A shady future for Brazilian agriculture?

Obstacles to and opportunities for agroforestry as a sustainable alternative to current agricultural practices

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LUCSUS
Lund University Centre for Sustainability Studies

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Abstract: As the negative environmental impacts of contemporary agriculture become still more evident and widespread, the question of how to feed future generations while preserving the vital stability of the planet's environment is more urgent than ever. Major institutions are targeting the environmental sustainability of agriculture, internationally as well as in Brazil. Brazil is one of the largest agricultural countries in the world and also home to vast and vulnerable ecosystems of global importance such as the *cerrado* and the Amazon. In this thesis, I investigate agroforestry as a more sustainable alternative to contemporary agricultural practices in Brazil, seeking an answer to the question: what are the main obstacles to and opportunities for a wider adoption of agroforestry in Brazil? To answer this question, I synthesise the insights from 18 interviews with Brazilian agroforestry stakeholders and 57 literature sources on Brazilian agroforestry. The result is two tables with 11 obstacles and 8 opportunities, suggesting factors hindering the proliferation of agroforestry in Brazil and what potentially could stimulate it. I use the multi-level perspective (MLP) theory to analyse the case of Brazilian agroforestry as a potential sustainability transition of Brazilian agriculture, understanding agroforestry as a niche innovation challenging the socio-technical regime of agriculture in the country. I conclude that several regime tensions and niche momenta are present in Brazilian agriculture, interacting with the obstacles and opportunities to agroforestry that I identified. Although agroforestry seems to be gaining grounds in Brazil, it is difficult to say anything conclusive about whether it will bring about a sustainability transition in Brazilian agriculture. Transitions are rarely clear-cut nor well-defined and furthermore they are often difficult to identify in real time. However, it seems probable that a transition towards more sustainability will happen eventually, although the scope and pace is uncertain. Finally, it is worth considering that production-side approaches, such as agroforestry, alone cannot guarantee future food sufficiency. An increased focus on the impact of dietary behaviour and food waste must accompany a more sustainable production.

Keywords: agriculture, agroforestry, sustainability transitions, multi-level perspective, Brazil, sustainability science

Wordcount: 13,714

Resumo: Enquanto os impactos ambientais negativos da agricultura contemporânea ficam cada vez mais evidentes e extensos, a pergunta de como alimentar gerações futuras e ao mesmo tempo preservar a estabilidade vital do meio-ambiente se torna mais urgente do que nunca. Muitas instituições chaves estão abordando a questão da sustentabilidade da agricultura, tanto internacionalmente quanto no Brasil. O Brasil é um dos maiores países agrícolas do mundo e acolhe ecossistemas enormes e frágeis de importância global como o cerrado e a Amazônia. Nesta dissertação, investigo a agrofloresta como uma alternativa mais sustentável para as práticas agrícolas contemporâneas no Brasil, procurando responder à pergunta: quais são os principais obstáculos e as principais oportunidades para uma maior adoção de práticas agroflorestais no Brasil? Para responder esta pergunta, sintetizo perspectivas de 18 entrevistas com stakeholders agroflorestais no Brasil e 57 fontes da literatura sobre agrofloresta no Brasil. O resultado é apresentado em duas tabelas com 11 obstáculos e 8 oportunidades, indicando fatores impedindo a proliferação de agroflorestas brasileiras e fatores que poderiam estimulá-la. Utilizo a teoria do *multi-level perspective* para analisar o caso da agrofloresta brasileira como uma potencial transição para a sustentabilidade na agricultura brasileira, entendendo agrofloresta como um nicho desafiando o regime sócio-técnico da agricultura do país. Chego à conclusão de que várias tensões de regime e vários momentos de nicho estão presentes na agricultura brasileira, interagindo com os obstáculos e as oportunidades que a agrofloresta enfrenta, conforme identifiquei. Mesmo que a agrofloresta pareça estar se fortalecendo no Brasil, é difícil dizer se ela acarretará numa transição para a sustentabilidade no âmbito da agricultura brasileira. Transições raramente são nítidas ou bem definidas e geralmente são difíceis identificar enquanto acontecem. Porém, parece provável que uma transição para um futuro mais sustentável acabe acontecendo, embora o âmbito e a velocidade sejam desconhecidos. Para concluir, vale enfatizar que abordagens focando na produção, como agrofloresta, em si não conseguem garantir alimentos suficientes no futuro. Uma maior atenção a comportamento alimentar e desperdício de comida precisa acompanhar uma produção mais sustentável.

Palavras-chaves: agricultura, agrofloresta, transições para a sustentabilidade, multi-level perspective, Brasil, ciências da sustentabilidade

A Dane doing research in Brazil (foreword)

Gilberto stopped the car and rolled up the window to prevent the dust from entering. With routine precision he cut down a cocoa pod and opened it with the machete before passing it to me in the low-hanging afternoon sun. Pineapple, jackfruit and bananas followed later as pleasant intermezzos in the tour of the farm, complementing Gilberto's patient explanations and answers about being an agroforestry farmer in Brazil.

Although I have been obsessed with agroforestry for several years, Sucupira Agroflorestas, owned and run by Luiza and Gilberto, was the first agroforest I ever visited. It was not the last. I had numerous doubts about doing fieldwork in Brazil instead of doing my research closer to home. Studying sustainability science and considering myself a dedicated environmentalist, I find it hard to justify the 1.274.6 kg of CO_2[1] my flight to and from Brazil emitted. And with a background in critical social sciences, I am slightly uncomfortable with being a white North-European doing research in a developing country.

But I am happy that I did. The enthusiasm, knowledge and dedication of the many people I interviewed and interacted with was deeply inspiring and the insights and perspectives I have gained from my first-hand experience with the subject matter of my thesis have been invaluable. I went with humility and have firm ambitions of channelling the results of my research back to the Brazilian agroforestry community through the production of illustrative material in the period after defending the thesis. I really hope that one or several people will end up finding the thesis useful.

I want to sincerely thank Irene Cardoso, Mário Jorge Campo dos Santos, Luiza Avelar and Gilberto Terra, Ernst and Cimara Götsch, Murilo de Lima and Paula Siqueira Pires, Rafael Tokarski, Fabiola Buriti and Renata Coelho, Eduardo Martins, Márcio Armando, Augusto Carvalho, Sofia Carvalho and Rômulo Araújo, Rodrigo Matta Machado, José Mário Lobo, Patrícia Vaz, Marco Curatella, Felipe Noronha, Paula Costa and Valter Ziantoni and the people from Agrofloresta do Futuro. For the time and effort they put in the interviews as well as help, accommodation and shared moments of thought, laughter, food and music. It has truly been a personal and emotional experience as much as an academic one.

I am also very grateful to all the marvellous people that hosted, fed, accompanied, encouraged, critiqued and questioned me during my time in Brazil. I am grateful to all my friends and colleagues at LUMES for two life-changing years, for all the shared frustration, growth and laughter. I am grateful to SIDA for the MFS fieldwork grant without which I could not have done the interviews in Brazil. Finally, I am grateful to my supervisor, Torsten Krause, to Alice, Laura and Luciana (my thesis group), to Jakob, Mauricio and a lot of other people who have helped and inspired me throughout the process of shaping this research. Thank you, very much.

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[1] Calculated with the UN ICAO Carbon Emission Calculator: https://www.icao.int/environmental-protection/CarbonOffset/Pages/default.aspx

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Abbreviations

AFOLU – Agriculture, forestry and other land use
CGIAR – The Global Research Institution for Food-Security
Embrapa – *Empresa Brasiliera de Pesquisa Agropecuária* or the Brazilian Agricultural Research Corporation
FAO – The Food and Agriculture Organization of the United Nations
ICRAF – The World Agroforestry Centre
ILPF – *Integração lavoura-pecuária-floresta* or Integration of crops, livestock and forestry
IPCC – The Intergovernmental Panel on Climate Change
MLP – Multi-level perspective
MST – *Movimento dos Trabalhadores Rurais Sem Terra* or the Landless Workers' Movement

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1. Introduction

1.1 The situation

The United Nations (United Nations, 2015), the World Bank (World Bank, 2019), the Intergovernmental Panel on Climate Change (IPCC) (Field et al., 2014) and the Global Research Institution for Food-Security (CGIAR, n.d.) all agree that 1. a major challenge for humanity is to guarantee sufficient food for a rapidly growing population and, b. the current food production system cannot continue. This is due to the multiple and severe environmental externalities it causes and as climate change will affect current production conditions significantly. Many approaches to make agriculture more sustainable exist (Crews, Carton & Olsson, 2018; Pasini, 2017; Wezel et al., 2014). Agroforestry is one particularly promising land use system with the potential to reconcile food production with the carrying capacity of the planet (Canuto, Camargo, Urche & Ávila, 2017; Clough et al., 2011; Didonet, 2015; FAO, 2017; Leakey, 2014; Wilson & Lovell, 2016). Agroforestry is broadly defined as the deliberate integration of woody perennials (e.g. trees and shrubs) with crops and/or livestock on the same land (Atangana, Khasa, Chang & Degrande, 2014). It holds the potential to slow down, stop or even reverse global trends of soil erosion, biodiversity loss and nutrient and pesticide pollution of water ways as well as mitigate climate change and provide natural pest control (chapter 2.2).

Brazil, the world's largest sugar, coffee and beef producer and second largest producer of soy and maize (Embrapa, 2018), is home to vast and fragile biomes such as the Amazon rainforest and the cerrado savanna which both are threatened by intensive agriculture and grazing (Decaëns et al., 2018; Filho, Ribera & Horridge, 2015; Hunke, Mueller, Schröder & Zeilhofer, 2015; Levy, Lopes, Cohn, Larsen & Thompson, 2018; Schultz et al., 2019). Rapid biodiversity loss (Decaëns et al., 2018; Filho et al., 2015; Schultz et al., 2019), soil degradation (Hunke et al., 2015) and CO_2 emissions (Filho et al., 2015) are among agriculture's impacts in Brazil. Agroforestry has existed in the country for millennia (Maezumi et al., 2018; Siminski, Santos & Wendt, 2016) and is currently being rediscovered as a potential pathway for Brazilian agriculture.

1.2 The thesis

I strive to answer the following question: *What are the major obstacles to and opportunities for a wider adoption of agroforestry practices in Brazil?* I draw on a literature review and data collected in Brazil through stakeholder interviews to answer it. I am using the sustainability transitions approach and the multi-level perspective (MLP) theory in particular to help me interpret my data.

In chapter 2, I present a brief background to agriculture and agroforestry, globally and in Brazil. In chapters 3 and 4, I lay out the theoretical and methodological foundation of the research. In chapter 5, I present the obstacles and opportunities that I identified and analyse them through the lens of the MLP. Finally, in chapter 6 I discuss the need to look beyond yields and implications of the results. In chapter 7, I conclude the thesis.

2. Agriculture and agroforestry in the world and in Brazil

"Satisfying increased demands on agriculture with existing farming practices is likely to lead to more intense competition for natural resources, increased greenhouse gas emissions, and further deforestation and land degradation" (FAO, 2017, p. x).

