, technical support, and more.

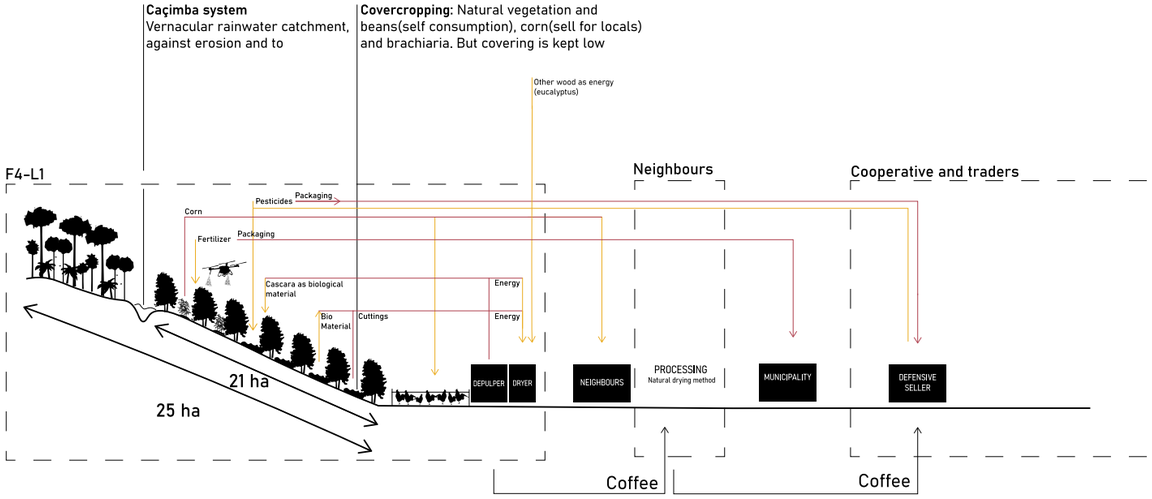


Section of group of small and mid-sized farms (Based on Interviews)

Case Study Farmer Type M

Mid-size farmers are from 10 to 50 hectares in size. These farms still harvest with hand machines, since the region is so mountainous that a completely mechanised harvest is impossible. However, machinery for other parts of the farming process is often possible, like a small tractor. These farms are more high-technology, using techniques like drones (F4-M1), which indicates a higher capacity to invest and experiment. However, they are still using fully sun-grown methods. These farms widely use some type of cover cropping or biological material, and usually have done so for a few years.

This specific example is a mid-size farm experimenting with the distribution of pesticides through drone usage. It has a corn intercrop in one of its coffee plots for self-consumption, and sometimes gives it to cattle and neighbours locally. They still sell most of their coffee to cooperatives, but process their coffee into green coffee. For them, accessibility is a problem in getting enough labour, for example. They were interested in trying new things, like composting. However, the shortage of labour and decreased productivity were the biggest reasons not to, at the moment.

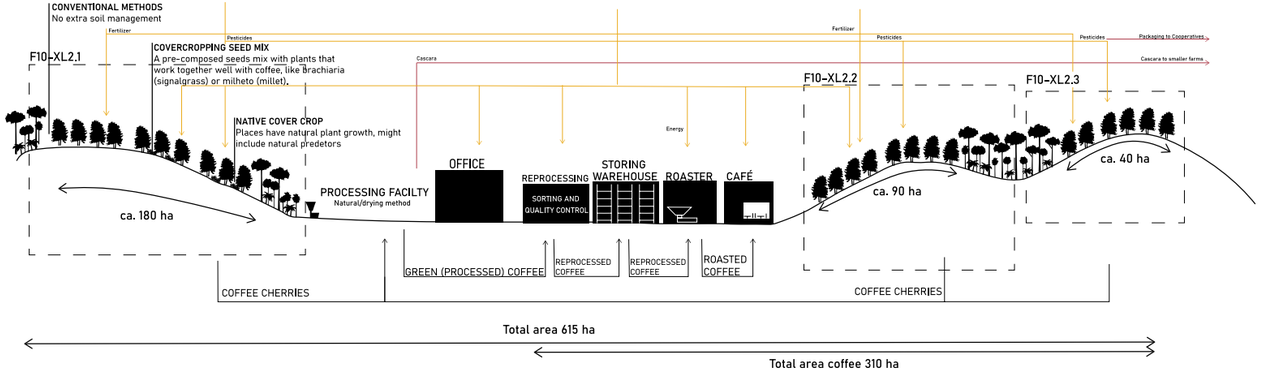


Systemic section of mid-sized farm (Based on Interviews)

Case study farmer type L

These farms, of more than 50 ha, have the highest capacity for change, but are not necessarily most likely to implement sustainable change. They have the capacity to buy extra land (F8-XL1) and extra inputs as defined by their conventional methods. Where possible, they will implement mechanisation. However, since this region is mountainous, that is not a given. They are less dependent on cooperatives (F10-XL2) and will definitely have their own processing site. Often they have extra functions like a roastery or a warehouse.

This example farm was one within a company that owns three farms. This one of about 180 ha was the biggest of the three, and was only three years old. It consists of multiple smaller farms, bought and then put together. In new plots on the farm, experiments were done with cover cropping and biological material. However, these methods are newer in these bigger farms. The landscapes are large and stretch whole mountains, including a small percentage of Atlantic rainforest. This farm group was an organised company that took all steps in the value chain themselves, being almost completely independent from cooperatives.



Systemic section of large farm group(Based on Interviews)

Summary of the Research Results

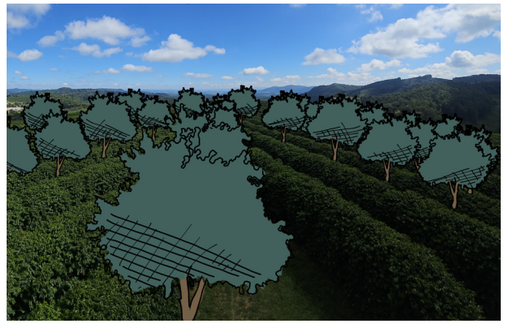
From the site analysis, interviews, stakeholder analysis and multi-criteria analysis, it is clear that an integrated approach involving all stakeholders is essential for a successful transition in the region's coffee sector.

The research shows that the sector faces serious environmental, economic and social challenges. Climate change is already impacting coffee production, and while some adaptation is present, a deeper systemic shift is needed, which reduces external dependencies and aligning policies to support sustainability.

Economically, producers remain focused on yield due to low coffee prices and insufficient returns for sustainable practices. Without smore substantial incentives, the transition to circular methods remains out of reach for farmers. Socially, unsafe labour conditions and limited institutional support for small farmers further complicate change.

The multi-criteria analysis highlights that large farms cause the most environmental harm but also offer the greatest potential for impact if reformed. Small farms, despite their lower footprint, face stronger economic and social barriers and need targeted support. Mid-sized farms show moderate capacity and challenges, requiring tailored strategies to enhance sustainability.

Based on this analysis, each farm type requires a tailored approach. The following vision statements reflect the specific challenges and opportunities identified for small, mid-sized and large farms, offering targeted directions for a circular transition.

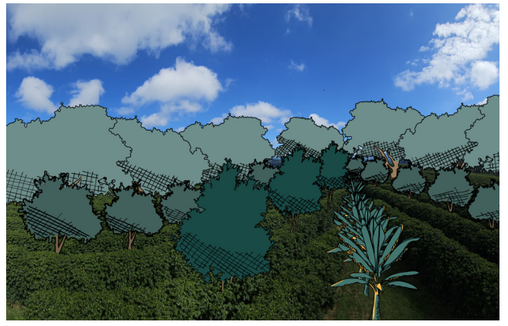


CASE STUDY FARM TYPE S

Smallholder coffee farmers thrive through strong community networks and shared circular practices. By building collective capacity, sharing resources, and working together, these farmers can overcome individual limitations and create resilient systems for a just transition.

CASE STUDY FARM TYPE M

Medium-sized coffee farms as connectors and innovators in the transition to circular agriculture. These farms balance productivity with environmental and social conditions, pioneering in innovations or supporting smaller farms through knowledge exchange and collaboration.



CASE STUDY FARM TYPE L

Large-scale coffee farms as leaders in the transformation toward circular self-sufficiency. With the resources and infrastructure to adopt diverse, regenerative practices, these farms have to reduce dependency on external inputs and avoid environmental harm. As knowledge hubs, they can support regional change by setting an example in fair labour practices, ecological restoration, and systemic circular innovation.

Impressions of regenerative agricultural methods

Designs

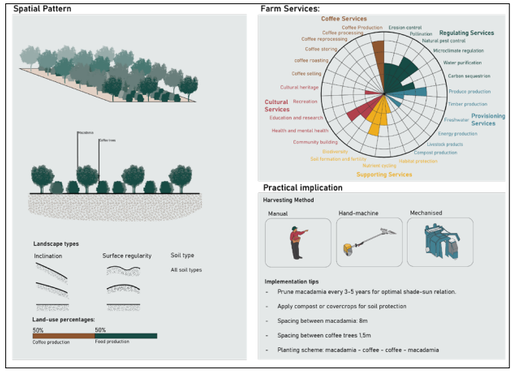
In this chapter, the conclusions of the research results will lead to spatial designs. These designs consist of a toolbox for farmers transitioning towards circular practice. The toolbox consists of multiple typologies, for agricultural methods and extra intervention typologies to complement these practices. This chapter will go through the typologies, present a methods for choosing the right pathway per farmer and will show show examples of pathways. Ultimately this chapter makes suggestions for policy and regulation that support farmers in the transition.

Agricultural Typologies

The agricultural typologies show the alternative coffee-producing cultivation methods that farmer can choose from in their transition towards a circular farm, consisting of multiple regenerative agricultural methods.

The next pages will show the agricultural typology cards, which include in detailed info, including their farm services, possible landscape types possible harvesting methods and recommendations for implementation.

These typologies will be complemented by intervention typologies, that have various functions and benefits. In future steps of making the toolbox these typologies would also get a typology card.



Agricultural typology cards

FARM SERVICES

The agricultural typology cards will include farm services diagrams.The farm services diagram will give an overview of the values of the typologies, allowing one to compare the pros and cons of choosing the pathway towards transition. The typologies of a new coffee farm include five topics: provisioning, regulating, cultural, supporting, and coffee services.

PROVISIONING SERVICES

These services describe the production outputs of a typology, excluding coffee production. This service offers an overview of the most direct type of income for farmers through producing fruits and vegetables, wood, energy or water. These types offer the most direct kind of economic return in the current system, or help a farm become more self-sufficient, needing less outside help.

REGULATING SERVICES

These services focus on maintaining ecological processes and regulating ecosystem resilience (Goel, 2024). If these processes are adequately maintained, adaptation to climate change is a significant benefit. Negative externalities, like emissions and pollution of local waterbodies, will decrease. These services rely heavily on agricultural methods but can also be topped off with environmental intervention typologies focusing on buffering or filtering.

CULTURAL SERVICES

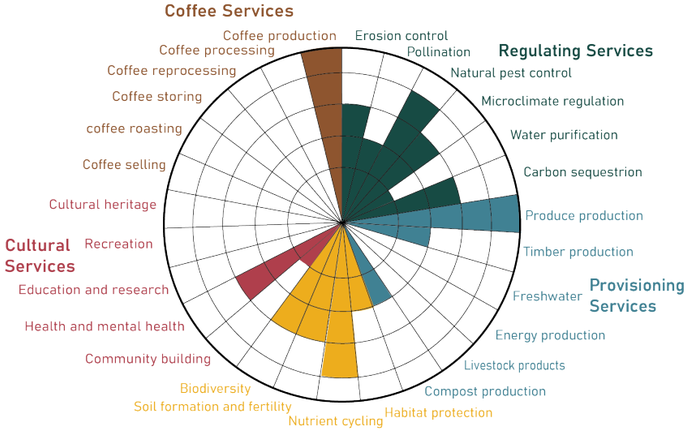
Cultural services account for the non-material values that benefit human life and health (Goel, 2024). This section addresses the benefits people can obtain from the typologies in education, health, community, cultural, and recreational values. These services mainly have a social impact.

SUPPORTING SERVICES

These services support ecosystem functionality by protecting vital ecosystem cycles and properties (Goel, 2024). Due to the fragmented landscapes of the Atlantic rainforest, biodiversity and habitat protection are especially important to increase and support. The maintenance of soil, fertility, and nutrient cycles is essential for the production processes of coffee and other crops (Goel, 2024).

COFFEE SERVICES

Since a coffee farm can have more functions than producing coffee, coffee services add the perspective of the value that other functions of the coffee value chain can bring to a farmer.



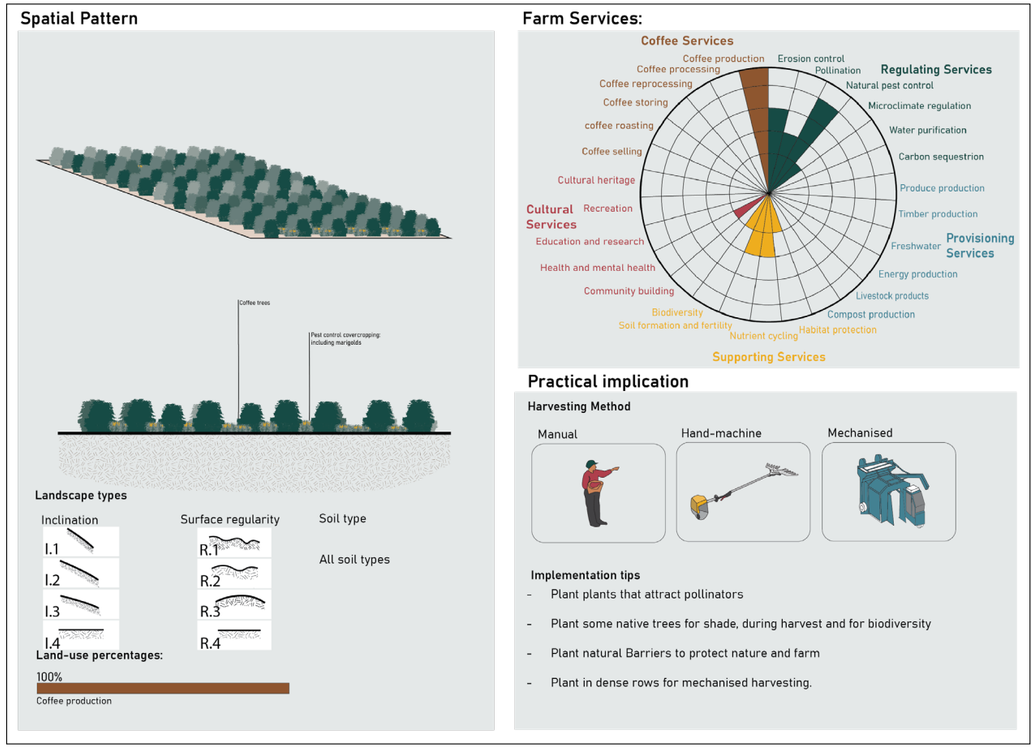
Farm services diagram

Cover cropping

The baseline typology for agricultural typologies is cover cropping. Carefully choosing the types of plants can result in many advantages. For example, plants that attract certain natural predators to pests that coffee plants are sensitive to can decrease the necessity of chemical inputs. Research suggests that using buckwheat or sunn hemp will increase the rate of natural predators, in the form of wasps and helpful mites, and decrease the amount of natural “weeds” that could be harmful to the coffee plant. Shows the potential of the biological control that this strategy can have.