Agriculture has always affected the natural environment. In 1989, Jackson & Piper wrote an often-cited paper in which they express concern with the problem *of* agriculture, rather than with problems *in* agriculture. They see the recent development in agricultural practices merely as details in a long process of human destruction of our environment and Tilman (1998) conclude that agriculture has been the cause of soil fertility loss throughout all of human history. More recently, Crews, Carton & Olsson (2018) point out that one of the most profound problems with agriculture is the reliance on simplified production systems dependent on constant disturbance and annual variations of crops, which dates back to the first human plant domestications 10,000 years ago.

Particularly since the 1950's, a significant shift has occurred in agriculture and a substantial acceleration of agriculture-induced environmental depletion, largely due to profound changes in agricultural practices often referred to as the *green revolution* (Isgren, 2018; Tilman, 1998). Technological innovations such as genetic modification of crops, chemical fertilisers and pesticides, mechanisation and an increase in irrigation has completely altered agriculture (Crews et al., 2018; Foley et al. 2005; Isgren, 2018). The green revolution has allowed for incredible increases in yields, but at a high environmental price (FAO, n.d.; Foley et al., 2005; Isgren, 2018; Tilman, 1998).

To get an idea about the environmental impact of agriculture, the planetary boundaries-framework (Rockström et al., 2009; Steffen et al., 2015) offers a good entry point (figure 1, next page). The two most compromised of the nine boundaries, *biosphere integrity* (biodiversity) and *biogeochemical flows* (nitrogen and phosphorous), are tightly linked to agricultural activity and so are the two next-most compromised, *land-system change* and *climate change* (Steffen et al., 2015). Biosphere integrity is affected by both agriculture-related land use change and agrichemicals. Nitrogen and phosphorous are the main components of synthetic fertilisers and anthropogenic nitrogen application has risen seven-fold since the 1960's to an extent where it now equals all natural inputs (Foley et al., 2005; Tilman, 1998).

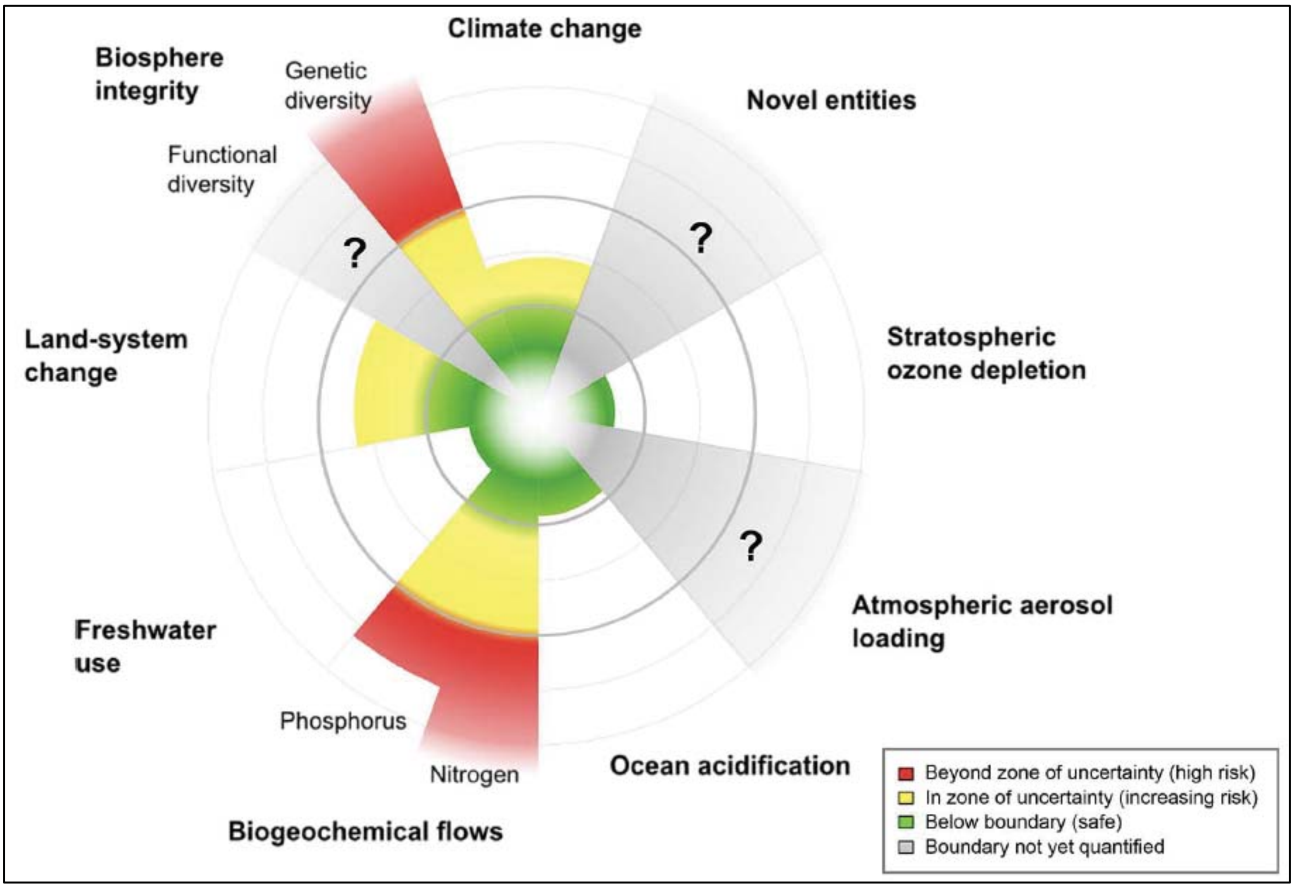

Figure 1. The planetary boundaries (Steffen et al., 2015). The three boundaries in 'high risk' and the two in 'increasing risk' are all directly related to agriculture.

Land use changes (e.g., deforestation, drainage of swamps, conversion of grasslands etc.) to make way for agriculture threaten biodiversity (Crews et al., 2018; Foley et al., 2005) and is associated with substantive emissions of greenhouse gasses such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) (FAO, 2017; Edenhofer et al., 2014; Tilman 1998). According to the IPCC (Edenhofer et al., 2014), agriculture, forestry and other land use (AFOLU) is the sector with the largest net anthropogenic greenhouse gas emission, accounting for approximately 24 % of total emissions in CO_2 equivalents. Agriculture is the largest contributor of non-CO2 greenhouse gasses with 56 % of global emissions (Edenhofer et al., 2014).

Soil degradation is another issue of great concern. Soil is incredibly important as a key element in the water cycle and as "the physical substrate for most of our food production" (Amundson, Berhe, Hopmans, Olson, Sztein & Sparks, 2015, p. 1). Water stored in soil represents around 65 % of fresh water globally and is the source of 90 % of the water used in agriculture. It also functions as a carbon reservoir much larger than the atmosphere and biosphere combined (Amundson et al., 2015). A complex set of feedback mechanisms allows undisturbed soils to preserve features such as thickness and carbon and nutrient content almost indefinitely. Cultivated soils though do not share this stability and anthropogenic interference with the soils affect their productivity and the geochemical cycles to a large extent (Amundson et al., 2015). Current agriculture practices are responsible for significant soil depletion (the loss of fertility and other qualities of the soil) and soil erosion (the loss of soil) at rates far beyond natural replenishment (Amundson et al, 2015; Crews et al., 2018; FAO, 2017; Foley et al., 2005; Tilman, 1998; UNCCD, 2017).

Water scarcity, pollution and eutrophication caused by irrigation, fertilisers and pesticides is another serious issue (Foley et al., 2005; Mateo-Sagasta, Zadeh, Turral & Burke, 2017; Tilman, 1998). Agriculture accounts for approximately 70 % of global fresh water consumption (World Bank, 2017) and leaching of agrichemicals, organic matter, nutrients, and sediments from agriculture is one of the major causes of global water pollution, exacerbating global water shortage (Mateo-Sagasta et al., 2017). Human health hazards from agrichemicals (Crews et al., 2018) and increase in resistant diseases and pests (Tilman, 1998) are other widespread and serious problems caused by modern agriculture. FAO's statement opening this chapter seems pertinent.

2.1 A brief overview of agriculture in Brazil

The Brazilian agricultural sector produces more than 400 different products and 13 % of Brail is covered by planted pasture, 9 % by cropland and 8 % by native pasture (Embrapa, 2018). The main crops in 2018 by hectares of production were soy, maize, sugar cane, beans, wheat, coffee and rice (IBGE, 2019). Brazil is the largest global producer of sugar, orange juice, coffee and beef and second largest of soy and maize and the dominating forestry crops are eucalyptus and pine (Embrapa, 2018). In 2016, the agribusiness accounted for 23.6 % of the Brazilian GDP, 45.9 % of Brazilian export value (Embrapa, 2018) and at the last national census in 2010, the agricultural sector occupied 14.7 % of the Brazilian workforce (IBGE, n.d.).

Brazilian agriculture has been characterised by considerable intensification over the past decades (Embrapa, 2018; Lapola et al., 2014). Between 1977 and 2017, the grain production increased 5 times while the cultivated area only increased 0.6 times due to technological improvements and intensification (Embrapa, 2018). The characteristics of the farmed land have changed in accordance, considering that 53 % of cultivated land was occupied by monoculture production in 1990 whereas that number was 70 % in 2011. In the same period, beef export increased 7.2 times and soybean 5.3 times and the share of genetically modified crops has risen dramatically too, all indicators of a reorientation towards large-scale commodity farming intended for export (Lapola et al., 2014).

A significant concentration of land and revenue in Brazil has occurred over the past decades (Embrapa, 2018; Lapola et al. 2014). Whereas family farms and other types of small-scale farms[2] operate more than 75 % of

[2] Lowder, Skoet & Raney (2016) operationalise this as farms smaller than 2 hectares.

active agricultural land globally (Lowder, Skoet & Raney, 2016), the "2006 national census revealed that nearly 75 % of all agricultural land (2.3 million km^2) is in the hands of large-scale commodity-oriented farmers, who own only 10 % of all farm land titles in [Brazil]" (Lapola et al., 2014, p. 29).

2.2 Agroforestry and its benefits

The intensive green revolution-style agriculture cannot continue as our primary model for food production, but what should replace it is less obvious. Pasini (2017) offers an extensive overview of various typologies of alternative agricultures such as organic, biodynamic, biological, regenerative, holistic, climate smart, conservation and agroecological agriculture as well as permaculture and agroforestry. These typologies of sustainable agriculture all aim to make human food production less environmentally destructive. While they all have their merits and deserve thorough scrutiny, I focus on agroforestry. Agroforestry is one of several management practices proposed for the future of global food and agriculture by the FAO (2017). In the context of Brazil, the Brazilian Agricultural Research Corporation, Embrapa (2018) similarly recognises the great potential of agroforestry in its 2030 vision for the future of Brazilian agriculture. But what exactly is agroforestry and what makes it a good alternative for our food production?

Agroforestry is a rather broad concept, but a common definition is that agroforestry is "land-use systems, practices or technologies, where the woody perennials (shrubs, trees, bamboo…) are deliberately integrated with agricultural crops and/or animals in the same land management unit, in some form of spatial arrangement or temporal sequence" (Atangana et al., 2014, p. 36). The word *agroforestry* is a new frame for an old picture, as the integration of trees with crops and animals is a practice considered as old as agriculture itself, practiced in all corners of the world where it is not too cold for trees to grow (Atangana et al., 2014; Wilson & Lovell, 2016; Zomer, Trabucco, Coe, Place, Noordwijk & Xu, 2014). As a modern agricultural science discipline though, agroforestry is more recent and has only become object to systematic study and improvement within the past 40 years or so (Zomer et al., 2014). The major agroforestry systems prevalent in the tropics are home gardens, perennial crop-based systems, shifting cultivation, alley cropping, improved fallow, shelterbelts and hedgerows, woody perennials on rangeland and pasture, multi-layer tree gardens and multi-purpose trees on cropland (Atangana et al., 2014).

Figure 2. An experimental agroforestry system for citrus fruit production (own photo). Fazenda da Toca in the state of São Paulo.

Multiple approaches exist for how to classify different types of agroforestry. One very common classification is based on the elements included in the system, dividing agroforestry into agrosilviculture (crops and trees), silvopasture (trees and livestock) and agrosilvopasture (trees, crops and animals), sometimes including aquasilviculture where aquaculture is combined with trees (Atangana et al., 2014; Moraes, Amâncio & Resende, 2011). Another classification approach is based on the system complexity, identifying systems in a continuum between simple consortiums (often just one tree species and an annual crop, typically grown in rows to optimise mechanisation) and complex or biodiverse agroforestry (with a high number of species, often grown in more complex spatial configurations but can also be in rows) (Miccolis et al., 2016; Padovan, Pereira, Pezarico & Otsubo, 2016). Temporal dynamics are another way of understanding agroforestry as either static (a fixed plot design that is maintained over time) or successional (mimic the dynamics of natural succession, altering the system as it matures) (Miccolis et al., 2016; Padovan et al., 2016; Siminski et al., 2016).

Considering the broadness of the concept and that the modern rediscovery of agroforestry is relatively recent, it is difficult to assess the global extent of agroforestry. However, Lasco, Deflino & Espaldon (2014) estimate that around 30 % of the global rural population is practising some type of agroforestry and Zomer et al. (2014) found that 43 % of global agricultural land can be considered agroforestry, defined as agricultural land with a tree cover superior to 10 %. Zomer et al. (2014) further conclude that agroforestry is increasing globally and is most prevalent in Southeast Asia and Central and South America.

Although agroforestry covers multiple types of systems with highly varying degrees of complexity and ecological interaction, the introduction or preservation of trees on farmland is generally understood to be associated with a wide range of environmental and social benefits. As a part of my literature review (chapter 4.1), I synthesised benefits of agroforestry from 89 literature sources (appendix 2). The literature represents a wide variety of agroforestry systems relative to the considerations of classification in the paragraphs above. Table 1 shows the primary benefits identified.

Table 1. Benefits of agroforestry identified in literature (own creation). The '# lit.' column shows the number of times the benefit was mentioned in the 89 literature sources and the '% lit.' column shows that number as a percentage of the total. The sources are included in appendix 1.

Benefit of agroforestry	# lit.	% lit.
Soil conservation	17	19
Increased soil fertility	16	18
Carbon sequestration and fixation	15	17
Biodiversity promotion and conservation	9	10
Biological pest control	9	10
Resilience of production systems and livelihoods	8	9
Increased productivity	8	9
Water conservation and improvement	7	8
Diversification of products and income	6	7
Microclimate regulation	6	7
Food security	5	6

Table 1 contains many environmental benefits that relate to the problems caused by contemporary agriculture. Nonetheless, it is crucial to be cognisant that any agroforestry system does not necessarily provide all of the listed benefits. The particular benefits brought by a given system depend on local climatic and biogeochemical conditions as well as the specific configurations of the system. This, in turn, depends on the priorities, knowledge, skills and socio-economic capacity of who is responsible for the system. It is important to bear in mind that agroforestry always must be intimately based on specific local circumstances (Coe, Sinclair & Barrios, 2014; Quinion, Chirwa, Akinnifesi & Ajavi, 2010) and that proliferating and up-scaling agroforestry is much more than a transfer of knowledge and inputs. Rather, it "involves building partnerships, assisting communities to mobilise resources, and promoting effective participation of stakeholders to test, disseminate, adapt, and evaluate new innovations in a sustainable manner" (Franzel, Cooper & Denning, 2010, p. 532).

I adopt a rather inclusive understanding of agroforestry, aligning to the definition quoted from Atangana et al. (2014) in the beginning of this chapter. Complex and agroecologically founded systems are likely to be more environmentally beneficial than simpler systems, but it seems that most agroforestry systems are superior to conventional agriculture in terms of biodiversity habitat, nutrient cycling, soil conservation, water use, carbon storage and resilience.

2.3 Agroforestry in Brazil

According to Embrapa (2018), millions of hectares in Brazil are already under some type of agroforestry management and they expect agroforestry to reach 20.6 % of Brazilian agricultural land by 2030. To talk about agroforestry in Brazil without emphasising the history of indigenous agroforestry practices would be incomplete. According to Siminski et al. (2016), archaeological studies suggest that agroforestry in south-eastern Brazil dates back approximately 2,500 years and that large areas of the Atlantic rainforest were managed in shifting agricultural systems at the time the Europeans arrived in the Americas. Maezumi et al. (2018) recently found evidence that polyculture agroforestry formed the subsistence foundation for the development of complex societies in the eastern Amazon already 4,500 years ago. In both the Atlantic and Amazonian rainforests, the arrival of the Europeans has altered the indigenous farming practices drastically, particularly since the green revolution (Siminski et al., 2016). Despite this, agroforestry is often considered to be a new innovation when promoted for example in the Amazon (Béliveau et al., 2017; Bendahan, Poccard-Chapuis, Medeiros, Costa & Tourrand, 2018; Hoch, Pokorny & Jong, 2012; Salim, Miller, Ticona-Benavente, Leeuwen & Alfaia, 2018; Slinger, 2000). As such, traditional agroforestry is losing grounds to conventional agriculture at the same time as modern agroforestry is being promoted in the same areas as a new innovation.

When studying Brazilian agroforestry, it is useful to be aware of two prevalent concepts referring to agroforestry systems with different terminologies. First, Embrapa is promoting an approach called *ILPF* (integration of crops, livestock and forest), described as a strategy for sustainable food production integrating agricultural, animal husbandry and forestry activities in the same area either in consortium, succession or rotation (Embrapa, n.d. a; Neto, Viana, Alvarenga, Queiroz, Simões & Campanha, 2015). I would argue that ILPF and agroforestry can be treated as synonymous and that the difference is primarily semantic. The second concept is *syntropic agriculture* developed by Ernst Götsch. Syntropic agriculture can be considered a specific type of complex successional agroforestry based on systematic pruning, maximum ecological occupation, no use of pesticides and a minimal use of organic fertiliser and irrigation limited to the very initial phase of establishment (Pasini, 2017). It gained international attention in 2015 with the video *Life in Syntropy* (available at YouTube) presented at the COP21 in Paris and has a strong presence in the Brazilian agroforestry community.

Figure 3. Ernst Götsch inspecting a cocoa tree at his farm in the state of Bahia (own photo).

3. Sustainability transitions and Brazilian agroforestry

In this chapter, I first situate the thesis within the field of sustainability science and the study of sustainability transitions. Then, I present the multi-level perspective (MLP) and how it can help understand contemporary Brazilian agroforestry. Lastly, I present three critiques of the theory relevant to its applicability to my research.

3.1 Sustainability transitions

Sustainability science has emerged with the increasing realisation that science and technology play a significant role in the challenge of reconciling human development goals with the limitations of the planet (Clark & Dickson, 2003; Kates et al., 2001). Spangenberg (2011) describes sustainability science as an umbrella term, covering a maturing and vibrant field of research, distinguished by a normative focus on sustainability problems rather than by specific disciplinary characteristics. It is an inter- or transdisciplinary and problem-driven endeavour contributing to the implementation of sustainable development (Clark & Dickson, 2003; Kates et al., 2001; Spangenberg, 2011). Spangenberg (2011, p. 276) states that "sustainability science is usually understood as research providing the necessary insights to make the normative concept of sustainability operational, and the means to plan and implement adequate steps towards this end".

To plan and implement adequate steps to operationalise the normative concept of sustainability in human societies, is essentially a question of creating change. The study of sustainability transitions is a broad field of research attempting to understand the nature and dynamics of change, or transitions, towards more sustainable societies (Frantzeskaki, Loorbach & Meadowcroft, 2012; Geels, 2011; Hörisch, 2015). As described by Coenen, Benneworth & Truffer (2012, p. 969), transitions are "understood as shifts or 'system innovations' between distinctive socio-technical configurations encompassing not only new technologies but also corresponding changes in markets, user practices, policy and cultural discourses as well as governing institutions". Sustainability transitions of socio-technical systems then, are those transitions leading to more sustainability in the system (Hörisch, 2015).

Frantzeskaki et al. (2012, p. 24) points out that such sustainability transitions entail "major changes to existing structures (e.g., institutions and markets), cultures (e.g., the culture of consumerism) and practices (e.g., unsustainable practices such as resources exploitation)" and are inherently uncertain and difficult to plan. First, sustainability is a collective good-problem, associated with challenges such as prisoner dilemmas and free riders (Geels, 2010; 2011). Determining the relative importance of individual sustainability challenges is complicated and private actors will have less incentive to act proactively. This implies that civil society and public authorities are likely to be key drivers until enough has changed for it to become attractive for private actors to get engaged. Second, many contemporary sustainability problems (such as climate change, biodiversity loss, resource depletion etc.) happen on very long-term time scales and have a global nature, thus lacking immediate visibility and tangibility in local systems. Cause-effect chains are uncertain as culpability is diffuse and the affected people often are either temporally distant (future generations) or spatially distant (other regions or countries) (Geels, 2010).

Two aspects are crucial to bear in mind when working with sustainability transitions, according to Frantzeskaki et al. (2012). First, achieving sustainability and guaranteeing societal cohesion and equity is depending on broad inclusion of different actors working at different levels and in different areas. Second, it is essential to pay close attention to innovation as tightly linked with sustainability. Innovation is understood as a broad evolutionary development and redefinition of existing culture, structures, practices and infrastructures. Beyond development and refinement of technology and engineering, innovation in different scales and domains is what drives societal transition to higher degrees of sustainability (Frantzeskaki et al., 2012). The *socio-technical* adjective used in sustainability transitions studies is capturing exactly this insight, i.e., innovations and transitions are not understood as occurring mainly in technological systems but also in markets, user practices, policies and cultural meanings (Geels, 2010).

Within sustainability transitions studies, several approaches and frameworks have been developed to analyse the processes of sustainability transitions in socio-technical systems and the role of innovations in such processes. The MLP approach is one of the most applied (Gottschick, 2018).