Besides that, adding a cover crop increases the soil quality and promotes nutrient cycling, potentially increasing the crop yield of certain coffee varieties (De Sousa et al., 2025).

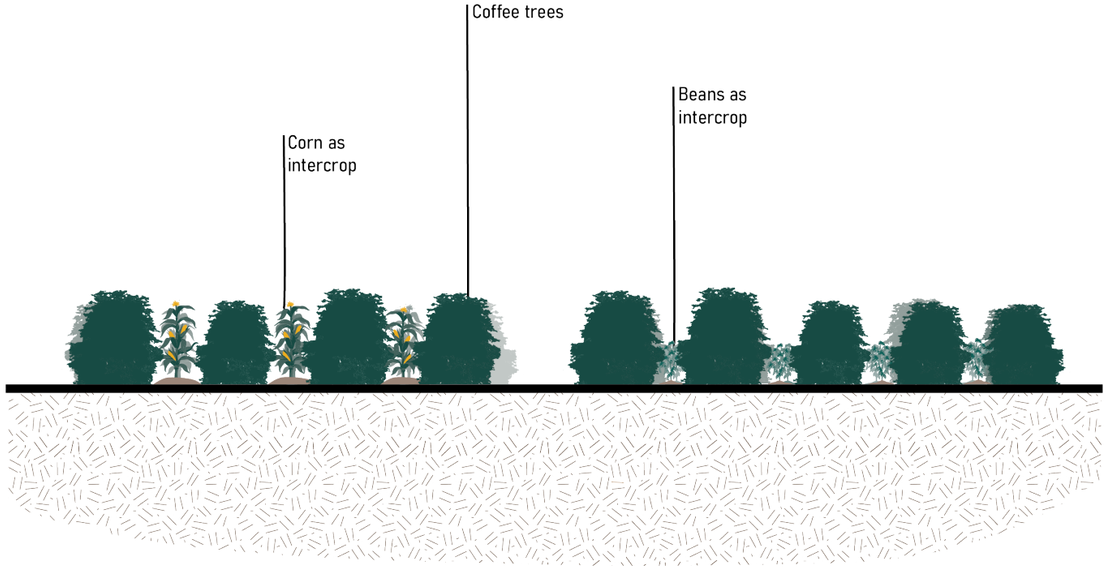
Urochloa decumbens showed good potential as a cover crop, increasing the amount of valuable nutrients, protecting the soil from erosion, and slightly enhancing the farm’s biodiversity (De Sousa et al., 2025). With this typology, the restoration of nature and habitat protection and microclimate regulating are still underserved; therefore, extra intervention to complement this typology is necessary.

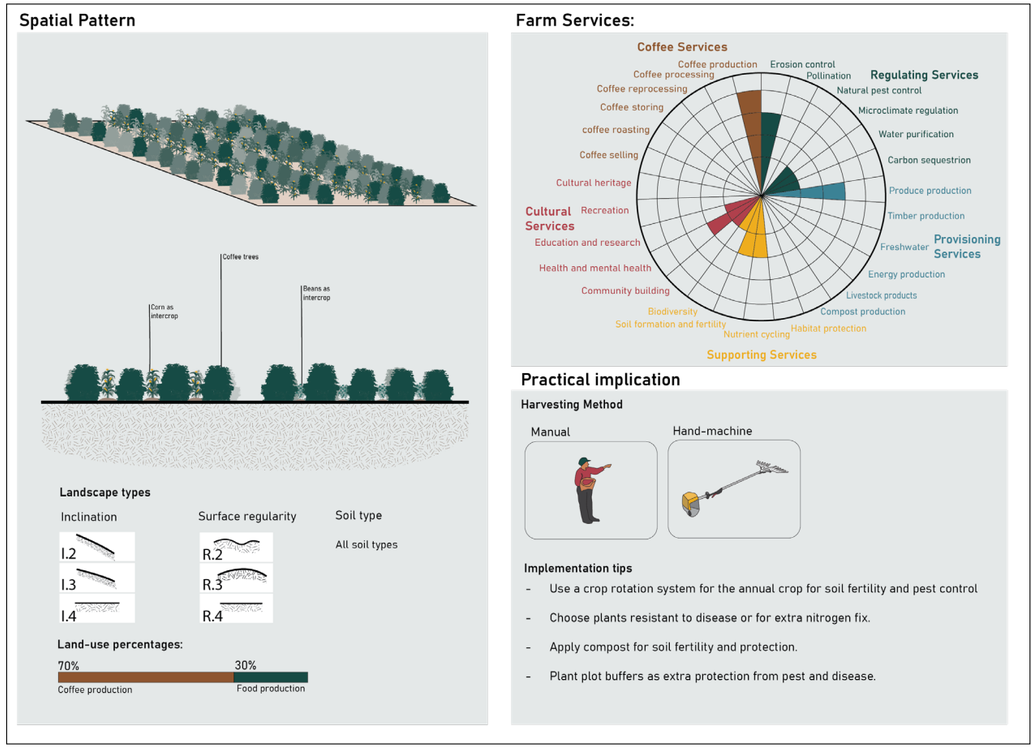


Intercropping w/ annual

Intercropping with annual plants is a good choice, and when choosing the right crops, it can have many benefits. Like covercrops, it can protect the soil, from temperature and erosion and it can be good for nutrient cycling. Legumes can be especially good choices, since they are nitrogen-fixing plants, and therefore, they add fertility to the soil (Souza et al., 2010).

To maximise soil health, it is recommended to rotate the type of crops used as an intercrop.

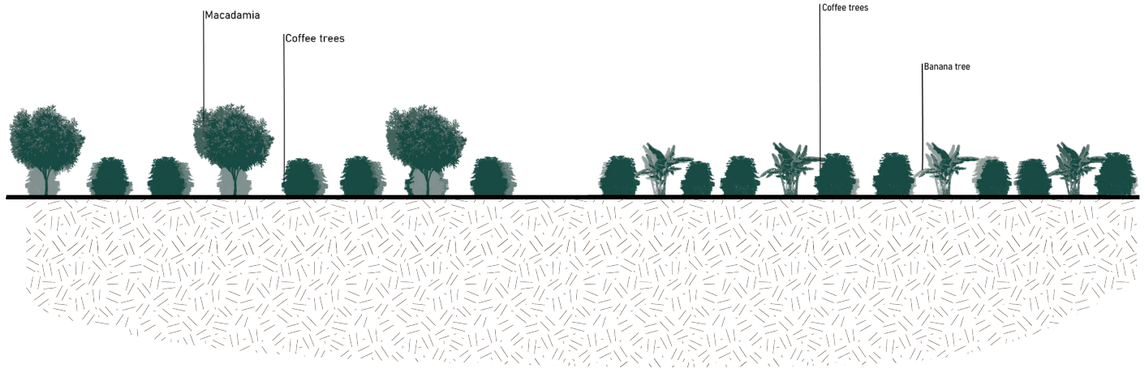


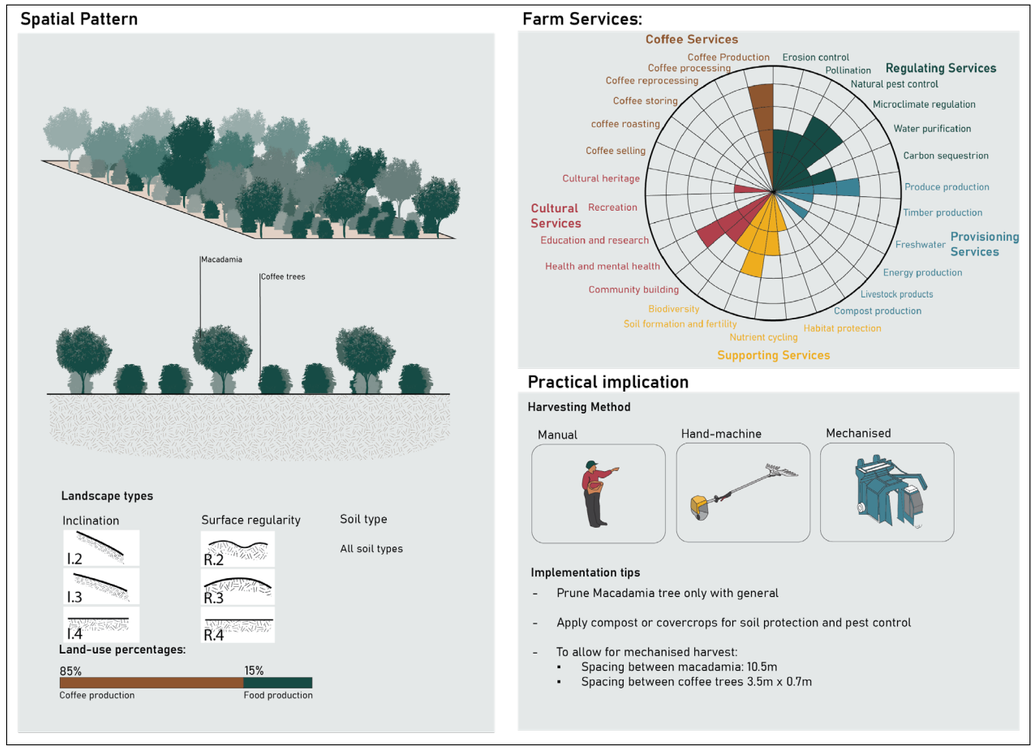


Intercropping (w/ Perennial plants)

Intercropping is a system where an increase in shade and productivity and improved soil quality can be found. Research suggests that a Macadamia tree, specifically a Hawaiian cultivar HAES 816, can be a perfect match with Arabica coffee plants, increasing the total profitability of the farm compared to completely sun-grown coffee (Perdoná & Soratto, 2016). The tree canopy allows for enough shade to decrease heat on the coffee plant, while providing enough sun for high productivity of coffee. This specific intercropping system could still allow for a fully mechanised coffee harvest (Perdoná & Soratto, 2016).

However, without extra intervention, pest control might still be needed (Perdoná & Soratto, 2016), so it is recommended that it be combined with extra intervention to decrease the pests and diseases. The addition of a perennial plant increases biodiversity and protects and improves soil quality. Intervention typologies still have to be added to integrate with nature. Other good options for intercropping are banana plants (Musa para,disiaca) which is easy to manage, produces good biological material and is very compatible with coffee (Souza et al, 2010) .

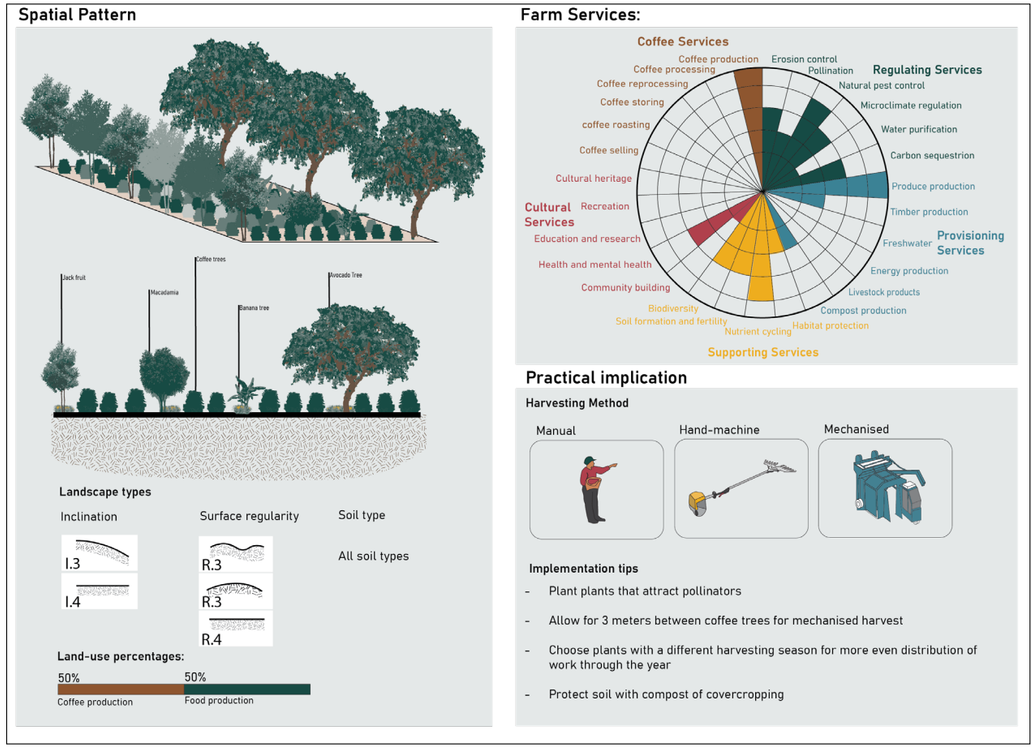




Functional Agroforestry

A functional agroforestry system mixes a structured intercropping system and a rustic agroforestry system. With the right spacing and layout, mechanisation of coffee plants would be possible. With this system, the farm's biodiversity is higher than with a singular crop intercrop; however, the diversity and complexity of plant management will increase. This system would still be applicable without the proper surface inclination, regularity and spacing for mechanisation. The structure of this system still allows for easier harvesting conditions.