3.2 Brazilian agroforestry seen through the multi-level perspective

The MLP is a theory drawing on insights from science and technology studies, evolutionary economics and institutional analysis (Coenen et al. 2012; Geels, 2011) and did not originally focus on sustainability transitions but on socio-technical transitions in general (Hörisch, 2015). Today, the MLP is used extensively to study sustainability transitions, particularly following the ideas and conceptualisations of the Dutch researcher Frank Geels (Gottschick, 2018). According to Geels (2011), transitions happen in non-linear processes between three levels of analysis: niche innovations (micro-level), socio-technical regimes (meso-level) and socio-technical landscapes (macro-level). The three levels each consist of a heterogeneous cluster of elements and the degree of structuration increases from micro to macro (Geels, 2007; 2011). Geels (2011) emphasises that socio-technical regimes are the primary interest of the MLP as the theory understands transitions as defined by shifts between regimes. Thus, both the landscape and niche levels are considered derived concepts as they are understood in relation to the regime. The regime is understood as the deep structures, i.e., "semi-coherent set of rules that orient and coordinate the activities of the social groups that reproduce the various elements of socio-technical systems" (Geels, 2011, p. 27). The regime is not homogenous but rather composed by various sub-regimes that might stabilise each other or create tensions (Geels, 2011).

Niches are essentially practices and technologies deviating significantly from the existing regime and niche-actors (entrepreneurs, start-ups, visionaries) hope to have the niche innovation included in or replacing the regime. Niches are crucial for transitions as they are the driving force of systemic change and an essential source for alternative visions (Geels, 2011). Smith (2007) observes that niche actors also are heterogeneous and that tensions can occur between committed idealists and pragmatists who are willing to make compromises in order to translate the niche innovation into forms more compatible with the regime. The landscape is the exogenous context influencing how niches and regimes interact and can be understood as the material and technological circumstances sustaining society as well as demographic trends, political ideologies, societal values and macro-economic patterns (Geels, 2011). Figure 4 shows how these relations could look like applied to Brazilian agriculture and agroforestry.

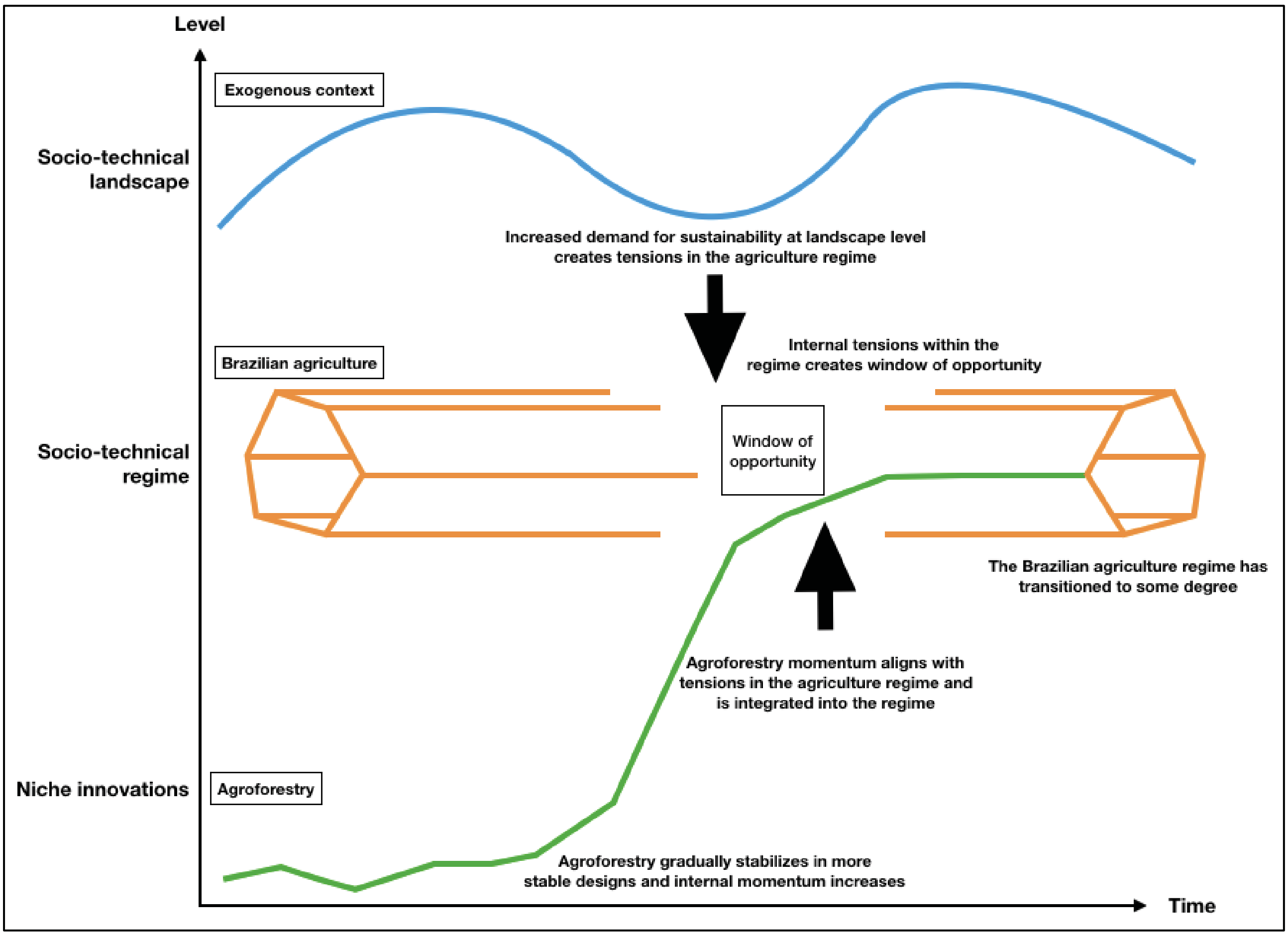

Figure 4. Conceptual illustration of transitions in the MLP, as it could happen in Brazilian agriculture (adapted from Geels & Schot, 2007). The multilevel dynamics align, allowing the agroforestry niche to influence the agricultural regime.

I understand the exogeneous socio-technical landscape of the Brazilian agriculture production to be composed from several factors. Demographic trends within the country (migration from countryside to cities) and domestic and international economy and trade in agriculture commodities are important. So is the increasing awareness of agriculture's lead role in environmental degradation and developments in agricultural policies. Prevalent value systems and culture in society also influence how agricultural production and produces are perceived and valued. The socio-technical regime is the established agricultural system, characterised by Smith (2007, p. 435) as primarily an "intermediary activity between a supply industry (agrichemicals, machinery, etc.) and a processing and retailing sector". Standardisation, mechanisation and specialisation characterise modern farming (chapter 2) and 75 % of active agriculture land in Brazil is operated by large-scale industrial companies (Lapola et al., 2014). However, it is important to be aware that the regime is not homogenous and contain other practices than green revolution-style industrial agriculture (Embrapa, 2018). Agroforestry is understood as a niche innovation, positioned in stark opposition to the regime and in constant interaction with both the regime and the landscape. Also here, it is important to be aware that the niche is heterogenous. Agroforestry is a broad concept and many different approaches co-exist and compete in Brazil. Talking about Brazilian agroforestry as a niche innovation is useful for analytical purposes but requires being cognisant of the conceptual simplification behind such analysis.

According to Geels (2007), the MLP understands transitions as occurring when certain configurations align at all three levels (as it happens in figure 4). The overarching logic sees landscape level changes or events creating tensions at the regime level, either in the whole regime or in one or several sub-regimes. These tensions could be a. technical problems, b. changes in cultural values and public opinions affecting the evaluation of the adequacy/acceptability of existing technologies, c. changes in regulations that can no longer be met by available technologies and d. changes in market and consumer preferences. Such tensions at the regime level might create windows of opportunity for niches, provided that these have gathered sufficient internal momentum to seize the opportunity. Competition between niche and regime level actors can take place at the market as well as through lobbying for specific regulations or research support, infrastructure or symbolic struggles (Geels, 2007; Geels & Schot, 2007; Smith, 2007).

A complicating circumstance in the transition dynamic is stabilising lock-in mechanisms of the incumbent regime such as a. the alignment of scientific knowledge, engineering practices, production technologies, skills and procedures, b. regulatory requirements, c. consumer preferences and d. sunk investments in machines, infrastructure and competencies. Also, institutional commitments, shared beliefs and discourses, power relations, lobbying and narratives of lifestyle and wellbeing play in and together these elements create path-dependence making it particularly difficult for transitions to occur (Coenen et al., 2012; Geels, 2011; Smith, 2007).

3.3 Shortcomings and usefulness of the MLP

It is worth mentioning a few critiques of the theory that are of particular interest to this research. These critiques will be further discussed in relation to the research in section 5.3. First, the evolutionary understanding of innovation-driven transitions is strongly focused on temporal explanations and scale-based analysis while paying no or insufficient attention to spatial factors (Coenen et al., 2012; Raven, Schot & Berkhout, 2012). Coenen et al. (2012, p. 973) consider the omission of geographical detail understandable in an initial phase, but hold that with the maturing of the theory, "a better understanding of place-specific impacts on sustainability transitions seems necessary and even urgent to explain the geographical unevenness of transition processes". Raven et al. (2012) critique that the MLP tends to take the national territorial boundaries as the (arbitrary) default unit of analysis. A conceptual inclusion of spatial dimensions in the MLP could enrich the explanatory capacity of the theory with factors such as distance, spatial differentiation and reach (Coenen et al., 2012; Raven et al., 2012).

Second, Hörisch (2015) identifies a disproportionally strong emphasis given to the influence on sustainability transitions of large well-established firms (in the regime) and argues that entrepreneurship and start-ups (niche actors) should be subject to more attention. Large established firms, incumbents, are "unlikely to bring about radical, transformative sustainability-oriented innovations" (Hörisch, 2015, p. 288) due to the large degree of lock-in mechanisms described in the previous section. *Entrant* actors, on the other hand, are not in risk of compromising their own established business model or to lose large investments in systems and infrastructure and are thus much more likely to pursue radical sustainability-oriented innovations.

Lastly, Ramos-Mejía, Franco-Garcia & Jauregui-Becker (2018) call attention to the fact that almost all MLP research has been done in urban settings in Europe. They are sceptical toward a one-to-one application of the theory to the context of developing countries as they argue that the institutional landscape is significantly different in such countries. When applying the MLP, they argue, it is necessary to consider that developing countries often are characterised by "mixture of well- and ill-functioning institutions, in a context of market imperfection, clientelist and social exclusive communities, patriarchal households and patrimonial and/or marketised states" (Ramos et al., 2018, p. 217).

The MLP is a useful theory for conceptualising the adoption of agroforestry practices in Brazilian agriculture as a potential sustainability transition. With an awareness of the shortcomings discussed in the previous paragraphs, the MLP can help understanding the dynamics of change in Brazilian agriculture, analysing agroforestry as a niche innovation attempting to influence the multiple established agricultural practices currently making up the agriculture regime in the country. This analysis will be elaborated further in dialogue with my data in section 5.3 and 5.4.

4. Methods

To answer my research question, I draw on 18 semi-structured interviews and 57 literature sources. An overview of the scientific state of the art (the literature review) of a given area is an essential foundation of any scientific endeavour, as this allows me to begin from the most advanced position possible and helps to avoid wasting time on reinventing the wheel. The data I collected in Brazil complements but also partially challenges the views present in the literature and gives a deeper understanding of the particular dynamics at play in Brazil.

4.1 Literature review: standing on the shoulders of others

The literature review has several parallel functions in my thesis. First, it ensures that I have as comprehensive an understanding of the topic as possible before conducting my interviews. Additionally, it informs the presentation of agroforestry as a less environmentally degrading alternative for agriculture elaborated in chapter 2.2. Finally, it is one of two main sources of data to answer my research question.

While reading the literature, I took note of a. benefits of agroforestry relative to conventional farming (for chapter 22) and b. obstacles to and opportunities for more agroforestry (for the analysis). Afterwards, I compiled similar items (benefits, obstacles and opportunities) in ranked lists after how many sources mentioned them to identify the most important items.

Sample

My literature sample comes from two processes. I have been collecting articles on agroforestry for more than six months before officially starting my thesis which are included in the sample. This is complemented by a more focused search on Scopus, Web of Science, LUBsearch[3], the Springer Agroforestry Systems Journal, the International Journal of Agroforestry and Silviculture and the publications of the World Agroforestry Centre (ICRAF). The search terms I used were “agroforest*” + “Brazil” and “agrofloresta*” + “Brasil” to get results in both English and Portuguese. The searches were limited to the period 2000-2019. I selected literature looking for the two types of information mentioned above: a. benefits of agroforestry relative to conventional farming and b. obstacles to and opportunities for more agroforestry. These two processes left me with 89 articles of which 57 were specifically on Brazil and 32 on other tropical countries or global/regional tendencies. A complete list of the articles can be found in appendix 2.

[3] The online library of Lund University (https://www.lub.lu.se/en/find/lubsearch)

4.2 Interviews: talking with agroforestry stakeholders in Brazil

To gain a deeper knowledge of the specific situation in Brazil and to complement the insights from the literature, I have added the perspectives from relevant stakeholders in Brazil. The stakeholder perspectives were collected through semi-structured interviews in Brazil in the period from January 18 to March 18, 2019 (itinerary in appendix 3). The interviews were following an interview guide (appendix 4) with open-ended questions about a. what the interviewee understands as agroforestry, b. how the interviewee got engaged with agroforestry, c. what the interviewee sees as the main obstacles to and d. opportunities for more agroforestry in Brazil. In addition, I also asked in what kind of formats the interviewee thought it would be useful to communicate the results of this thesis to make them accessible to the agroforestry community in Brazil. Before beginning each interview, I made sure to explain my research and the purpose of the interview. I asked for written consent to use the data from the interview in the thesis and whether they wanted to be anonymous. I did my best to be as honest and transparent about my process and their role in the research and made it clear that they were free to end the interview or to withdraw their participation at any given time, during or after the actual interview. The interviews were recorded with consent from the interviewee, except for four: the three phone interviews and the one with Götsch, as I lost my recorder the day prior to that interview. During and immediately after each of the interviews, I wrote down obstacles and opportunities mentioned in the interview. Afterwards, I compiled similar items (obstacles and opportunities) in ranked lists after how many sources mentioned them to identify the most important items.

Sample

My sample of stakeholders is based on convenience sampling prior to the fieldwork and complemented by snowball sampling while in the field. It is important to make clear that this method does not give a complete and exhaustive picture of the perspectives of all Brazilian agroforestry stakeholders as this would be a task well beyond the scope of a master thesis, if at all possible. Rather, the sample provides an overview of perspectives of a wide selection of stakeholders involved with agroforestry. I did a total of 18 interviews, 15 face to face and three over the phone. The interview sample is composed of:
a. three university researchers, b. two researchers from state or federal agricultural research institutions, c. one researcher for a private company, d. two people involved with large-scale farming, e. one ex-federal deputy in the national congress, f. five stakeholders living from combined agroforestry production and agroforestry courses/consultancy and g. four stakeholders working mainly with agroforestry courses and consultancy. In the analysis, I will refer to the interviewees by their last name. A complete list of the stakeholders interviewed can be found in appendix 5.

4.3 Creating the syntheses

I combined the ranked lists of obstacles and opportunities from the literature and the interviews to get the synthesised weight of each item (individual obstacles and opportunities). Table 2 and table 3 in the following chapters 5.1 and 5.2 show the lists ranked after most total mentions shown in percent of total number of sources (18 interviews + 57 literature sources) as well as the percent of each of the data types. For the analysis, I left out items with less than three mentions and I only included the interviews and the 57 literature sources explicitly on Brazil.

One shortcoming of this approach is that it does not take weighing into account, i.e., the importance a given source ascribe to a specific item, but only the number of sources mentioning it. I chose this procedure in order to be able to make comparable units, which would be complicated if each source's weight assessment would be included. This way, the syntheses provide an overview of frequently mentioned items, but do not reflect the relative importance of each item attributed by individual sources. Furthermore, the interviews are specifically targeting obstacles and opportunities whereas these categories are derived in the literature that often focused on other aspects. This is likely the reason why the percentages of the literature sample generally are lower than the ones of the interview sample in table 2 and 3. The approach is adequate to create a bird's eye perspective of the situation, i.e., to understand what sort of obstacles and opportunities are prevalent. Further research could be done to include relative weight of each item.

Tables 2 and 3 reveal deviating positions on several items between the two data sources. These deviations could be explained by several factors. First, it is possible that the two sources simply have different perspectives on the obstacles facing Brazilian agroforestry and future opportunities, indicating a discrepancy between the general scientific understanding of the issue and that of the stakeholders. This could both suggest that the scientific actors engaged with the topic should be more sensitive to the analysis of the stakeholders (e.g. through more participatory approaches and transdisciplinarity) and that the stakeholders potentially could gain new insights on their situation through the scientific literature. Another explanation can be analytical errors in my process of analysing the content of the different sources. This could include failure to identify or understand obstacles mentioned by the source, lack of understanding of synonyms and related concepts or imprecisions in the categorisations of the various items. It is hard to say which explanation is more plausible, but the truth is likely to be a combination.

To create the synthesis by grouping various literature sources and interviewees' individual understanding of a given obstacle or opportunity, certain details are inevitably lost in the tables. Immediately after each of the two synthesis tables, each item is elaborated to recover as much as the rich details as possible.

5. Obstacles, opportunities and transition

In this chapter, I present my main findings, first the obstacles and then the opportunities. Subsequently, I use the MLP to analyse the findings in the context of sustainability transitions.

5.1 Obstacles to Brazilian agroforestry

It is worth noting that the different obstacles listed in table 2 are intimately linked. They are written out in separate items to create overview, but are not closed and complete entities, but rather interact with and influence each other to a large extent.

Table 2. Synthesis of obstacles identified in interviews and literature (own creation). '% tot.' shows the percentage of the 75 interviews and literature sources mentioning the obstacle, '% int.' shows the percentage of the 18 interviews mentioning the obstacle and '% lit.' shows the percentage of the 57 literature sources mentioning the obstacle. The sources are included in appendix 6.

	Obstacle to Brazilian agroforestry	% tot.	% int.	% lit.
a	Complexity of agroforestry and knowledge gap	**24**	44	18
b	Logic of production and infrastructure of market	**21**	50	12
c	Labour intensity and shortage of qualified labour	**17**	33	12
d	Conventional thinking in agricultural education and extension	**13**	44	4
e	Lack of consumer awareness and appreciation of agroforestry	**13**	39	5
f	Lack of support and incentives in public policies	**11**	11	11
g	Additional costs and difficulties of financing agroforestry	**11**	22	7
h	Lack of adequate machinery and equipment	**9**	39	0
i	Political influence of agribusiness	**7**	28	0
j	Production disconnected from nature	**7**	22	2
k	Erosion of traditional knowledge and rural culture	**5**	22	0

a. Complexity of agroforestry and knowledge gap

The most referenced obstacle to agroforestry is complexity. Agroforestry is centred around complex processes and the more diversified the system is, the harder it is to manage (Curatella, interview, 2019). To plan, establish, maintain and harvest in an agroforestry system requires more knowledge, more management, more administration and introduces more risks than conventional cropping systems due to their diverse nature (Agrofloresta do Futuro, interview, 2019). Costa & Ziantoni (interview, 2019) commented that this makes it extremely difficult for small-scale farmers to increase the production area to just a few hectares. It is further complicated by the circumstance that modern agroforestry is a rather new phenomenon and that it is largely absent in the public and private research institutions, meaning that there is scarce knowledge and information on how to manage complex agroforestry systems. There is a vast lack of knowledge concerning virtually all aspects related to agroforestry. Götsch, Noronha and Costa & Ziantoni (interviews, 2019) all highlight the great lack of basic natural science understanding of the ecological and biogeochemical processes in food production systems and of the particular interactions between species in diversified agroforestry systems.

There are no standard procedures or ready packages for those who want to engage with agroforestry whereas the technological packages for conventional monoculture production are pushed very actively to the farmers and technicians by the large companies (Nascimento, Padovan, Alves, Silva & Padovan, 2015). Furthermore, the knowledge that does exist can often be inaccessible to those who might be interested in engaging with agroforestry. Courses are often expensive and can be taking place far away, making it difficult or impossible for many people to attend them. Information freely available, for example on the internet, can be hard to understand if written in a foreign language or in complicated technical or academic style. And it can be difficult to locate for people with little formal education and possibly limited electricity or internet access.

Figure 5. Complex agroforest in the state of Goiás (own photo). The system requires extensive knowledge to plan, implement and maintain. It consists of many different annual and perennial species for both food, ecosystem services and biomass production and is a sharp contrast to the surrounding grasslands visible in the background.

b. Logic of production and infrastructure of market

As seen in chapter 2.2, one of the fundamental characteristics of agroforestry systems is diversity, to varying degrees depending on the specific system. The diversity of plants (and potentially animals) in agroforestry systems is what brings many of the environmental benefits, but it is also one of the main obstacles. This has to do with the production logic of modern agriculture (striving for simplification and specialisation) expressed in the material agricultural infrastructure. Modern agricultural production systems are designed for specialisation in one product per production, produced in large, steady and homogenous quantities of even quality (Noronha, interview, 2019). The entire system is based on simplification to allow for industrial efficiency of specialised production, distribution and marketing. Agroforestry systems are fundamentally different, considering that a complex agroforest can produce up to 30 different products (Lima, interview, 2019).