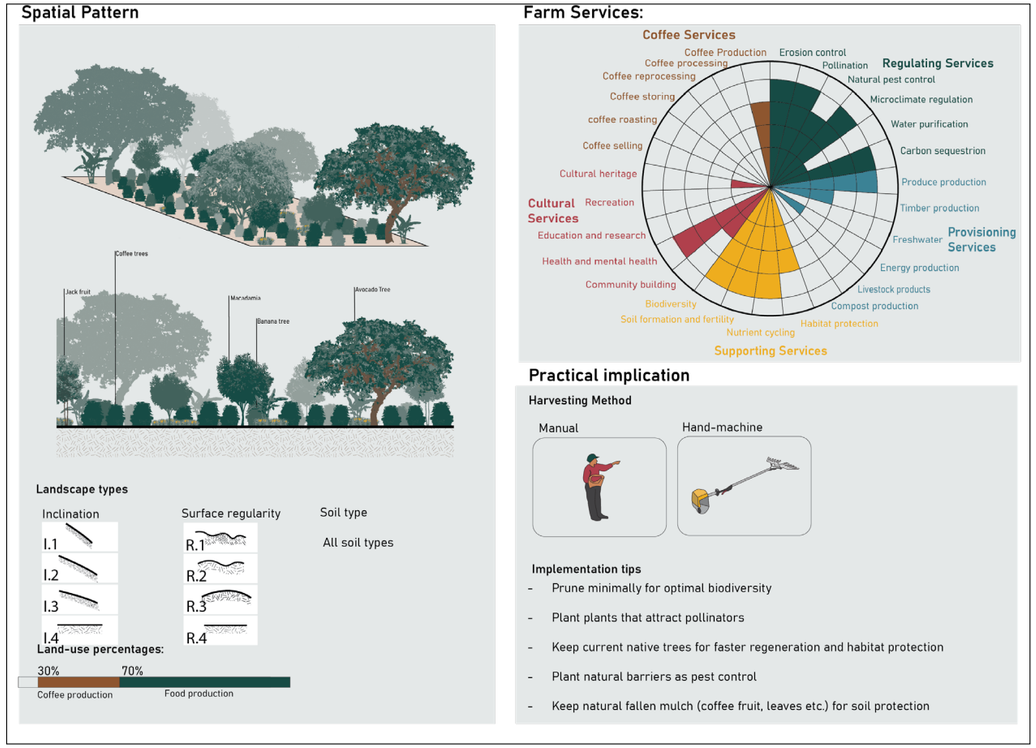
When choosing trees, allow for a mix of trees with different layers and benefits. Include trees that offer shade cover, plants that cover the soil and provide natural pest control and high biodiversity. take into account the harvesting season. If it differs from the harvesting season of coffee, this allows for a more evenly distributed amount of work. For example, choose the ice cream bean tree or Inga edulis tree that fixes nitrogen (Souza et al., 2010), and is suitable for harvest end of summer or the beginning of autumn (Organic Motion, 2025). Other good options include banana trees, for producing biological material, or avocado trees which is a valuable cash crop (Souza et al, 2010).



Rustic Agroforestry

A more rustic agroforestry system allows for a higher degree of supporting services, which creates a farm system that is integrated with nature. As a typology that offers shade and high diversity of plants this typology is one of the one effectively mitigates the effects of climate change at the same time (Gomes et al., 2020). Additionaly it is great for habitat protection and helps boost wild life (Souza et al., 2010).

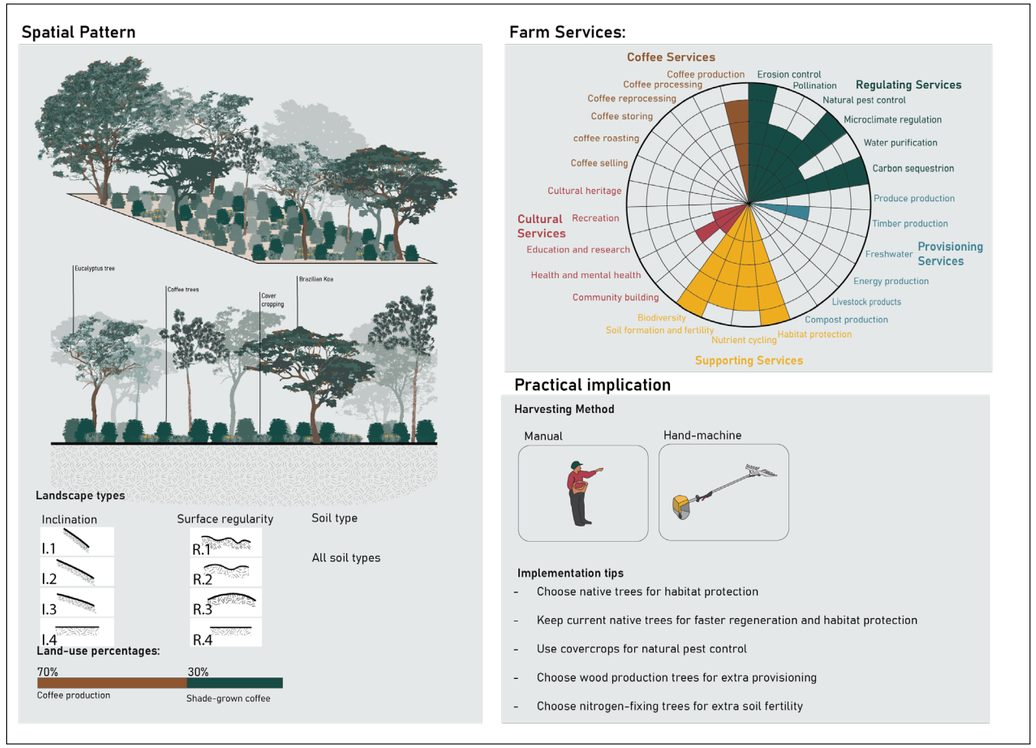
Just like the other typologies it is important to highlight that choosing compatible plants that complement the coffee trees is essential and do not compete with the coffee plants for water and nutrients (Gomes et al., 2020). This typology is based on extra production as alternative provisioning to the lower coffee production. Agroforestry has also been found to have better cost-benefits ratios, due to a decrease in cost (Souza et al., 2010). However, the amount of knowledge and skill needed for this complex system is a higher. Besides previously mentioned compatible plants,
jackfruit (Artocarpus heterophyllus), mango (Mangifera indica), Araçá (Psidium araca) and Jaboticaba (Myrciaria jaboticaba) have been mentioned as compatible with the Arabica coffee plants (Souza et al., 2010).



Shade-Grown Coffee

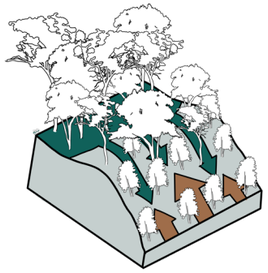
Typologies that have 30 per cent shade have been shown to have positive effects on mitigating and adapting to the effects of climate change (Coltri et al., 2019). The denser this typology, the more other positive effects a shade-grown typology can offer, like carbon sequestration and increasing the quality of coffee (Coltri et al., 2019). When this high density of tree cover is realised, this typology, therefore, has high scores of regulating and supporting services and can integrate with the Atlantic rainforest biome.

However, this increase in density decreases the productivity of coffee. This typology is not focused on the provisioning of other crops as an alternative to coffee. However, trees can be chosen that produce wood or other crops, giving the typology other economic benefits, with the diversification of income through selling or trading these crops. The papagai tree (Aegiphila sellowiana), bugweed, and Solanum mauritianum are suggested trees since they don't compete with the coffee tree too much. These more diverse agroforestry systems, do take a larger more impactful transition, with more complexity, but in the end offer high value for nature and the ecosystem.

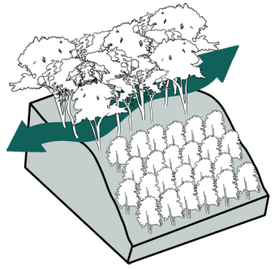


Pre-selection of Intervention Typologies

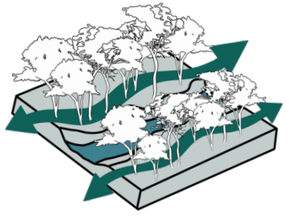
IT.1 COFFEE/MATA GRADIENT



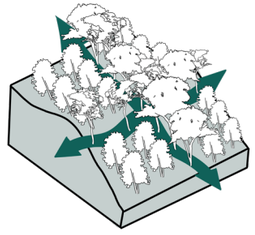
IT.2 FARM BUFFER



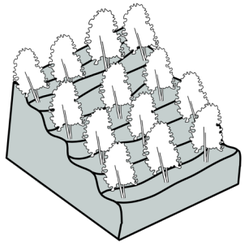
IT. 3 RIPARIAN BUFFER



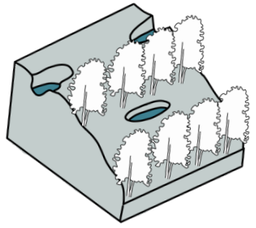
IT.4 PLOT BUFFER



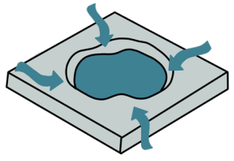
IT. 5 TERRACING



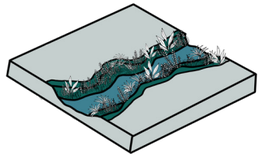
IT.6 CAÇIMBA SYSTEM



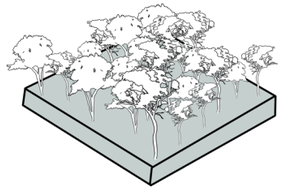
IT.6 RAINWATER CATCHMENT



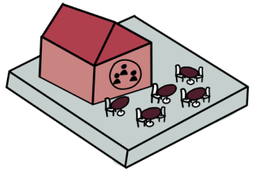
IT.7 ATURAL WATER FILTERS



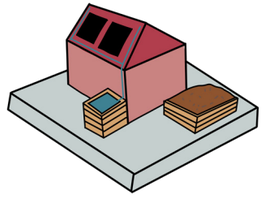
IT.8 CARBON SEQUESTRION FOREST



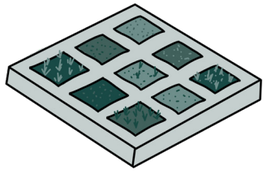
IT.9 COMMUNITY CENTRE



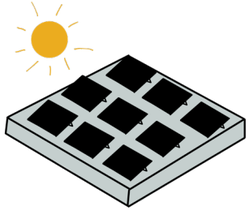
IT.10 CIRCULAR HUB



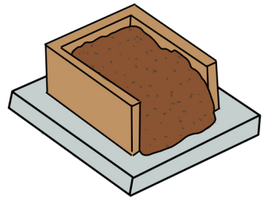
IT.11 VEGETABLE GARDEN



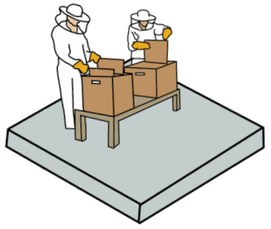
IT.12 SOLAR ENERGY FIELD



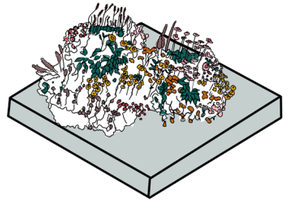
IT.13 COMPOSTING SITE



IT.14 BEE KEEPING



IT.15 POLLINATION GARDEN



Intervention typologies complement the agricultural typologgy with circular practices complementing them in a goals towards circular economy. Functions vary highly, from natural restoration or diversification of income to community building or regeneration of nutrients.

The Toolbox - How to use

As the toolbox consists of several steps, this page is a guide on how to follow these steps.

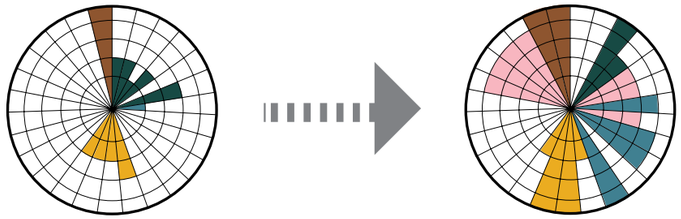
The first step of the toolbox consists of a contextual analysis, which will define the circumstances, that will differ per farm. Mostly, these circumstances cover the physical context of the farm, looking at surface and soil types and location of the farm. In addition current challenges are analysed.

Follow the arrows on the pages on the right-side to find your farm conditions and what consequence follows. The weighing table after the all four contextual analysis types show what consequences have the highest priority, based on the weighing of multi-criteria analysis. Some consequences are baseline consequences, which means they have to be completed no matter what. These are consequences that are included in current regulations, and should be addressed if this is not yet fulfilled. If these are not included in your chosen pathway this has to be added. Choosing a pathway can be done based on the weighing of the consequences. Multiple pathways might be possible.

STRATEGIC PATHWAYS

Strategic pathways per archetype are recommended based on the research results and the following vision statements, on the capacity and limitations of the various farm types.

These pathways are based on the farm services diagram. They start from the status quo following the path past typology cards filling the farm services diagram. The goals of the pathway and therefore the filling of the diagram change per pathway. The pillar coloured normally is the main goal, the pink coloured pillars are recommended additions for this pathway.



Pathway principle

How to read the toolbox

step 1: Identify your farm condition and location

step 2: Identify what consequence is linked to your conditions and location

step 3: Find your consequences in the pathway diagram and choose the pathway that fits best

step 4: Follow the pathway and choose your agricultural and intervention typologies

ICON LEGEND

CONDITION

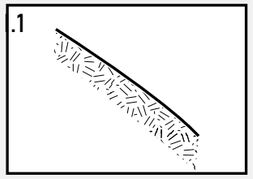
I.1	INCLINCATION LEVEL	W.1	LOCATION IN PROXIMITY TO WATERBODIES	S.7	SOCIAL CONDITION
R.1	REGULARITY LEVEL	U.1	LOCATION IN PROXIMITY TO URBAN AREAS	E.1	ENVIRONMENTAL CONDITION
S.1	SOIL TYPE	G.1	LOCATION IN PROXIMITY TO GREEN STRUCTURE		

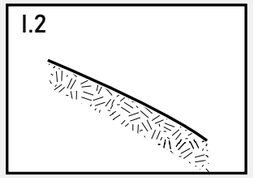
CONSEQUENCE

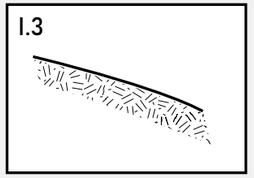
EC	ENVIRONMENTAL CONSEQUENCE	L	LIMITATION
SC	SOCIAL CONSEQUENCE		

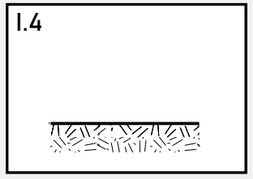
Contextual Analysis: Surface Conditions

INCLINATION

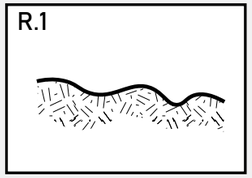


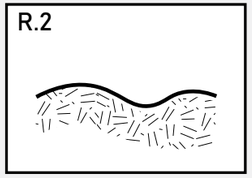


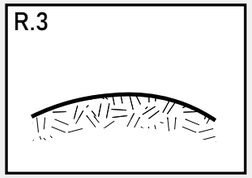


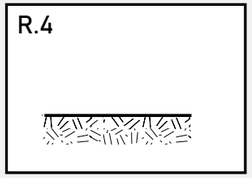


SURFACE REGULARITY

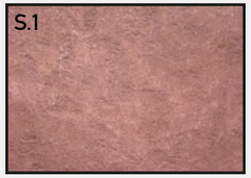








SOIL TYPE



Latosol (Celepar, n.d.)

Argisol(nutrição de safras, 2024)

Haplic Cambisol (by Author)

FARM CONDITION

CONSEQUENCE

I.1 / S.1 / S.3 + I.2 → EP EROSION PROTECTION

S.2 → WR WATER RETENTION

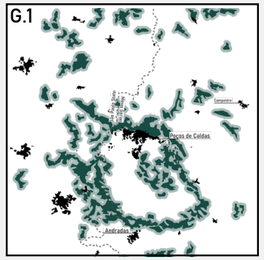
S.1 → SF SOIL FERTILITY

I.1 / I.2 / R.1 → NM NO FULL MECHANISED HARVEST

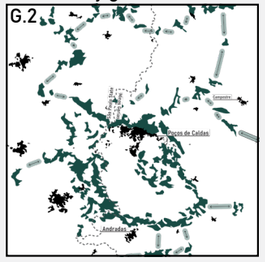
Contextual Analysis: Location of the Farm

GREEN STRUCTURE

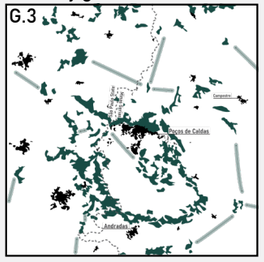
Primary green structure



Secondary green structure

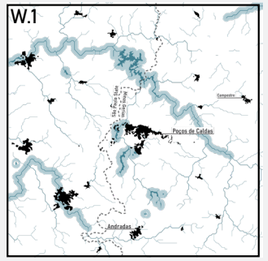


Tertiary green structure

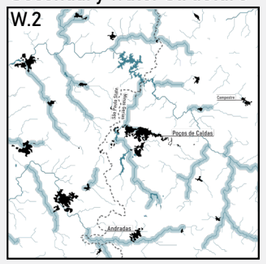


WATER STRUCTURE

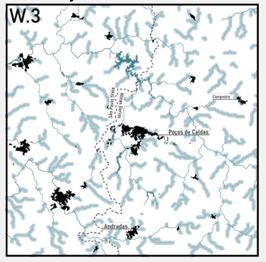
Primary water structure



Secondary water structure

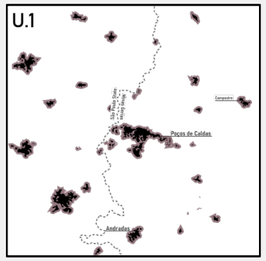


Tertiary water structure

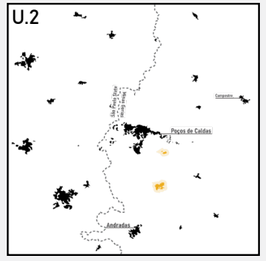


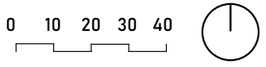
URBAN FUNCTIONS

Urban areas



Industry





FARM LOCATION

CONSEQUENCE

G.1 / G.2 / G.3 → EC — ECOLOGICAL CONNECTIVITY

W.1 / W.2 / W.3 → RB — RIPARIAN BUFFER

U.2 → IB — INDUSTRY BUFFER

U.1 → UB — URBAN BUFFERING

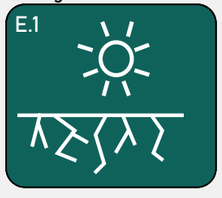
G.1 → RN — RESTORING NATURE

G.1 / W.1 / U.1 → CI — CHEMICAL INPUT RESTRICTIONS

Contextual Analysis: Environmental Conditions

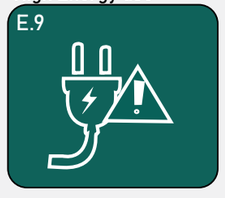
ENVRIONMENTAL CONDITIONS

Drought
E.1

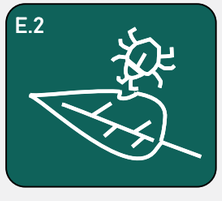


Excessive rainfall
E.5

High Energy use
E.9



Pests or Disease
E.2



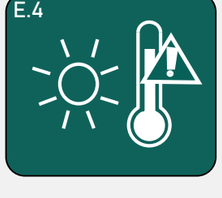
Soil degregation
E.6

Excessive biological waste
E.10

Erosion
E.3

Increased pesticide usage
E.7

Overexposure of sun
E.4



Biodiversity crisis
E.8

FARM LOCATION		CONSEQUENCE
E.1 / E.3 / E.5 / E.6	→	EP EROSION PROTECTION
E.1 / E.5	→	WR WATER RETENTION
E.2 / E.4	→	PC DISEASE PROTECTION
E.4	→	SC SHADE COVER
E.7 / E.2	→	FB FARM BUFFERING
E.7	→	WP WATER PURIFICATION
E.1 / E.6 / E.7	→	SF SOIL FERTILITY
E.9	→	EG ENERGY GENERATION
E.10	→	CP COMPOST PRODUCTION

Contextual Analysis: Social Conditions

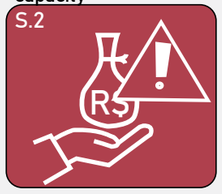
SOCIAL CONDITIONS

Scarce labour capacity

S.1

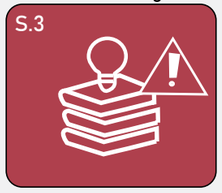
Low investment capacity

S.2



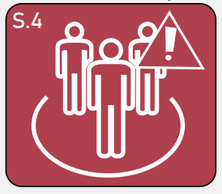
Lack of Knowledge Access

S.3



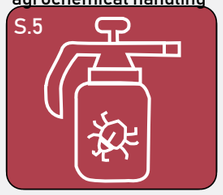
Lack of Community

S.4



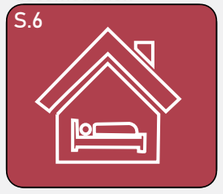
Working conditions: agrochemical handling

S.5



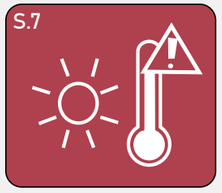
Working conditions: accomodation

S.6



Working Conditions: sun

S.7



FARM LOCATION		CONSEQUENCE
S.7	→	SC — SHADE COVER
S.6	→	AC — WORKING CONDITIONS: ACCOMODATION
S.5	→	AP — WORKING CONDITIONS: AGROCHEMICAL PROTECTION
S.3 / S.4	→	CB — COMMUNITY BUILDING
S.3	→	BK — BUILDING ACCES TO KNOWLEDGE
S.1 / E.3	→	LL — A NEED FOR A LOW LABOUR TRANSITION
S.2	→	LC — A NEED FOR LOW COST INTERVENTIONS

Choosing a pathway - Weighing of the consequences

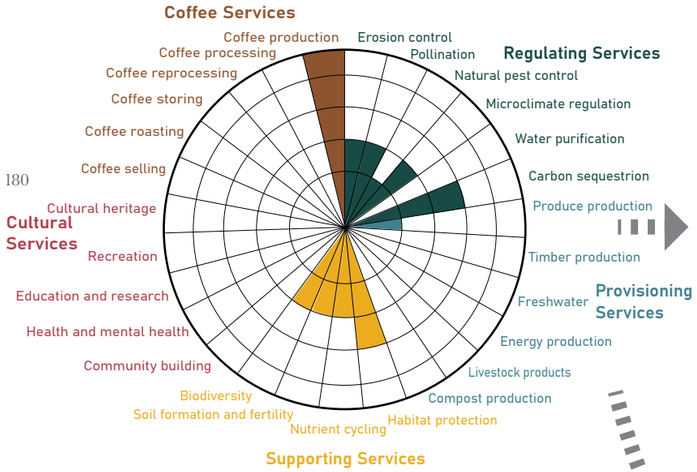
High weighing = high priority

CONSEQUENCE WEIGHING	
CONSEQUENCE	MCA WEIGHING
AC WORKING CONDITIONS: ACCOMODATION	Baseline
AP WORKING CONDITIONS: AGROCHEMICAL PROTECTION	Baseline
RB RIPARIAN BUFFER	Baseline
IB INDUSTRY BUFFER	Baseline
UB URBAN BUFFERING	Baseline
EC ECOLOGICAL CONNECTIVITY PATHWAY	1.5
RN RESTORING NATURE	1.5
WR WATER RETENTION	1.4
SF SOIL FERTILITY	1.4
DP DISEASE AND PEST PROTECTION	1.4
WP WATER PURIFICATION	1.4
CB COMMUNITY BUILDING	1.4
BK BUILDING ACCESS TO KNOWLEDGE	1.4
CP COMPOST PRODUCTION	1.4
EP EROSION PROTECTION	1.3
SC SHADE COVER	1.3
FB FARM BUFFERING	1.3
EG ENERGY GENERATION	1.3

Choosing a pathway - Preselection of possible pathway

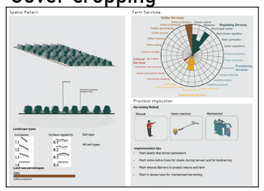
STRATEGIC PATHWAY	Deals with consequences:	Fits with limitations consequences
CASE STUDY FARM TYPE S		
SPS.1 ECOLOGICAL CONNECTIVITY	EC RN UB IB RB	NM LC CI
SPS.2 COLLECTIVE INTERCROPPING WORKING SCHEME	CB	NM LL
SPS.3 COLLECTIVY CIRCULAR COMMUNITY	CB CP EG	NM LL LC CI
SPS.4 NATURAL PURFICIATION BUFFER	EC UB IB RB AP RN WP	NM LL LC CI
CASE STUDY FARM TYPE M		
SPM.1 INNOVATER FARM	BK EG CP	NM CI
SPM.2 ECOLOGICAL CONNECTIVITY	EC UB IB RB	NM LL LC CI
SPM.3 ECOTOURISM FARM	CB BK RN AC	NM CI
SPM.4 COMMUNITY BUILDER	CB BK	NM LL CI
SPM.5 WATER BUFFER FARM	WR WP	NM LL CI
CASE STUDY FARM TYPE L		
SPL.1 SELF-SUFFICIENCY	EG WP WR CP AP EG	NM LL LC CI
SPL.2 CIRCULAR HUB	BK CP AP SF	NM LL CI
SPL.3 ECOTOURISM FARM	CB AP AC	NM CI
SPL.4 COMMUNITY BUILDER	CB BK	NM LL CI
SPL.5 ECOLOGICAL CONNECTIVITY FARM	EC UB IB RB RN	NM LL CI
SPL.6 RECLAIMING PASTURES	EG	NM LL CI

Strategic Pathways Example: Case study farm type S
SPS.3 Collective Circular Community Pathway

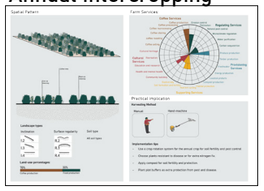


Step 1:
Agricultural typology:

Cover cropping

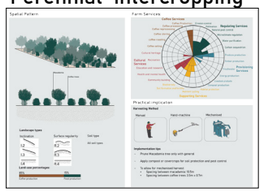


Annual Intercropping

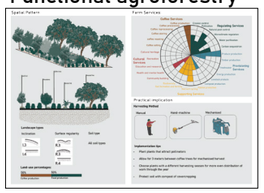


Implementation tips:
- Choose an annual intercrop to share with community, for food or animal feed

Perennial intercropping



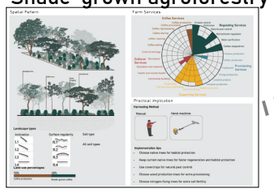
Functional agroforestry



Implementation tips:
- Choose a mulch producing plant and combine with compost production

Rustic Agroforestry

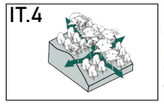
Shade-grown agroforestry



Implementation tips:
- Focus on quality of the coffee, by using selective harvesting methods
- Choose in combination with an intervention typology that produces extra income to compensate the productivity loss

Step2 :
Buffer typology

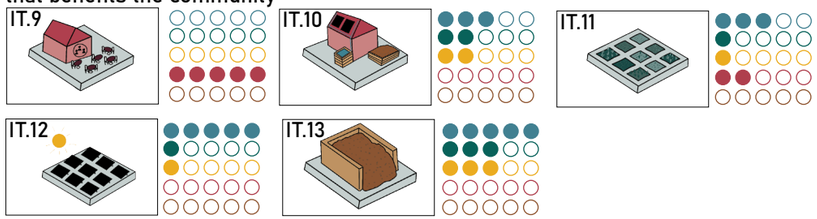
Plot buffer



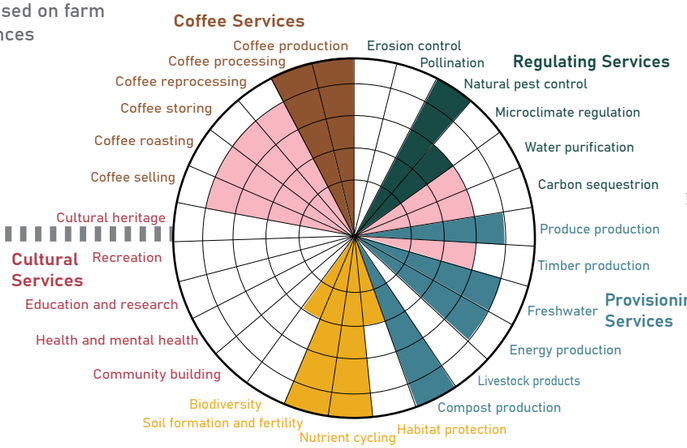
Farm buffer

No buffer needed

Step3 :
Choose one intervention typology that benefits the community



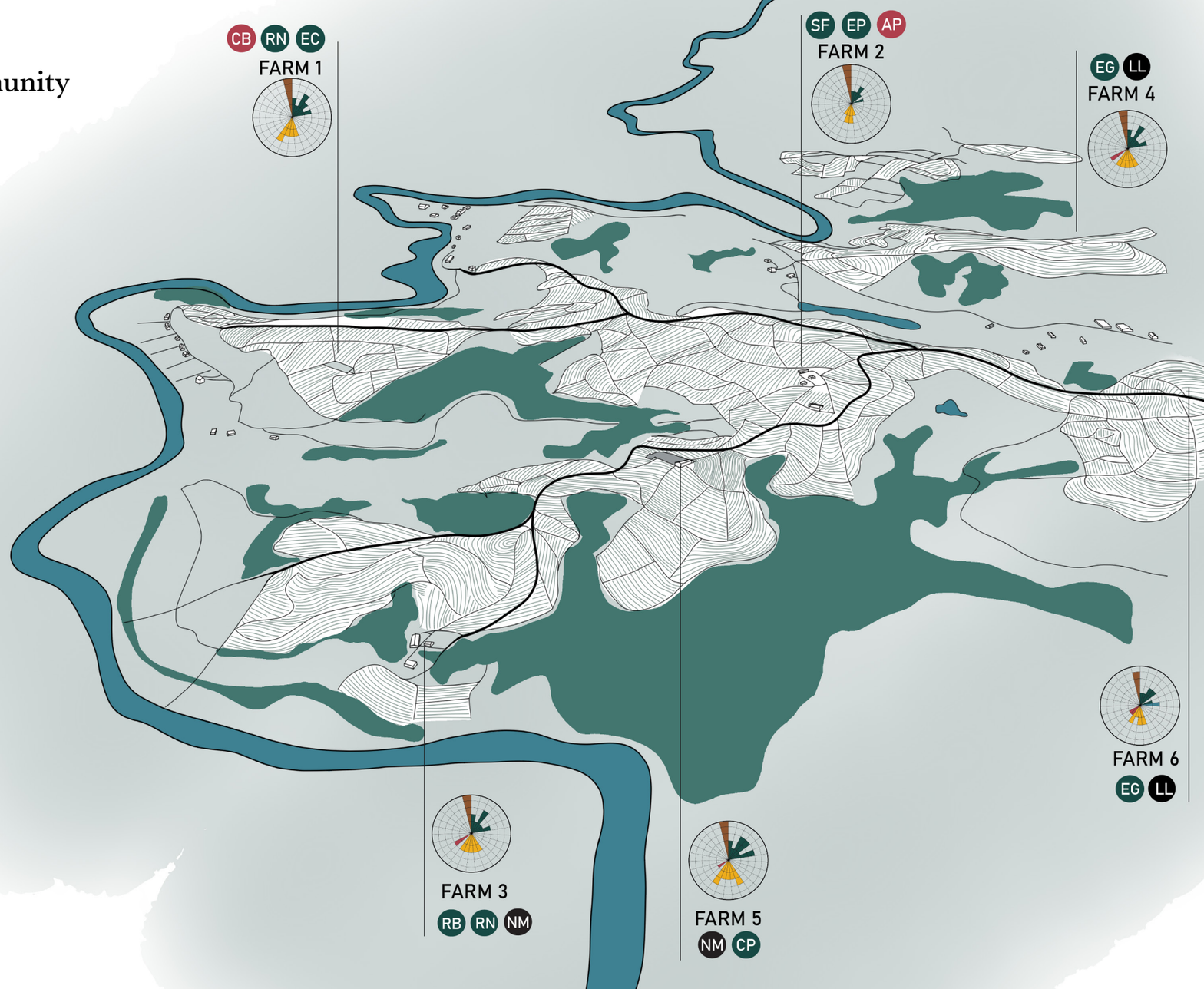
Implementation tips:
- Choose based on farm consequences



With the collective circular pathway, multiple farms work together to reach self-sufficiency in material flows. Farms each choose their own agricultural typologies and buffers according to these choices. Besides that, farms have to coordinate the flow or value they can offer to the circular community. This can be the generation of energy, the production of food, processing coffee, building a community space, etc. This also adds a social aspect to implementing the interventions' typologies and builds the community together. It is recommended that this be done as part of a local association or cooperative that supports smallholder farmers in collaborating.