Although not all agroforestry systems produce this many different products for commercialisation, their production does not fit with the logic and established infrastructure supporting conventional agriculture

(Cardoso; Costa & Ziantoni; Lobo; Curatella, interviews, 2019). This makes it difficult for agroforestry producers of all scales to find market for their production of a wider range of products in smaller and sometimes uneven quantities. The lack of a commercial market for other crops than the few ones produced industrially, the logistics of transportation and distribution and the challenge of finding buyers make it hard for agroforestry producers to live from their production. This is an obstacle that is particularly difficult to overcome for small-scale farmers. They are often located in remote areas and in a study of agroforestry in the Amazon, Hoch et al. (2012, p. 372) found that "poor infrastructure and distant markets still hinder a successful engagement of smallholders in commodity markets". Also, small-scale farmers do not benefit from the economy of scale and they have a harder time negotiating with buyers due to their relative unimportance.

c. Labour intensity and shortage of qualified labour

Complex and diversified production systems generally lead to more tasks to perform and the novelty of modern agroforestry as well as the practical circumstances of a diversified system with many types of plants and trees make mechanisation very complicated. Lima (interview, 2019) for example, estimated that around 90 % of trees in Brazilian agroforestry are planted manually, but also soil preparation, pruning, thinning, harvesting and other tasks related to the maintenance are executed almost entirely relying on manual work. This means that agroforestry becomes very labour intensive which adds to the complexity and makes it costlier.

Figure 6. Murilo de Lima planting vegetables in an agroforest he manages in the outskirts of Goiânia, capital city in the state of Goiás (own photo).

Another crucial aspect of this obstacle is the lack of available and qualified labour. Demographic trends see a continuous movement of young people towards the large cities, leaving the rural areas with a decreasing and aging population (Bendahan et al., 2018). Due to the complexity and the lack of ready packages, managing agroforestry systems require fairly skilled labour as well as knowledge about the specific local ecological reality of the given place (Didonet, 2015). As mentioned by Buriti & Coelho, Lima and Vaz (interviews, 2019), agroforestry also requires open-minded labour that understands and approve of the different logic behind agroforestry production. It is risky and expensive for agroforestry farmers to invest in training their employees as there is no guarantee that they will stay for a longer period. Finding sufficient labour with sufficient agricultural and ecological understanding and a sufficiently open mind is a major obstacle.

d. Conventional thinking in agricultural education and extension

Agroforestry is largely absent from institutions of agricultural (and related) education. According to the data, this has several explanations. First, since it is a new system within modern agriculture there is a lack of awareness and knowledge amongst those designing the curriculums and a lack of people qualified to teach. Second, Götsch (interview, 2019) observes a general lack of openness and curiosity for alternative ways of doing things at the universities and Avelar & Terra (interview, 2019) note how agroforestry is usually stigmatised and not taken seriously if brought up at all. Third, several interviewees (Armando; Carvalho; Carvalho & Araújo; Lobo; Martins, interviews, 2019) point out that there are strong ties between the agribusiness and educational institutions, shaping the mentality and philosophy taught to new generations of farmers, technicians and consultants towards the industrial solutions of agrichemicals and large machinery. Apart from financing universities, courses and later employing the graduates, the agribusiness also has extensive influence within Embrapa which affects the approach of their technical assistance personnel and rural extension officers (Carvalho, interview, 2019). Rural extension by the universities[4] is significantly under-prioritised whereas the industry can afford to offer technical assistance while selling their products.

e. Lack of consumer awareness and appreciation of agroforestry

The predominantly urban population is increasingly disconnected from nature and natural processes. At the same time as we have still less understanding of where our food comes from, we get still more used to the aesthetics and prices of food produced by industrial agriculture. We have gotten used to and now expect food that is homogeneous, spotless and inexpensive and we do not understand the actual environmental cost of this type of food (Buriti & Coelho; Vaz, interviews, 2019). Most consumers are unaware of or ignore the countless externalities of the food production and can do so because their cost is not included in the price they pay for it.

The fact that we as consumers are not cognisant of the many problems stemming from the food we eat, also mean that we are less inclined to choose food grown in a more sustainable way, potentially with a higher end price. Furthermore, Costa & Ziantoni, Machado and Tokarski (interviews, 2019) point out that most consumers have no idea what agroforestry is and are unaware of the environmental (and often health) benefits of agroforestry production. There is a lack of both a specific market for agroforestry products as well as a generalised ignorance of the benefits of agroforestry amongst the Brazilian consumers (Miccolis et al., 2016). Both Machado and Tokarski (interviews, 2019) found that the complete lack of labels and certifications

[4] According to Avelar & Terra (interview, 2019), public universities in Brazil are expected to divide their resources evenly between research, education and extension

is a considerable part of this issue while Costa & Ziantoni (interview, 2019) warned against the potential consumer apathy and decreased feeling of responsibility that such solution might cause.

f. Lack of support and incentives in public policies

Public policies are crucial in determining what sort of practices are encouraged and discouraged in a society. As Vaz (interview, 2019) commented, the fact that environmental and health externalities of industrial agriculture are not internalised in the product price is ultimately a political decision and public policies have a strong influence on what type of agriculture is promoted and favourable. Whether due to a lack of interest from the politicians, as suggested by Cardoso (interview, 2019), or direct vested interests of the agribusiness (obstacle i), current public policies are not working in the favour of alternative production systems such as agroforestry.

In a study comparing agroforestry with organic and conventional production of oranges, Belarmino (2017) found that the taxation and tariffs were comparatively disfavouring agroforestry, primarily through taxation of labour and financial capital. Complex bureaucracy for diversified systems (Miccolis et al., 2016) and the absence of subsidies to compensate the extra costs or reward the environmental achievements (Nascimento et al, 2016) are other issues. Coelho (2017, p. 485) explain how “restriction laws to the economic use of native species in Brazil constitute an additional factor which can inhibit agroforestry expansion, at least high diverse agroforestry with native biodiversity”.

g. Additional costs and difficulties of financing agroforestry

Agroforestry is generally associated with additional costs, particularly in the initial phase (Carvalho & Araújo; Noronha; Tokarski, interviews, 2019). This comes from investment in a. knowledge such as courses and consultancy and b. inputs, such as seedlings and organic fertiliser. Furthermore, agroforestry systems often have a longer implementation period before they begin giving return, due to the complexity and the emphasis on woody species that grow slower (Moares et al., 2011; Tokarski, interview, 2019).

While agroforestry farmers have a great need for credit, they do not necessarily have access to this. On the contrary, Avelar & Terra, Buriti & Coelho and Curatella (interviews, 2019) all point out that it is particularly difficult to obtain credit and loans to establish agroforests. This is because agroforestry does not fit into the categories of agriculture systems of the banks and finance institutions who do not know much about agroforestry. As they cannot assess the viability of the project and thus the probability of getting returns, they often reject the projects as a matter of precaution (Curatella, interview, 2019). Furthermore, the financial system is favouring large-scale enterprises, while it is expensive and complicated to loan money for small and medium-sized farmers (Buriti & Coelho, interview, 2019).

h. Lack of adequate machinery and equipment

The logic behind agroforestry is so essentially different from conventional agriculture that there is an almost complete lack of machinery and technical equipment suitable for agroforestry systems (Götsch, interview, 2019). Agroforestry involves complex processes related to planting, maintaining and harvesting, currently done almost exclusively by manual power, which is expensive and difficult to find.

Figure 7. Patrícia Vaz planting tree seedlings manually for a new agroforest on her land in the southern Minas Gerais (own photo).

There is a great need for machinery based on a different logic than the ones produced by the agribusiness. Machinery that is lighter so they do not compress the soil, can operate on slopes and is capable of multiple functions such as planting, managing and harvesting in complex production systems (Costa & Ziantoni; Curatella; Götsch, interviews, 2019). Noronha (interview, 2019) observes that there still is very little demand for this type of machinery, making it unattractive for the industry to invest in it. Finally, Costa & Ziantoni (interview, 2019) point out that some suitable equipment is emerging slowly in other countries but that the import of such items from abroad is both expensive and complicated due to taxation and bureaucracy.

i. Political influence of the agribusiness

The agribusiness has strong economic and political interests in maintaining the dominant position of the industrial agriculture model within public policies, education and production (Cardoso; Carvalho; Lobo; Machado; Martins, interviews, 2019). The agribusiness companies have strong economic power and through their influential lobby groups, they are able to influence the Brazilian government and congress, as explained by Carvalho (interview, 2019).

Recently elected president, Jair Bolsonaro, is a clear example of this connection as he is well-known for strong ties to the agribusiness lobby (Boadle, 2018; Phillips, 2019). During his presidential campaign he promised less environmental regulation and more freedom for the agribusiness (Phillips, 2019) and since his inauguration the first of January this year, he signed an executive order assigning the responsibility of protected areas to the agricultural ministry (Tutton, 2019). Until the 11th of April this year, 152 new toxic agriculture chemicals were liberated for use in the agriculture (Greenpeace, n.d.) and on the 11th of April a decree officially closed a series of environmental government agencies (Lisboa & Prizibisczki, 2019).

j. Production disconnected from nature

Modern agriculture aims at outsmarting nature through green revolution technologies such as agrichemicals, fertilisers, irrigation and genetic manipulation of seeds. Götsch (interview, 2019) observe that such adversary relation to our natural surroundings only can lead to negative outcomes and that we rather should strive to understand and integrate agriculture with the natural processes of life. Mattos (2006) further explains that a fundamental incompatibility exists between the cyclic logic of natural processes and the linear economic logic of modern productive systems and that any sustainable system of production and consumption must adopt a cyclic nature. Agroforestry, alongside other types of agroecological production systems, requires a profound involvement with and consideration for the natural environment and is fundamentally incompatible with industrial corporations, primarily committed to profit generation (Carvalho & Araújo, interview, 2019).

Figure 8. Sucupira Agroflorestas' productive area in the foreground bordering native Atlantic rainforest in the background (own photo). The former is strongly inspired by the latter, suggesting that a production logic closer to nature is possible.

k. Erosion of traditional knowledge and rural culture

The proliferation and consolidation of industrial farming has gradually eroded traditional knowledges of how to grow food and replaced it with universalised technological and industry-led knowledge. Traditional methods and insights are being devalued and marginalised and, according to Machado (interview, 2019), this is driving a simultaneous loss of customs, traditions, values and identity associated with the traditional ways of working the land. Land concentration and seasonal hiring alter rural populations' relation to the land and challenge rural livelihoods and culture (Buriti & Coelho, interview, 2019). Carvalho & Araújo (interview, 2019) point out that contemporary society is characterised by a dominant narrative favouring urban life while associating rural life with poverty, underdevelopment and other related characteristics. Santos (interview, 2019) mentions that it is difficult to revert these processes and convince rural producers that have adopted industrial methods to go back to more diverse and locally anchored practices.

5.2 Opportunities for Brazilian agroforestry

It is worth noting that the different opportunities listed in table 3 are intimately linked. They are written out in separate items to create overview, but are not closed and complete entities, but rather interact with and influence each other to a large extent.

Table 3. Synthesis of opportunities in identified in interviews and literature (own creation). '% tot.' shows the percentage of the 75 interviews and literature sources mentioning the opportunity, '% int.' shows the percentage of the 18 interviews mentioning the opportunity and '% lit.' shows the percentage of the 57 literature sources mentioning the opportunity. The sources are included in appendix 7.