SPS.3 A Current Small and Medium Farm Community

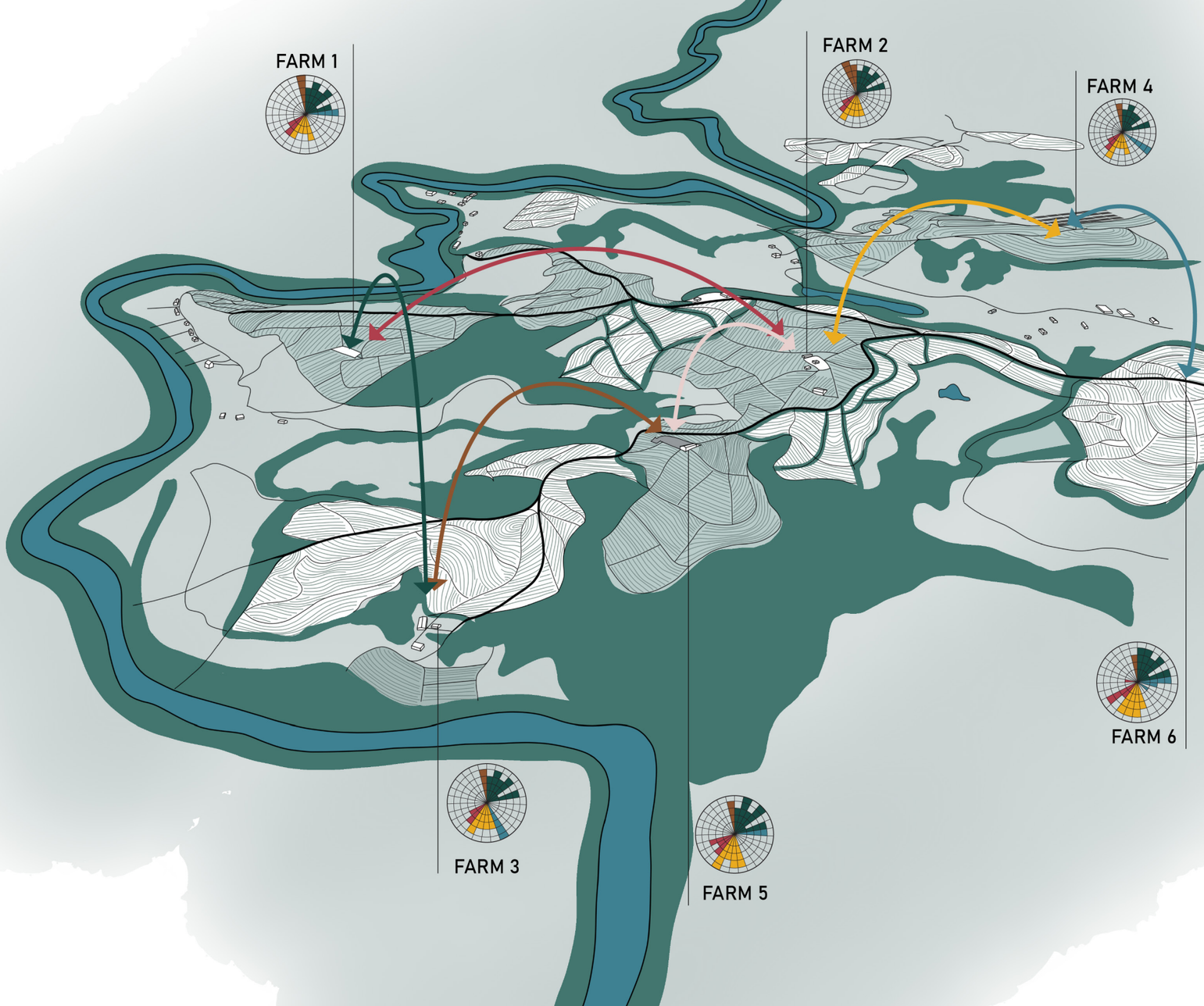
This drawing shows an overview of a fragmented landscape, showing farmers and their consequences including the farm services diagrams of the status quo.



- CB Community building
- RB Restoring nature
- NM No mechanisation possible
- RB Riparian buffer
- AP Working condtions: agrochemical protection
- SF Soil fertility
- EP Erosion protection
- EG Energy generation
- LL Low labour
- CP Compost production

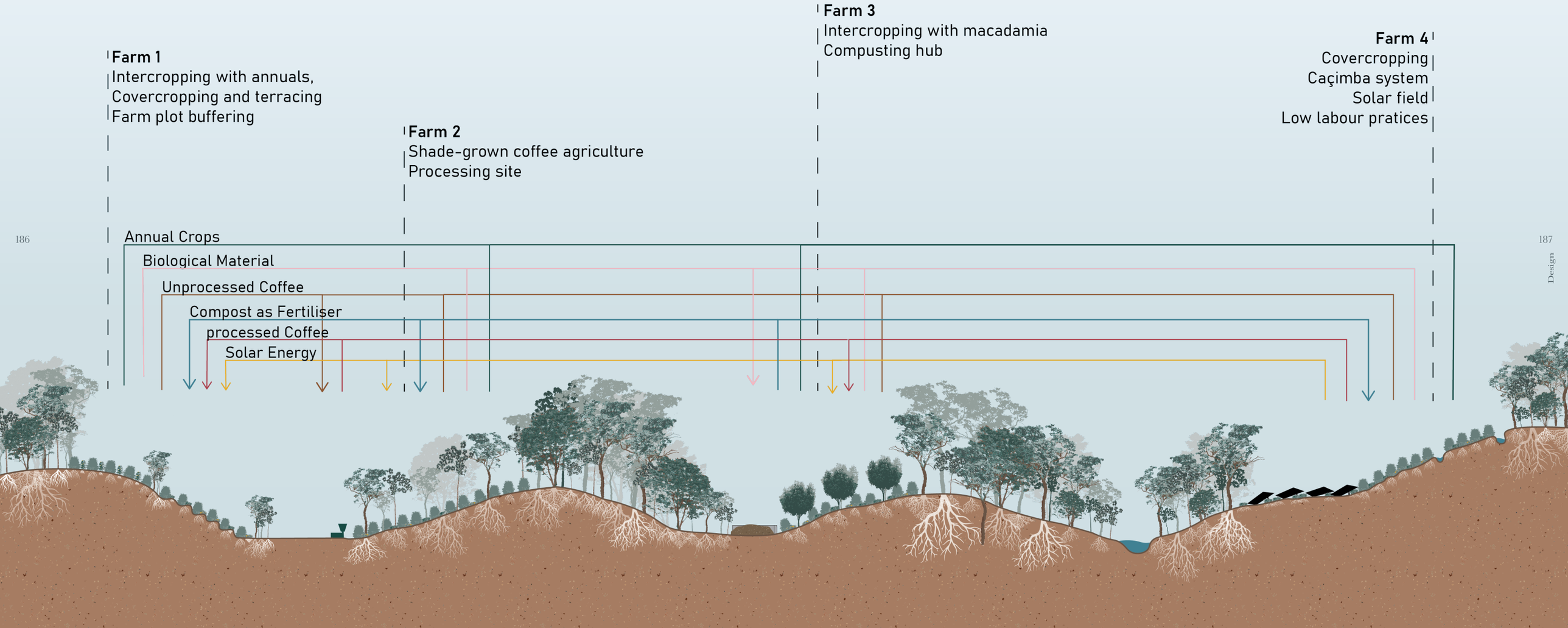
SPS.3 A Collective Circular Community

This drawing shows the vision of how a possible circular community of farms will look like. The vision is based on increasing the ecological connectivity, buffering farms, rivers and nature and collaboration between these farms.



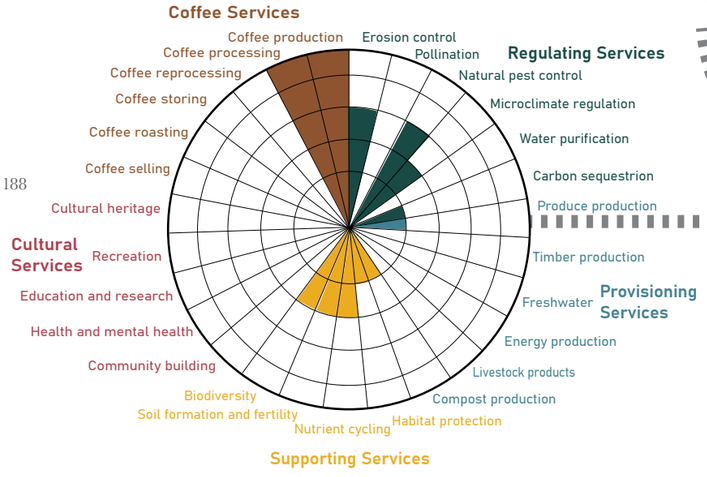
SPS.3 A Collective Circular Community

A section showing a community of small farmers that chose pathway SPS.3. All of them have one flow to share with community members, but the type of flow and intervention typology, a farm can choose based on its specfic consequences.

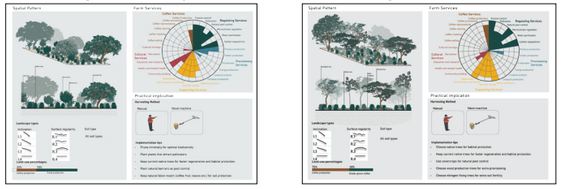


Strategic Pathways Example: Case study farm type M
SPM.3 Eco-Tourism Pathway

EXAMPLE OF CURRENT LARGE FARM TYPE

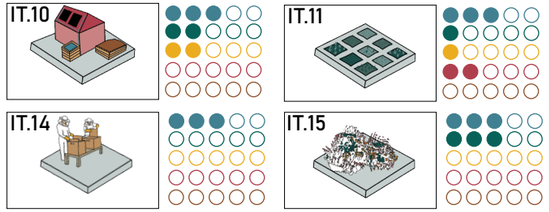


Step 1:
Recommended Agricultural Typology:
Rustic agroforestry or shade-grown coffee



Implementation tips:
- Transform the farm plot by plot

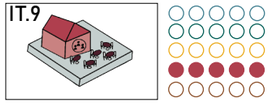
Step 1:
Add complementing intervention typologies (one of following)



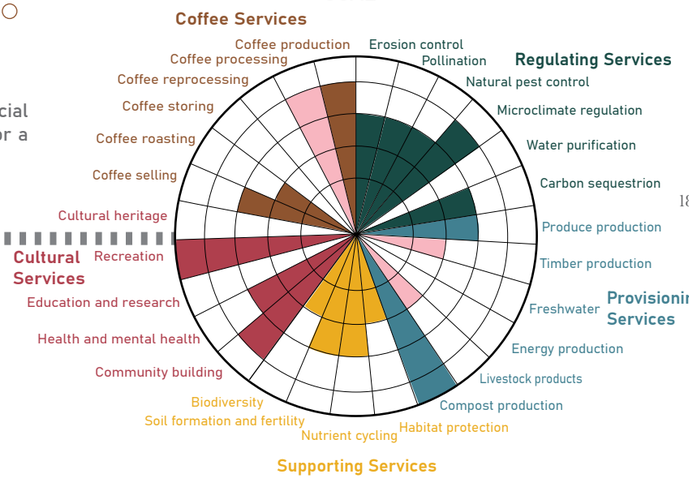
Implementation tips:
- Combine pollination garden with bee keeping
- Choose interventions to combine with social functions like community gardening or use it for a workshop

Implementation tips:
- Start tourism function, with low investment activities like tours, tastings or workshops
- Have mixed functions for the space

Step 2:
Tourism and community space



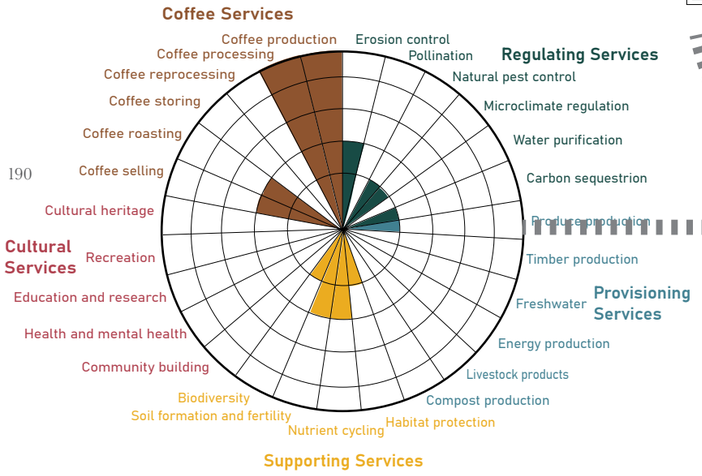
GOAL



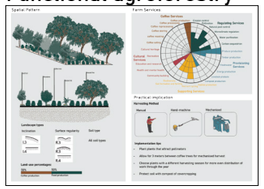
This pathway emphasizes cultural services as a primary farm output. It begins with selecting agricultural typologies that offer strong regulating and supporting services, since cultural functions also generate income here. Provisioning is lower compared to other pathways. In the short term, this could involve tours, tastings, or workshops, which require minimal investment. Long-term options include building a café or lodge to support community events, sell local products, or host seasonal workers and guests

Strategic Pathways Example: Case study farm type L
SPL.1 Self-Sufficiency Pathway

EXAMPLE OF CURRENT LARGE FARM TYPE



Step 1:
Recommended Agricultural Typology:
Functional agroforestry

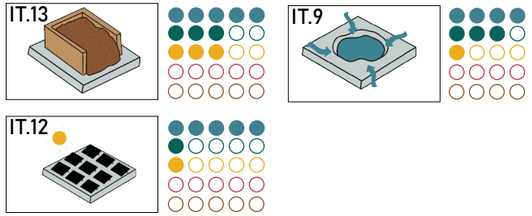


Implementation tips:
- Choose plants that decrease dependancy
  - Choose cover crop for natural pest control to decrease the dependency on pesticides
  - Choose nitrogen-fixing plant to increase soil quality

Implementation tips:
- Use carbon sequestring trees, to offset carbon used by machinery

Step 2: Buffer typology

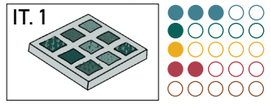
Step 3:
Production of flows



Implementation tips:
- Start with high dependency flows to have high impact quickly

Implementation tips:
- Combine with community functions to share knowledge
- Combine with extra coffee value chain functions to become for independant as a business as well
- Combine with offsetting typologies if there is still emmission or pollution (rom E.G. machniery)

Step 4: Complementing typologies



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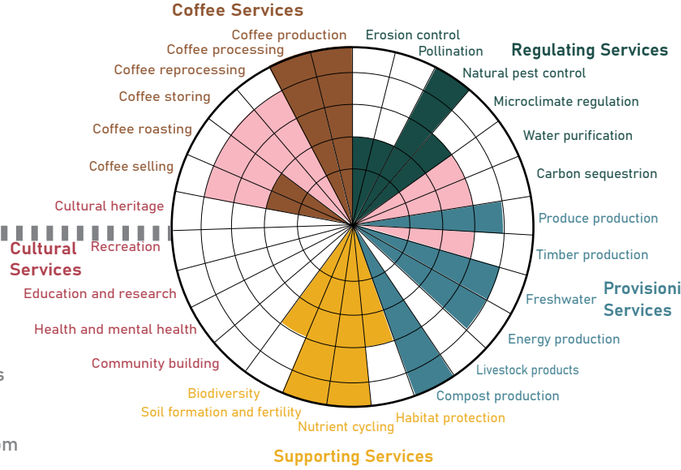


This pathway aims for full self-sufficiency in coffee and food production, reducing reliance on external inputs like water, energy, pesticides, and fertilizers. Through structured functional agroforestry and natural buffers, the farm becomes more integrated with its environment. Lower coffee yields are offset by reduced input costs and the production of additional crops.

Policy recommendations

To complement these pathways, policy recommendations are suggested to policy makers.

The coffee industry needs systemic change. These transitions of change, as well as social and environmental transitions for the coffee industry, don't happen on a straight or smooth path. They can be unpredictable and chaotic (Silvestri et al., 2021). The transitions involve the 'creation vs destruction' duality (Silvestri et al., 2021), simultaneously translating into a breakdown and a build-up pattern. On the one hand, it is essential to break down these unwanted, systemic practices, policies, and "bad behaviour" and, on the other hand, build up the development of new, more sustainable and durable practices. This results in an X-curve showing both patterns simultaneously. Policies and regulations should support these two patterns to direct the transition to systemic change.

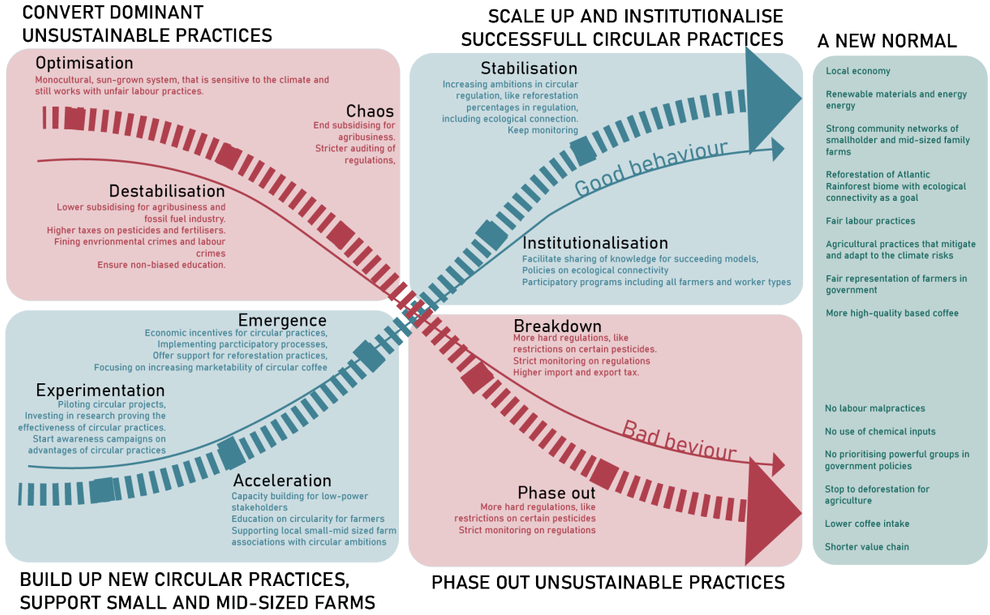
PATTERNS OF BREAKDOWN:

Breakdown patterns begin with optimisation, where a society has optimised specific processes and value chains. These processes keep getting minor improvements, and society keeps investing in a certain way of thinking and doing. However, the more we invest in these old systems, the harder it becomes to make significant changes (Silvestri et al., 2021). The coffee industry is stuck in this monocultural, sun-grown, industrial system, with unfair labour practices dating back hundreds of years. With factors like climate change, pressure is being put on these systems and patterns of breakdown start to show, emphasising that this system no longer works.

In the breakdown patterns for the coffee industry, there should be a focus on decreasing the power of the Brazilian coffee agribusiness (Fernandes, 2024), lowering the dependency on chemical inputs, fertilisers, and non-renewable energy, since the interviews concluded that all farm types have a high dependency on pesticides and fertilisers. Labour malpractices should not be possible anymore, just like deforestation.

Policies and regulations should include a stop to funding for agribusinesses and a tax increase for unsustainable practices. Current labour policies should be regulated more strictly, and fines should be imposed for crimes against fair labour. At the same time, practices dependent on non-sustainable practices and external inputs should be demotivated through higher taxes and a stop to subsidising unsustainable practices and technologies. Awareness campaigns should focus on the negative externalities that result from these non-circular practices.

The many actors in the coffee value chain lead to a lower income for farmers. Creating a more local, shorter value chain, through, for example, taxing extra steps like exporting or importing other coffee could aid a more fair distribution along the chain. However, there should be regulations in place, to secure that higher price, does not end up with farmers.



A system that calculates footprints, or a cap and trade system like the EU ETS, could support a phasedown of emissions and pollution (European Environment Agency, 2024). It works with an overtime decreasing allowance for emissions, so use of fertilisers and energy creates a financial incentive to pollute less and offers predictability in the breakdown pattern.

This systemic change will lead to a new type of system with new values, new behaviours, and a new normal. A more sustainable practice will lead to a lower total productivity in coffee; therefore, there is a need for behavioural change, also including consumer behaviour.

PATTERNS OF BUILD-UP

Simultaneously, a pattern of build-up should develop the more sustainable practices. Silvestri et al. (2021) say: “Patterns of build-up are about shaping alternative ways of thinking, working, and organising”. A completely new system has to become the new normal. Build-up patterns should focus on sustainable practices, supporting them through economic incentives and investments, creating awareness about the positive effects, changing consumer behaviour, and developing policies and regulations. Moreover, vulnerable groups with little power should be supported in making these changes.

In the context of the coffee industry, smallholder farmers and communities should be built up. Seasonal and informal workers should be supported through regulation and support of unions, and circular practices should be incentivised and supported by investments in experimentation and piloting projects. Another topic to focus on is the marketability of organic, sustainable and circular coffee. Besides that, in this region, the reforestation and connection of nature are essential, so giving a voice to nature is important. Policies should focus on reforestation programs, and ecological connectivity should be a main focus in this fragmented landscape. Incentivising these programs through economic benefits could increase farmers’ drive to make such impactful changes.

Extra support and education for the farmers are also necessary. Transition into new practices requires education and aid. Farmers should have access to the right plants for reforestation, agroforestry, or intercropping. Management of the new forested areas is complex, and with all the novelty, the need to share knowledge between field experts, farmers, policy makers, cooperatives, and other stakeholders is essential to stimulating change sustainably.

During this policy change and decrease in coffee production, there is a need for behavioural change from consumers. This is shown as a continuous event throughout the X-curve. Marketing should focus on this behavioural change towards lower coffee intake, with a higher quality and a higher sustainability rating, with local businesses as the focus. Marketing and experiments should also focus on integrating substitutions for coffee, like a local herbal tea, made in a coffee agroforest.

BRINGING IT TOGETHER

To give a new system the highest chance of succeeding, these incentives have to link together for a common goal (Blauwhof et al., 2022). When all incentives are separate from each other, they cannot accelerate and institutionalise; they will stay in the experimentation phase and will not build up enough power to change a rigid system (Blauwhof et al., 2022).
When combining the patterns of breakdown and build-up, these policies can work simultaneously towards a transition,

For example, tax increases on pesticides and chemical fertilisers can be combined with tax breaks for more circular alternatives, like composting and seed mixes for covercropping with natural pest control. In addition, fines for environmental crimes, like illegal deforestation, can go into projects incentivising reforestation or distributing plants native to the Atlantic rainforest. Or crimes regarding illegal labour practices, going to unions that support the voice of these unheard workers.

These two patterns must occur simultaneously. When an optimised and efficient system starts breaking down, the build-up pattern must also take its place to maintain balance.
Therefore, this X-curve can also be used as a framework for monitoring the strategy’s progress. It can be used to see how far you are and to see if going to the next step is possible without chaos happening too much.

Conclusion and Discussion

Conclusion

SUB QUESTIONS

1: Which circular economy practices can be implemented in the coffee value chain, and how has this been done so far?
The definition of a circular economy to thrive is broader than only material circularity. The system should be based on a society that supports it through politics, economy, and community, from social, environmental, and economic perspectives.

Circular economy practices in coffee farming include regenerative cultivation practices like agroforestry, intercropping, cover cropping, decreasing input amounts, catching and filtering rainwater, and generating renewable energy. By-products can be reused by composting or using them as biofuel, and excessive carbon emissions can be captured through buffer forests. Communities are an essential factor; sharing equipment and knowledge reduces the amount of resources needed.

Brazil's current coffee production system has already implemented some key circular practices. Throughout the case study region, there has been a recent trend of soil management through cover cropping or adding biological material on the farm. By-products from the farming system are reused on the soil, and the generated energy is partly renewable. Many coffee associations and cooperatives exist, sharing technical knowledge and building a community. However, the systems surrounding coffee production are based on efficiency and profit, benefiting large companies. Conventional, monocultural farming methods are used, with a high dependency on chemical inputs. Vulnerable groups are created, including smallholder farmers and the surrounding ecosystem. The system is focused on productivity, export, and efficiency, not on building a thriving society that is balanced between all pillars of circularity.

2: How do these circular economy practices contribute to the transition of a changing climate, and what stakeholders are involved?
The effects of climate change are already showing in Brazil, and they are getting worse year after year. Interviewees have referred to having to deal with drought, increased pests and diseases, over-exposure to the sun, which coffee trees are sensitive to and more. Therefore, there is a need to adapt to these consequences. However, it is also essential to avoid further degradation of the ecosystem and fight these issues at their root cause to mitigate these effects.

Changing the cultivation methods to regenerative farming methods that regenerate nature instead of degrading it is essential for adaptation and mitigation. These methods can avoid chemical inputs and protect coffee plants from diseases through their shade typologies and polycultural characteristics. Restoring the natural environment will also mitigate these effects as it will restore essential ecosystem functions, such as restoring rain patterns. By decreasing inputs needed for the farm, generating energy, catching rainwater, and reusing materials, a farm indirectly mitigates the effects of climate change by reducing its footprint and emissions.

Although farmers are directly responsible, external parties, like cooperative associations and government programs help by sharing technical knowledge and providing assistance. However, currently, sustainability ambitions often lack, especially with large profit-based companies. External support is available in the Brazilian government, but these funds are not fairly distributed among a representation of Brazilian farmer types. To aid the systemic transformation from conventional to circular coffee production, this funding should be fairly distributed.

3: How can the circular economy practices enhance a fair coffee value chain, and what stakeholders are involved?
As mentioned, a circular economy can only thrive based on fair values. A fair value chain should include fair distribution of burdens and benefits, Recognition of vulnerable groups and fair decision-making throughout different organisational units.

By reducing harmful chemicals and promoting regenerative practices, circular models lower the negative impact on workers and nearby communities, while also protecting nature, a key but often overlooked stakeholder. Community-based solutions and circular hubs can foster knowledge sharing and capacity building, empowering small producers to collectively act and reduce dependency on large corporations that often hold disproportionate bargaining power.

Fair decision-making across all organisational levels is essential for a circular and just system. Local associations play a crucial role in representing vulnerable voices and driving inclusive governance. Governments, too, must support this shift by implementing transparent and equitable policies prioritising circular practices and ensuring protections for marginalised groups. Ultimately, a circular economy grounded in fair values strengthens social justice within the coffee value chain.

4: Which archetype of Brazilian coffee farmers can have the most significant impact on the climate transition and social justice while transforming towards circular production?
The results of a multicriteria analysis provided a detailed overview of each farmer archetype's potential impact. The status quo was assessed through environmental, social, and economic criteria. These results show that the largest archetype (Archetype XL) currently has the most significant issues and impact when all criteria are added up and the weighing is added.

However, the analysis offers a more comprehensive overview of all archetypes and impacts in various categories of circularity. The study uncovered that when looking at social and economic criteria, the smallest archetype (XS) has the most potential for improvement with circular practices, linked to farmers' vulnerability and capacity to change. This group currently has a low income, low power, and external support. Interventions should empower this group and be based on capacity building.

5: How can these circular practices be used to implement changes in a case study of a production archetype in Brazil?
Strategic interventions should be custom-made to the specific circumstances and needs of each farmer archetype. Equally important is the contextual analysis of individual farms, which involves assessing their priorities and limitations. This includes evaluating environmental factors such as soil conditions, topography, the localised impacts of climate change, and socio-economic and labour conditions. While all farms can benefit from a shared foundation of circular practices, it is essential to recognise their diverse needs and that not all interventions are universally applicable or equally effective across different contexts.