	Opportunity for Brazilian agroforestry	% tot.	% int.	% lit.
l	More research in agroforestry	**15**	28	11
m	Lead by example and reference cases	**15**	56	2
n	More agroforestry in education and extension	**13**	22	11
o	Promotion of mind-shift	**12**	44	2
p	More political support	**9**	22	5
q	Organisation of farmers	**9**	33	2
r	Innovation of machinery and equipment	**8**	33	0
s	Integration of agroforestry into land restoration efforts	**7**	17	4

l. More research in agroforestry

The primary opportunity identified for Brazilian agroforestry is more research. The ecological and biogeochemical processes and interactions between species as well as benefits and disadvantages relative to other production systems, management and maintenance practices, innovation of equipment, farmer organisation as well as economic viability and marketing of agroforestry products all are areas that need more research (Avelar & Terra; Machado; Noronha, interviews, 2019). Such knowledge is essential to improve agroforestry production, limit production-environmental benefit trade-offs and make agroforestry more competitive. Multi-stakeholder integration bringing together researchers, farmers and technicians and employment of participatory research methods are highlighted as essential to the production of new innovative knowledge and to the dissemination of new and existing knowledge within the agroforestry community (Carvalho et al., 2005; Padovan et al., 2016; Porro & Miccolis, 2011; Souza et al., 2012).

m. Lead by example and reference cases

To lead by example and to tutor and prepare others to do the same is the most referenced opportunity in the interviews. As put by Götsch (interview, 2019), take initiative and show others that it is possible rather than wait for something or someone to improve the conditions and prepare the way. The dissemination of agroforestry practices will happen gradually through one-to-one peer contact as well as through networks and associations. Santos (interview, 2019) talk about the importance of agents of multiplication and Lima (interview, 2019) about disseminators (difusores), i.e., resourceful individuals with a potential to influence others. Creating and promoting practical results (success stories, reference cases, best-case examples) that demonstrate the viability of agroforestry can be a strong case for more agroforestry. A healthy, productive and economically viable agroforest can convince sceptics, or at least make them question their assumptions. It can inspire people who did not know about it or have never seen it in function, and it can provide confidence that it is possible for those keen on establishing agroforests themselves. Following the logic of "show don't tell", Avelar & Terra (interview, 2019) see a potential of this approach to convince small- and medium-size farmers as well as banks and other investment institutions. Martins (interview, 2019) add both researchers and technical professionals to the list. Ultimately, such ripple effects can create a considerable momentum and in the longer term potentially influence larger societal structures.

Figure 9. Volunteers from the NGO Re-ação and curious by-passers like myself managing a community agroforest in the outskirts of a public park in the middle of Brazil's capital, Brasília (own photo). Applied experience and meaningful conversations inspire and convince.

n. More agroforestry in education and extension

Concerned with education and training rather than the production of knowledge, more inclusion of agroforestry in education and extension is another key opportunity (Armando; Curatella; Lima; Lobo, interviews, 2019). Agroforestry will have to be integrated into the curriculums and practices of educational institutions such as universities, Embrapa and other actors working with educating and training of farmers, technical assistance personnel and rural extension professionals. This is essential for the dissemination of agroforestry practices as well as to guarantee qualified labour to work in an increasing number of agroforests. This can also happen outside the established institutions, e.g., through private courses and schools and online resources, as pointed out by Armando and Lima (interviews, 2019).

o. Promotion of mind-shift

This opportunity is very broad and is not necessarily strictly limited to agroforestry but has direct and profound potential to advance the adoption of agroforestry in Brazil. Götsch (interview, 2019) emphasises the crucial importance of compassion and non-judgement in human interaction for people to opt for systems such as agroforests which benefit the greater good and not just themselves. Buriti & Coelho (interview, 2019) see the necessity of a radical reorientation of societal values through education and dialogue, eventually replacing the dominant mentality of competition with one of cooperation and solidarity. This, to promote environmental conservation and human wellbeing (for example through agroforestry) as more important than profit and personal gain at the expense of others. More awareness of the true costs of current agriculture and the benefits of agroforestry (Buriti & Coelho; Carvalho & Araújo; Machado; Tokarski, interviews, 2019) and a profound reconnection of consumer and the food they consume as well as the people and processes producing that food (Lobo; Martins, interviews, 2019) are more tangible and equally important elements in such mind-shift.

p. More political support

Political incentives and disincentives are of crucial importance for the adoption of agroforestry and it is difficult to imagine major advancements without political support (Machado, interview, 2019). Political support is necessary to remove structural barriers and to create incentives to establish agroforestry. Including environmental costs of food production in consumer prices could position agroforestry systems better in competition with conventional agriculture, as suggested by Carvalho & Araújo (interview, 2019). Subsidies and other incentives for production systems with less externalities are another approach. Moraes et al. (2011) recommend establishing a politically regulated market for payment for ecosystem services whereas Porro & Miccolis (2011) suggest giving stronger priority to already existing policies such as the Food

Acquisition Programme (PAA) and the National Programme for School Food (PNAE), both favouring family farmers.

Figure 10, 11. Rômulo Araújo shows the quality of the soil in one of the agroforest plots at Sítio Raíz, close to Brasília (own photo). The area is characterised by soil erosion but here the soil is fertile and has a clear structure. Political support for this type of environmental improvement could provide incentive for more agroforestry.

q. Organisation of farmers

Organisation of stakeholders in networks, cooperatives and associations is an essential way to promote agroforestry by facing the obstacle of complexity and a host of related challenges as a collective. This type of organisation can facilitate knowledge sharing and help the individual farmer to handle challenges related to production, distribution, marketing as well as to create community and solidarity, as pointed out in the interview with Agrofloresta do Futuro (interview, 2019). Also, managing certification or establishing self-certification, creating aggregate value by processing raw materials and influencing the public narrative of food production becomes more feasible through organisation. Avelar & Terra (interview, 2019) mention the cooperative Cooperafloresta in Vale do Ribeiro, the MAIS network, the organisation Mutirão Agroflorestal and the work of MST (the Landless Movement) in Riberão Preto as examples of this approach to deal with the many challenges collectively.

r. Innovation of machinery and equipment

Machinery and equipment designed with a fundamentally different logic than the one behind the large heavy machines used in current industrial agriculture is an important factor in the adoption of agroforestry in Brazil. As pointed out by Götsch (interview, 2019), mechanisation of processes of planting, maintaining and harvesting the different agroforestry crops (e.g., herbs, vegetables, roots, berries, fruits, grains, beans, nuts etc.) in agroforests will greatly improve the economic viability of agroforestry which is crucial to the proliferation of such systems. Lightweight and multifunctional machines to ease the manual labour requirement in agroforestry would make it more accessible and would open up for adoption at a much broader range and much larger scale. The innovation and testing of such equipment should be funded both by private and public investment as suggested by Vaz (interview, 2019) and will be still more viable the larger the agroforestry community grows.

s. Integration of agroforestry into land restoration efforts

Agroforestry can potentially serve a double function in the case of restoration of degraded land and reforestation efforts. Lima (interview, 2019) explains that restorative agroforestry systems, similar to production agroforests but with higher proportion of native species and a greater emphasis on environmental functions than production, could complement or replace many of the current inefficient practices adopted in legal reserves (Reservas Legais) and permanently protected areas (Áreas de Preservação Permanentes). The mandatory buffer vegetation around waterways and bodies is a particularly interesting potential for agroforests as many land owners would have a stronger incentive to make an effort with the buffer vegetation if it provided them with food and fibre parallel to the environmental restoration (Lobo, interview, 2019). This could possibly open their eyes to the benefits of agroforestry and encourage them to expand the agroforestry element on their land in the longer run. In 2016, the Brazilian chapter of ICRAF published a 266 pages technical guide on how to use agroforestry for ecological restauration in the *cerrado* and *caatinga* ecosystems in Brazil (Miccolis et al., 2016) to reconcile conservation with production. They explain that while nature often is able to restore degraded areas, human intervention can both accelerate and improve this process while also harvesting various benefits without compromising the ecosystem.

5.3 Understanding Brazilian agroforestry as a potential sustainability transition

The focus on obstacles and opportunities of my research question can be understood as factors respectively impeding or advancing the adoption of agroforestry practices as a niche innovation in the Brazilian agriculture regime and the consequent sustainability transition such adoption could lead to. In the following section, I will interpret my data through the lens of the MLP, analysing agroforestry in Brazil as a potential sustainability transition[5].

Global agriculture is in urgent need of becoming more sustainable. In Brazil, the stated mission of both the federal ministry of agriculture (MAPA, n.d.) and of Embrapa (Embrapa, n.d. b) mention increasing environmental sustainability as one of the main priorities for Brazilian agriculture. At least officially, transition towards more sustainability in the agriculture seems to be on the agenda in Brazil.

Sustainability transitions can occur when internal processes at landscape, regime and niche level align in certain ways (Geels, 2010; 2011). In other words, transitions depend on serendipitous timing of landscape level change, regime tensions and niche momentum. The global and national imperative for increased sustainability in agriculture and even for entirely new ways of producing food can be considered a landscape level change favourable to this particular sustainability transition. This kind of change at the landscape level destabilises the status quo of the regime, creating internal and external tensions which open up manoeuvring space for niches to challenge it, providing that the niche has gathered a certain momentum. This flow was illustrated in figure 4 in chapter 3.2. In a recent review of socio-technical dynamics of low-carbon transitions, Geels, Sovacool, Schwanen & Sorell (2017) suggest various drivers of niche momentum and regime tensions that might stimulate transition if aligning the right way (figure 12).

	Niche momentum	Regime tensions
Techno-economic	Price/performance improvements as a result of R&D, learning by doing, scale economies, complementary technologies, and network externalities	Technical failures, disruption of infrastructures, accumulating negative externalities (e.g., CO2 emissions
Business	New entrants or incumbents from other sectors are more likely to drive radical innovation than traditional incumbents. Their success may lead to "innovation races" when other firms follow a first mover	Shrinking markets, economic difficulties in incumbent industries, loss of confidence in existing technologies and business models, reorientation toward alternatives
Social	Growing support coalitions and constituencies improve available skills, finance, and political clout	Disagreement and fracturing of social networks, defection of key social groups from the regime
Political	Advocacy coalitions lobby for policy changes that support the niche innovation such as subsidies and supportive regulations	Eroding political influence of incumbent industries, declining political support, removal of supportive policies, introduction of disruptive policies
Cultural	Positive discourses and visions attract attention, create cultural enthusiasm, and increase socio-political legitimacy	Negative cultural discourses undermine the legitimacy of existing regimes (e.g., coal and climate change, diesel cars, and air quality)

Figure 12. Drivers of niche momentum and regime tensions (adapted from Geels et al., 2017).

[5] It is important to remember that agroforestry previously has been the dominant way of producing food in areas like the Amazon, as explained in chapter 2.3.