The results of this study suggest that farm strategies should be based on farm size and contextual characteristics. Small farms are best positioned to focus on social and economic capacity building, which can be achieved through collective action and community engagement. With higher flexibility, medium farms can implement more drastic interventions in the short term and serve as hubs for innovation or be connectors within local community networks. Large farms, which have, by far, the highest capacity for transformation, can lead in facilitating regional change by becoming a circular hub, or they can aim for complete self-sufficiency. These strategic directions should be aligned with the internal drivers and motivations specific to each farm type.

MAIN RESEARCH QUESTION:
"How could the implementation of a socio-ecological spatial strategy, including circular interventions, mitigate and adapt to the effects of climate change while creating a fair value chain for coffee producers in Southeast Brazil?"
The implementation of a socio-ecological spatial strategy that includes circular practices can help coffee producers in Southeast Brazil both adapt to and mitigate the effects of climate change, while also supporting a fair value chain. Circular practices such as regenerative farming, using fewer chemical inputs, composting organic waste, collecting rainwater, and reusing by-products help restore natural systems, lower emissions, and make farms more resilient to problems like drought, pest degraded soils. These shifts also reduce the need for external resources, making the farms more self-sufficient, economically stable and sustainable for the long term. Furthermore, integrated planning that includes reforestation, agroforestry, and ecological corridors strengthens biodiversity and water regulation, creating landscape-level resilience to climate impacts.

This thesis focuses on the perspective of the Brazilian coffee farmer. It has become clear that there is a high degree of variety within this group, which faces challenges in different ways and with various capacities to change. These farmers differ in land size, access to markets, financial stability, and technical knowledge. Smallholder and family farms often face the most significant constraints, such as limited capital and low market access. These farms can benefit from working together through community networks that build social capital and increase access to training and funding. In contrast, larger farms often have greater capacity to absorb risk, adopt innovation, and invest in new practices. These actors can play a critical role in leading transitions by piloting circular approaches and supporting the broader farming community. This thesis offers a practical toolkit tailored to each farm type within the case region, designed to support decision-making and foster a just, circular transition.

Policy must support this just transition for farmers by simultaneously dismantling unsustainable practices and overly powerful stakeholders while investing in circular practices and lower-capacity stakeholders. Through tools such as targeted taxes, subsidies for agroecological methods, enforcement of fair labour regulations, and spatial planning for reforestation and ecological connectivity, policymakers can guide systemic change and aid farmers. To create a fair value chain, it is important to ensure that policy and regulations are made inclusively and transparently, and that vulnerable groups, including the deforested rainforest, are considered. Notably, the X-curve framework allows policy to strategically balance patterns of breakdown and build-up, ensuring the transition is structured. Policies can therefore lay the groundwork for a climate-adaptive circular coffee economy that is fair and just.

Discussion

INTERPRETATION AND CRITICAL ANALYSIS

This research was set out to create a comprehensive analysis and design for Brazilian coffee farms of a case study region in Brazil, grounded in circular practices. A key finding in the study was the complexity of farms and stakeholders, following the formulation of the farmer archetypes. However, it has to be acknowledged that the farmer archetypes are simplifications within the complex diversities of these stakeholders. Real-world farmers will not always fall into a defined category. However, this simplification brought structure to the complexity necessary to make strategic interventions for such a diverse group of actors.

The multi-criteria analysis (MCA) offered a systematic method to evaluate the intricate Brazilian coffee farming system. The analysis assesses the status quo of farmer archetypes to evaluate the impact and opportunities per category. However, several assumptions had to be made to conclude the analysis. National references were used for the regional MCA, which might result in a lack of nuance in the analysis, which actually does exist within the region. Besides that, often sources from reports about the Brazilian coffee industry lacks info on the size or characteristics of specific farm types. When it does, it is frequently divided into smallholder and large farms, leaving room for speculation on the definition of these farm types and where mid-size farmers fit in. This leads to a lack of nuance in the analysis because distinctions between archetypes cannot be made.

Furthermore, between the weights of the criteria there was moderate difference, as the criteria were pre-selected and all judged to be important. However, this closeness may also indicate that there is insufficient distinction between the highest- and lowest-ranked criteria, which could lower the intended impact of the weighting.

The interviews added a qualitative angle and the human perspective to this research. It is important to look at these real-world issues from multiple perspectives, through the eyes of the most affected stakeholders. However, qualitative data has some factors to take into account. The data is the lived experience of people, and at times, there is a need for interpretation. A bias may influence the results, although an effort was made to avoid that. However, the questions were selected centred on particular themes related to, for example, climate change and the circular economy, potentially suggesting a thematic preference.

There were some factors that might have influenced the representation of the stakeholder groups in the selection of the interviewees. The need for a proper representation of the stakeholder group was thoroughly discussed upfront. Still, the final interviewee group was also selected through pre-existing connections of a contact person, with a small window of time where stakeholders had to be available, due to limited time for fieldwork. The representation may create a slight bias towards certain groups.

IMPLICATIONS FOR THEORY, POLICY AND PRACTICE

This research contributes to the theory and practice of circular economy, offering a specific approach to an ordinary agricultural commodity. It gives a comprehensive overview of current circular coffee production practices in the case study region (the Immediate geographic region of Poços de Caldas) and gives the perspective of the farmers of this region, rather than only focusing on empirical research and results, and offers a spatial solution bridging environmental, social and economic topics, which are highly interdependent.

This project focused on a specific stakeholder group, Brazilian farmers, making bottom-up strategies. However, the analysis concludes that external support is needed for such a substantial transformation. Policies and practices need to be more focused on this transformation, supporting vulnerable farmers, and this project offers recommendations for these frameworks. The toolkit also offers a practical guide towards these goals, but for farmers.

FURTHER RESEARCH:

Besides this question, more research should be done to increase the potential for a just transition towards a circular economy. In the context of Brazil, extra research should be done to get a comprehensive understanding of the differences among farmer types. To find out more about each farmer's capacity and what drives them to change their limitations.

Besides that, it is critically important to quantify the results of circular interventions.
A radical transformation within a rigid system like the coffee industry is unquestionably going to have substantial barriers in its way. When farmers' livelihoods depend on it, farmers need conclusive proof that a method works. They need to have a better understanding of what is at the end of the road because of the significant risks. This research could be related to economic productivity and yield, which are important factors for farmers, or the positive environmental or social impact of circular practices.

Moreover, the toolkit should be piloted, followed by an evaluation of its effectiveness, to give users the ability to trust the system before they use it, as well as its user-friendliness. Participatory methods can be used to expand the toolkit further with more typologies, pathways, and recommendations.

GLOBAL IMPLICATIONS

Although the project did not focus directly on the global value chain, a transition within the Brazilian system will have a significant impact on the dynamics of the entire coffee industry. As the largest coffee-producing country in the world, Brazil plays a central role in shaping global supply, pricing mechanisms, and production standards. A shift toward more sustainable, circular, and socially just practices in Brazil can set a precedent and generate ripple effects across the global market. These changes challenge the current model of cheap, high-volume commodity coffee exports and place pressure on the broader system to transform.

These pressures become especially visible in the role of large corporations and traders, many of whom operate in a monopsonic context where a small number of buyers hold disproportionate power over a large number of fragmented producers. This market structure weakens short and sustainable value chains and limits farmers' bargaining power, which often discourages them from undertaking the complex transition toward circular practices. For systemic change to occur, there is a need to do further research on the role of these powerful companies more critically and to hold them accountable for their impact on producers and the environment.

As mentioned previously, consumers also play an important role. For example, the purchasing behaviour of someone drinking coffee in Europe directly influences the demand for certain types of Brazilian coffee. This raises an important question for further research and practice: how can local efforts to build fair and circular systems impact the global system, which currently rewards unsustainable, profit-based practices?

Reflection

Reflection

RELATION BETWEEN GRADUATION TOPIC, MASTER TRACK URBANISM AND MASTER PROGRAM.

The Master, the track Urbanism and the graduation topic are linked in the required way of thinking. During the project, systems thinking played a key role. I analysed the coffee industry as a whole, through which I found the most pressing issues in the industry, rather than isolating a single issue, which might have been the initial starting point. I now view the coffee value chain as a network, and see the interrelationship between actors, flows and more.

Another relation between the topic, track, and master's program is the spatial lens of the project, which offers a new perspective on existing research about coffee cultivation and circular economy. This spatial lens allows me to create concrete interventions for the complex issues at hand, which is a useful tool taught throughout the Master's on different topics. Topics that are often crossed in the Urbanism master's track and now have an important place in my master's thesis are, for example, circular economy, spatial justice, sustainable and regenerative agriculture, etc.

RESEARCH AND DESIGN

My choices for methodology have significantly guided my analysis. Although it is good to have an idea or preference when starting, having a chosen methodology can scope the project by having a pre-set choice. When starting the process, I was unaware of how complex and layered the topic would become. At the starting point, the motivation for the thesis topic was an environmental perspective, but soon I understood that social issues had an essential role in the coffee industry. This came to be one of the key aspects of my thesis.

Additionally, after the initial analysis, it became clear that one design for all coffee farmer types would not be realistic, due to the large differences between farmer types. This guided my choice to do a multi-criteria analysis and thoroughly research these differences. The multi-criteria analysis and, after that, also the case study analysis, both are guiding the design. Since the differences are so great, these analyses are essential to fit the design in its context, and without them, the design would be more unrealistic and generic. The design, therefore, has really been based on a thorough system analysis, with a focus on implementation, with the main stakeholders and their context at the forefront.

APPROACH AND PROCESS

During this thesis project, I tried multiple new things. I worked on new topics, like circular economy and spatial justice, which had been part of the master's courses, but I had not done a deep dive project. I used new methodologies and a multi-criteria analysis, interviewed stakeholders, and made a toolkit for stakeholders. Besides that, I worked in a completely different context from all other projects I have worked on before, in my bachelor's and in my master's. By trying all these new methods and doing fieldwork by myself in a new country, I have stepped out of my comfort zone and gained experiences that I value highly.

Travelling to Brazil was a key learning moment in this project. Interviewing stakeholders outside my bubble was an eye-opener. These conversations gave depth to my project and helped me understand the realities behind the data. Including the diverse perspectives of farmers and local experts showed me how essential lived experience is in shaping design strategies. Besides that, I learnt professional skills, like interviewing, data management, finding contact persons and working with external organisations. I also became much more aware of my positionality, how working from a distance (geographically and culturally) influenced my assumptions and interpretations, becoming self-aware of my perspectives and how they were shaped by my own context. While doing the multi-criteria analysis, I was forced to look at the broad picture. I had to include not only the environmental perspective but also the social and economic perspective. Balancing all these criteria was a challenge, but it taught me how to make structured trade-offs to identify what type of interventions had the most impact across different farmer types. It showed me the value of having a systemic, interdisciplinary approach and how to manage complexity.

ASSESSMENT OF ACADEMIC, SOCIETAL, AND ETHICAL RELEVANCE AND TRANSFERABILITY

The project's relevance lies in integrating circular economy principles and environmental and social aspects into the coffee sector. By exploring synergies across spatial, ecological, economic, and social systems, it offers an interdisciplinary perspective for future research.

Adding a spatial strategy is especially valuable, as this aspect is often underexplored in research. While this thesis focuses on the Region of Poços de Caldas, the methodologies practised and results found are also relevant to other coffee-producing regions experiencing similar pressures. With slight alterations to the location, the toolkit made in the project could be implemented and used by producers around Brazil. Besides, the methodology's structure is designed to be adaptable to other regions or perhaps other agricultural value chains or commodities that share similar challenges.

This toolkit aims to raise farmers' awareness of the topics that influence them so intensely and give them concrete, tangible steps to take regarding these complex issues.
The project also addresses societal challenges within the coffee value chain, most notably the unfair distribution of profit in relation to labour. It emphasises the importance of designing long-term, grounded in nature conservation and community-centred solutions, particularly for communities that currently lack a voice in society.

Farmers are the central stakeholders in this project. Since they will be stakeholders having to transition, they should be heard. Therefore, interviews with them are key data. Besides that, nature should be seen as an unheard stakeholder. Throughout history, mostly the colonial history within Brazil, the Atlantic Rainforest has been intensely exploited. Within my project, reforestation and ecological biodiversity are key to a circular, just and environmentally adaptive strategy.

From an ethical standpoint, the project deals with personal data, especially through interviews. This type of personal data had to be handled with care, both in how information is interpreted and how it informs proposed strategies. The impacts on social structures are also critical. Any suggested changes must acknowledge the transitions these communities are already navigating due to climate shifts and economic instability.

Furthermore, the topic in and of itself has an ethical quality to it. The aim is take into account key stakeholders for the betterment of our society and nature. It stemmed from a curiosity behind the drink we so often consume in Europe, and ended with a search and drive to create a valuable tool for people to transition into a more sustainable, in the broadest sense, way of producing the crop.

SELF-DEVELOPED REFLECTION QUESTIONS

How did my own biases and distance from the Brazilian context shape the project?

As a Dutch student working on a project deeply rooted in the Brazilian context, I have become increasingly aware of how my positionality has shaped my understanding of the coffee industry and the assumptions I brought into the work from an outside perspective. Before this project, I had never been to Brazil. My knowledge of the country, its culture, and its socio-political dynamics was lacking, so it was important for me to understand the historical and social layers of the country. This is one of the reasons that going to Brazil and adding the stakeholder interviews was so important as well. Finding actual coffee farmers to speak to was vital to understanding this context and their perspective. For example, without having gone there, it would have been easy to assume that a European framework could be placed in Brazil, without adaptation. However, these concepts are built on the European context and must align with local values.
This also raises an ethical question: Who am I to propose changes for a community that I am not a part of? These types of questions raise an awareness of my biases, which I took with me into the research and interviewing phases. I made sure not to take a role as an 'expert' but rather a 'researcher' interested in learning new perspectives.

How did my project reflect my values, interests and vision as a future professional?

For this master's thesis, I had the opportunity to put together a project that reflected my values and interests. It started with an interest in coffee and climate change, but when understanding the deep social and systemic issues in the chain, this could not be left out. Sustainability and equality are both values that are important to me and that should go hand in hand. This project has allowed me to dive deeper into these values and see how they can go together in a real-life project. issues
As a future professional, I would be interested in continuing to find strategic solutions for systemic change in interdisciplinary projects. I would like to work on projects that aim for long-term solutions and take into account its stakeholders.

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Appendix

Data Management Plan

Plan Overview

A Data Management Plan created using DMPonline

Title: Reimagining the Coffee Industry in a Circular Economy

Creator: Juliette Heeskens

Affiliation: Delft University of Technology

Template: TU Delft Data Management Plan template (2025)

Project abstract:

This Urbanism project looks at social and climate challenges in the coffee industry from a Brazilian farmer's perspective. This thesis offers a circular economy as the solution and tries to find the overlapping interventions that circularity can offer. This project aims to deal with these challenges holistically by finding synergetic solutions.

During the first part of the project, a multicriteria analysis will determine the impact within various archetypes of coffee farmers in Brazil, from small-scale “family” farming to large-scale “entrepreneurial” farmers, that Brazil is known for. For this analysis interviews and a survey should give an insight into the farmers' perspective, asking if current circular strategies are present and if they are interested in adapting to more circular strategies, including reasoning and challenges they are facing.

Through the evaluation of the multicriteria analysis, one archetype will be chosen for a case study in the continuation of the project. The analysis of the case study will include interviewing stakeholders present at the case study location. This archetype will be a representative case of one of the archetypes, but some questions will include more location-specific details, like spatial challenges or challenges regarding local policies.

following that, scenarios for diverse circular strategies will be designed. Lastly, an evaluation of these scenarios will be the basis for a toolbox for the Brazilian farmer archetype.

ID: 170587

Start date: 02-09-2024

End date: 20-06-2025

Last modified: 21-02-2025

Reimagining the Coffee Industry in a Circular Economy

0. Adminstrative questions

1. Provide the name of the data management support staff consulted during the preparation of this plan and the date of consultation. Please also mention if you consulted any other support staff.

1. The DMP has been shared with my thesis supervisor Arjan van Timmeren via DMPonline, and reviewed by them on **[date of consultation/review]**
2. **[Name, Surname of the Data Steward]**, Data Steward at the Faculty of Architecture and the Built environment, has reviewed this DMP on **[date of review]**.

2. Is TU Delft the lead institution for this project?

- Yes, leading the collaboration - please provide details of the type of collaboration and the involved parties below

In this project, Tu Delft is leading the research. This thesis collaborates with the Centre for Circular Economy in Coffee (C4CEC). C4CEC is a global precompetitive platform for enhancing and nurturing the circular economy principles and practices within the coffee sector. Data will not be shared directly with organisation.

I. Data/code description and collection or re-use

3. Provide a general description of the types of data/code you will be working with, including any re-used data/code.

Type of data/code	File format(s)	How will data/code be collected/generated? *For re-used data/code: what are the sources and terms of use?*	Purpose of processing	Storage location	Who will have access to the data/code?
Personally Identifiable Information (PII): Name, email addresses, company name, company location	.pdf, .xlsx	Contact information for participants taking part in interviews, received [from participant sign-ups, professional network, etc.] Informed consent forms are signed digitally and contain participants' name + email.	Location, company name: identifying the type of stakeholder to be able to group them, Name, email address, company name: for administrative purposes	TU Delft OneDrive	Juliette Heeskens + Arjan van Timmeren + Juliana Gonçalves
Audio-recordings of interviews with actors in the coffee value chain	.mp3	Interviews are conducted during on-site visits toBrazil Audio-recordings are made on an external device, before being moved to OneDrive Recordings are deleted after transcription	Capturing the perceptions on Circular economy from stakeholders in the coffee value chain	External recording device (temporary storage) + TU Delft OneDrive (primary storage)	Same as above
Anonymous transcriptions of interviews	.txt	Anonymous transcriptions created manually based on audio-recordings.	Privacy-preserving data on Circular Economy in the coffee industry from participants (experts on topic)	TU Delft OneDrive	Same as above
Anonymised survey data on opinion on circular economy in the coffee industry + location of the company + size of the company	.csv	Online survey in Qualtrics: instructions for TU Delft research will be adhered to: an anonymous link will be used and IP-address tracking will be turned off. The survey is distributed via mailing list by (Contact persona and researcher in the coffee industry in Brazil and contact person for C4CEC) : project members do not have access to this mailing list.	Capturing the perceptions on Circular economy from stakeholders in the coffee value chain in Brazil and the current use of Circular strategies	Qualtrics server (temporary storage) + TU Delft OneDrive	Same as above
Report/thesis	.pdf	Serves as a record of the process as well as documentation.	Long-term documentation	TU Delft Repository	open

II. Storage and backup during the research process

4. How much data/code storage will you require during the project lifetime?

- 250 GB – 5 TB

5. Where will the data/code be stored and backed-up during the project lifetime? (Select all that apply.)

- Another storage system – please explain below, including provided security measures
- TU Delft OneDrive

OneDrive: Primary research data storage. Only TU Delft team members (Master's student and supervisors) have access. Survey and interview data will be stored in separate folders, and within the interview folder, there are separate folders for audio recordings and anonymous transcriptions. Informed consent forms and contact information are encrypted separately from research data to minimise risk of re-identification.
External recording device: Used as a temporary storage location for recorded on-site interviews. Interviews will be deleted from the device as soon as they are moved to OneDrive.
Qualtrics server: Server of online survey platform. Temporary storage for anonymous survey responses.

III. Data/code documentation

6. What documentation will accompany data/code? (Select all that apply.)

- Data – Methodology of data collection

The data from interviews and surveys will not be shared in a data repository, however the methods in which data is collected will be described and explained in the master thesis report, which is made publically available in TU Delft Repository.

IV. Legal and ethical requirements, code of conducts

7. Does your research involve human subjects or third-party datasets collected from human participants?

If you are working with a human subject(s), you will need to obtain the HREC approval for your research project.

- Yes – please provide details in the additional information box below

I intend to apply for ethical approval from the Human Research Ethics Committee, but have not yet done so.

8. Will you work with personal data? (This is information about an identified or identifiable natural person, either for research or project administration purposes.)

- Yes

The research data collected in the project will be anonymised, but processing of personal data is required for conducting the research project.

9. Will you work with any other types of confidential or classified data or code as listed below? (Select all that apply and provide additional details below.)

If you are not sure which option to select, ask your Faculty Data Steward for advice.

- No, I will not work with any other types of confidential or classified data/code

10. How will ownership of the data and intellectual property rights to the data be managed?

For projects involving commercially-sensitive research or research involving third parties, seek advice of your Faculty Contract Manager when answering this question

The student conducts the research independently and is the owner of the interview and survey data. The anonymised interview and survey data underlying the graduation report will be included in the body and appendix of the MSc thesis, which will be uploaded with public access to the TU Delft Repository.

The intellectual property rights are framed by a graduation agreement between Delft University of Technology, myself and C4CEC.

11. Which personal data or data from human participants do you work with? (Select all that apply.)

- Telephone number, email addresses and/or other addresses as contact details for administrative purposes
- Names as contact details for administrative purposes
- Free text fields (for instance, in questionnaires) in which participants could unintentionally share personal data
- Audio recordings
- Proof of consent (such as signed consent materials which contain name and signature)
- Names and/or geolocation information as part of research data

The online survey data are collected anonymously via Qualtrics (using anonymous links and without collecting IP-addresses). Mostly multiple-choice or yes/no questions are used in the survey, to avoid unintentionally processing additional personal data. Some free text fields will be included asking questions as specific as possible, about the topic of circular economy.
Participant data for interviewees is anonymised when recordings are transcribed
Personally Identifiable Information (PII): Name, email address, work region, company name, data to identify the type of farm someone works at
Personally Identifiable Research Data (PIRD): Personal research data processed for interview participants and via the online Qualtrics survey includes:

- audio recordings (interview only)
- professional opinion on circular strategies in the coffee industry (interview only)
- occupation/part of the value chain: farmer, processor, trader, cooperative employee, seasonal/permanent worker on farms. (interview only)
- Region: to be determined. region in which they work. multiple options of coffee-producing regions in Southeast Brazil.
- Income: to know if someone earns low, middle or high income, no specific numbers are asked.
- perception on circular economy (survey only)
- Spatial features and conditions of the regions

12. Please list the categories of data subjects and their geographical location.

Interview participants are experts on the coffee industry in rural areas in Brazil, exact locations are to be determined but i.e. regions: Minas gerais, São Paulo and Espírito Santo.
Survey participants are residents in rural areas of Brazil i.e., Minas gerais, São Paulo and Espírito Santo.

13. Will you be receiving personal data from or transferring personal data to third parties (groups of individuals or organisations)?

- No

16. What are the legal grounds for personal data processing?

- Informed consent

The HREC informed consent guide and template will be used to create the informed consent forms for the interviewees (template 2 in the HREC guide). For the anonymous surveys, an Opening Statement (template 1 in the HREC guide) will be used in place of the explicit Informed Consent form.

17. Please describe the informed consent procedure you will follow below.

Interviews: The researcher will inform the potential participants about the goals and procedures of the research project. The researcher will also inform them about the personal data that is being processed and for what purpose. All participants will be asked for their consent for taking part in the study and for data processing by signing a digital informed consent form before the start of the interview.
Survey: For the anonymous surveys, an Opening Statement will be used at the start of the survey to inform participants about the

goals and procedures of the research project, as well as the type of information that is requested in the survey. Participants' agreement with the terms and conditions of the research is signified by clicking through to the survey.

18. Where will you store the physical/digital signed consent forms or other types of proof of consent (such as recording of verbal consent)?

Digital informed consent forms and contact information are stored in the TU Delft OneDrive and encrypted separately from research data to minimise risk of re-identification.

19. Does the processing of the personal data result in a high risk to the data subjects? (Select all that apply.)

If the processing of the personal data results in a high risk to the data subjects, it is required to perform a Data Protection Impact Assessment (DPIA). In order to determine if there is a high risk for the data subjects, please check if any of the options below that are applicable to the processing of the personal data in your research project.

If any category applies, please provide additional information in the box below. Likewise, if you collect other type of potentially sensitive data, or if you have any additional comments, include these in the box below.

If one or more options listed below apply, your project might need a DPIA. Please get in touch with the Privacy team (privacy-tud@tudelft.nl) to get advice as to whether DPIA is necessary.

- None of the above apply

23. What will happen with the personal data used in the research after the end of the research project?

- Anonymised or aggregated data will be shared with others

The anonymised research data consists of anonymised interview transcripts, anonymous survey data. This data will be used in the body of the thesis and included the appendix, but will not be shared in a data repository.

24. For how long will personal research data (including pseudonymised data) be stored?

- Personal data will be deleted at the end of the research project

Audio-recordings of interviews are deleted after completion of anonymised interview transcriptions. All other personal research data will be destroyed at the latest 1 month after the end of the project.

25. How will your study participants be asked for their consent for data sharing?

- In the informed consent form: participants are asked to give their explicit consent for sharing their (pseudonymised) personal data with restricted access with specific recipients for specific purpose(s)

All participants will be asked for their informed consent for data to be shared anonymously in the body of the MSc thesis, which is made publicly accessible in the TU Delft Repository. Participants who do not consent to their data being included publicly in the thesis will not be included in the research project.

V. Data sharing and long term preservation

27. Apart from personal data mentioned in question 23, will any other data be publicly shared?

Please provide a list of data/code you are going to share under 'Additional Information'.

- No other data/code can be publicly shared – please explain below why data/code cannot be publicly shared

VI. Data management responsibilities and resources

33. If you leave TU Delft (or are unavailable), who is going to be responsible for the data/code resulting from this project?

My supervisor Arjan van Timmeren, Professor at the department of Environmental Technology and Design, with email address A.vanTimmeren@tudelft.nl

34. What resources (for example financial and time) will be dedicated to data management and ensuring that data will be FAIR (Findable, Accessible, Interoperable, Re-usable)?

Research data are only shared within the MSc thesis: no additional resources are required.

35. Which faculty do you belong to?

- Faculty of Architecture and the Built Environment (ABE)

Mastertrack: Urbanism

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Interiew Questions with Farmers

Farm Identification

What size is the farm?
Is this a family farm?
What is the productivity of your farm? (in bags/ha
What is your harvesting method?
Do you grow any other crop, if so which way?
If you do grow another crop, which type?
Do you process your own coffee?
Do you roast your own coffee?
Do you sell and or trade your own coffee?
Do you have any other functions on your farm?
Are you connected to a cooperative?
If so, what is the size of this cooperative?
What functions does this cooperative do?
Do you share any functions or equipment with other farms?

Farming practices

have you expanded your farm in recent years?
why? E.G. due to doil degradation or loss is productivity?
Have you switched to mechanisation recently?
what have been the effects of that on your porductivity?
What have been other advantages or disadvantages?
Do you have areas set aside for (biodiversity) conservation?

Current waste management from farming and harvesting

What kind of waste do you generate from farming
Where do you dispose your waste?
Do re-use any by-product from coffee production?
If yes, what by-product and what for?
Are you connected to any industry in the region?
Are you connected to any other agricultural practices, and in what way?

Effects of climate change

Has your farm been affected by extreme weather events? like storms, floods, drought or frost?
What were the effects for your farm?
have you noticed a change in the last few years with these extreme weather effects?
How do you deal with these changes?
Have you seen a reduction on soil quality in the past years? if so, how?
Have you noticed any change in water availability in recent years?
Have you increased your use of pesticides and fertilizers because of climate changes?

Inputs

Do you know how your energy is gerenated, if so how?
What is the main water source on the farm?
Do you use an irrigation system? if yes, is it
Do you catch any rainwater? If yes, how?
Do you use pest control on your farm?
If yes, do you use it systemically or only on incident basis when neccessary?
Do you use fertilizer?
Do you use compost? if no, why not?
Do you use any other inputs? if so, which ones?

Spatial boundaries or restrictions

Is your farm located on a sloped, mountainous or flat area?
Does this cause restrictions? like not being able to drive a tractor or other machine
Is farm located next to natural areas?
Are any of these areas protected? (native vegetation or indigenous protection)
Does this cause restrictions or advantages?
Is your farm located next to any waterbodies?
Does this cause restrictions or advantages?
traders?
what kind of restrictions does this cause?
Do you face challenges with poor road conditions or lack of infrastructure?

Interest in changing to circular strategies

Would you be interested in starting to re-use by products of farming, harvesting or processing? if no, why not ?
if yes, what is restricting you right now to not do it?
What do you feel you would need to change to start reusing by-products of coffee?
Would you be interested in starting to share facilities with farms nearby? if no, why not ?
if yes, what is restricting you right now to not do it?
Would you be interested in changing cultivation methods towards more polycultural cultivation? if no why not?
if yes, what is restricting you right now to not do it?

Social Questions

Do you receive training or technical support for sustainable farming practices, pest control, or climate adaptation
Who gave you access to this training or support?
What kind of new farming techniques have you recently adopted, and where did you learn about them?
Do you get supported by local community? If so, in what way?
Do you have hired employees that have permanement contract?
Do you hire seasonal workers during harvesting season?
Do you hire through external employment agencies?
Do you have access to governement subsidies /policies? If so, which ones?
Are you included in any participatory processes of the government?
Are you supported by any other organisation?
Are there governmental policies/subsudies that motivate you for more nature-inclusive cultivation methods?
Are there governmental policies/subsudies that motivate you to re-use coffee waste?
Are there government incentives for adopting solar panels, biomass, or improving energy efficiency?
Are there governmental policies/subsudies that motivate to implement any other circular practices?
Are you certified? if so which certification?
if not, why did you not pursue certification?
What motivated you to pursue certification?
What are the biggest challenges of getting and maintaining certification?
How has certification impacted your farm's and sustainability practices?
Do receive any assistance for pursuing certification?