Figure 13 illustrates how the obstacles from table 2 influence the niche momenta negatively, suggesting that overcoming these obstacles might boost the various niche momenta. Figure 14 illustrates the dynamics between the regime tensions observed in Brazilian agriculture and certain opportunities from table 3 and figure 15 the dynamics between the regime tensions not observed and certain obstacles from table 2.

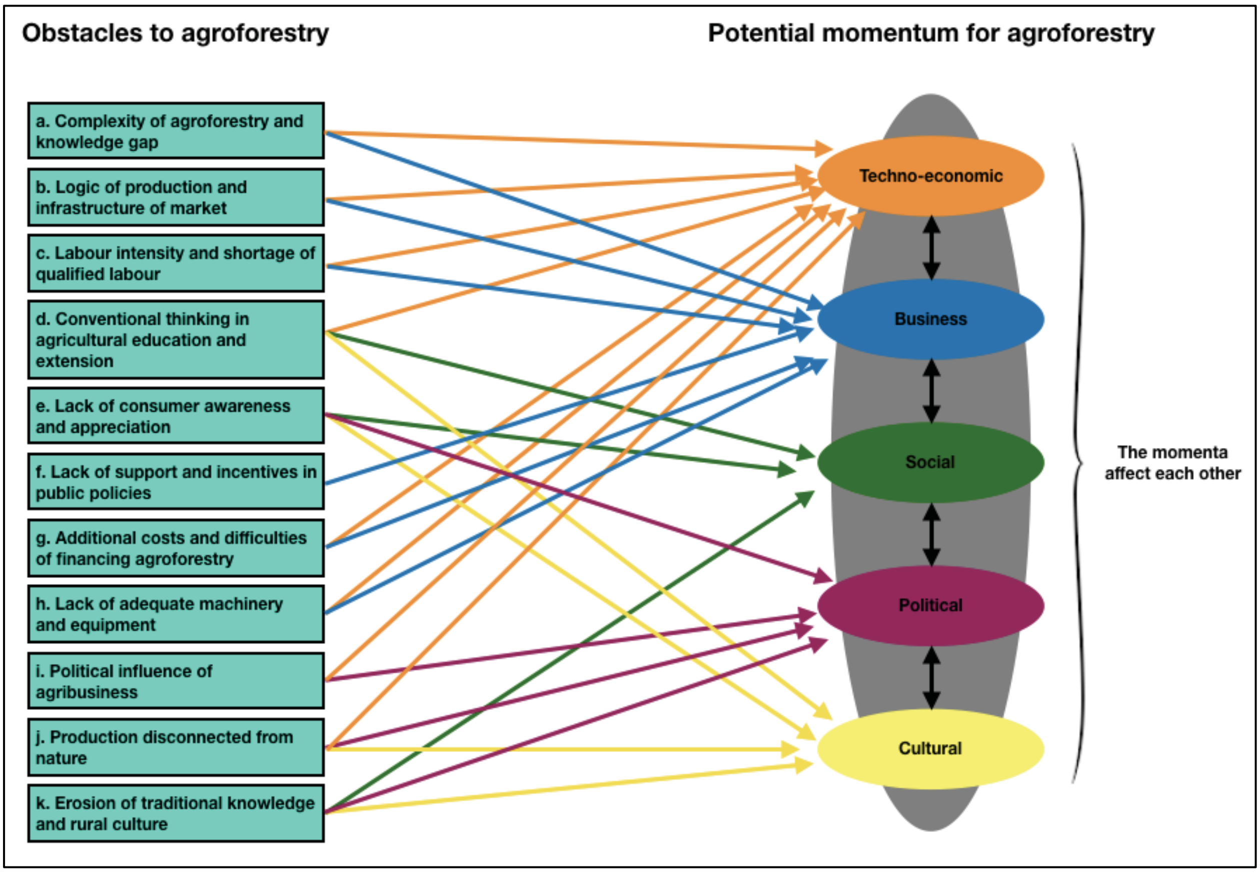

Figure 13. Identified obstacles to Brazilian agroforestry negatively influencing the niche momenta (own creation, partially based on Geels et al., 2017). Overcoming the obstacles could accelerate the niche momenta for Brazilian agroforestry.

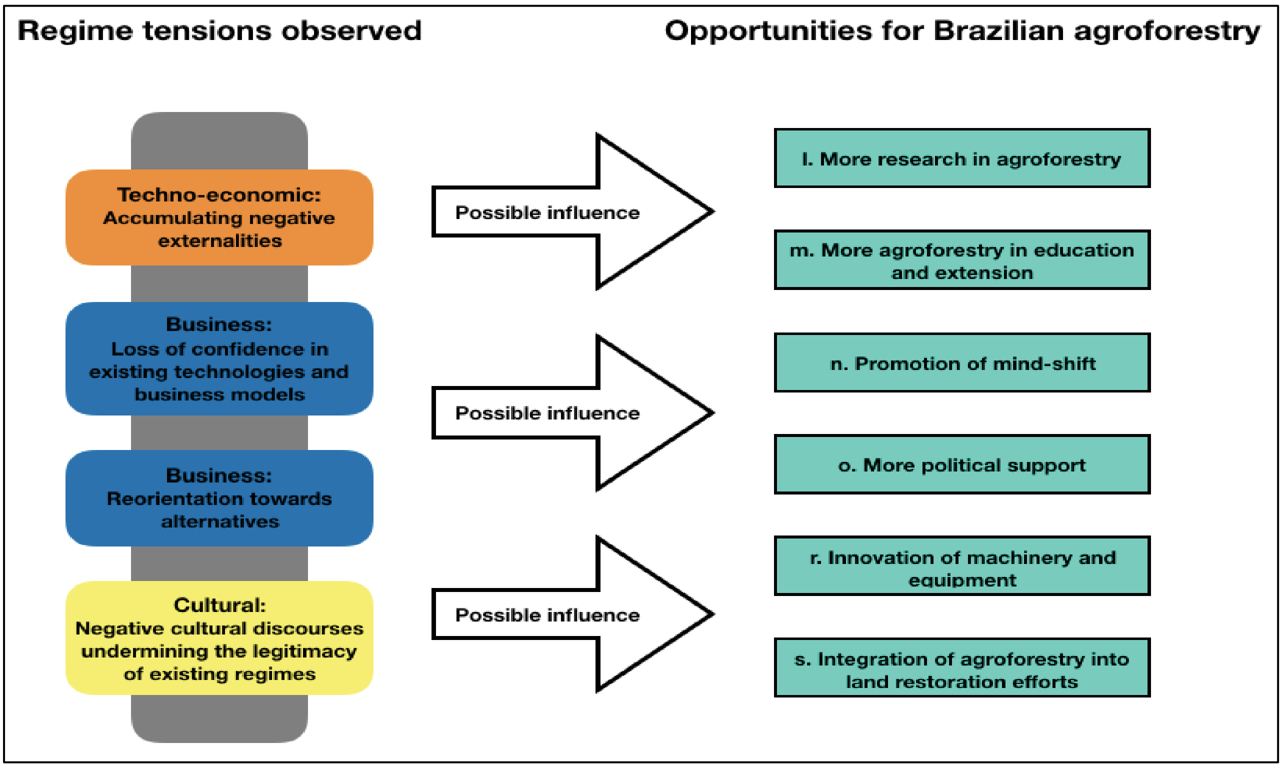

Figure 14. Observed regime tensions and opportunities for Brazilian agroforestry (own creation, partially based on Geels et al., 2017). Regime tensions might inspire multi-level actions towards opportunities for Brazilian agroforestry.

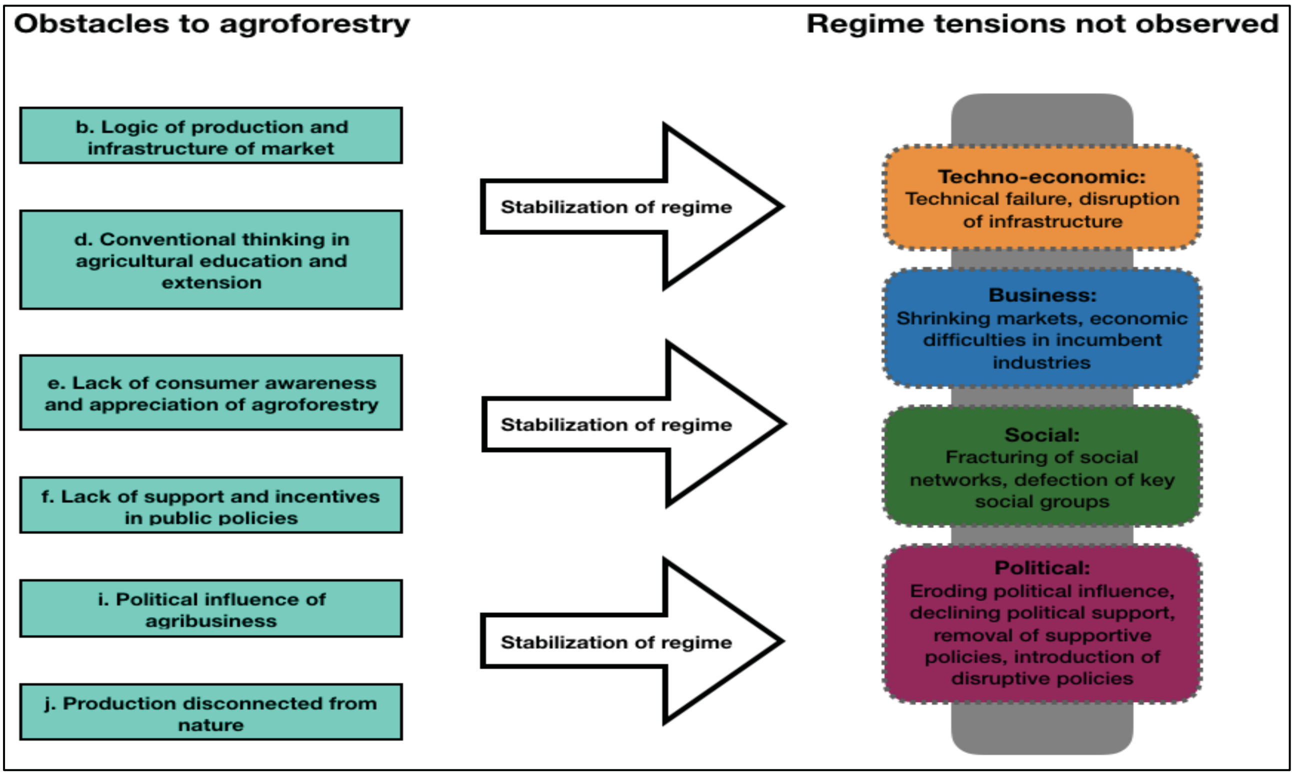

Figure 15. Obstacles to Brazilian agroforestry and regime tensions not observed (own creation, partially based on Geels et al., 2017). Specific obstacles stabilise the regime and prevent regime tensions.

In chapter 3.3, I introduced three critiques of the MLP that I find constructive for enhancing the MLP's analytical value for my research. Coenen et al. (2012) and Raven et al. (2012)'s emphasis on the spatial dimensions of sustainability transitions is highly relevant in the case of Brazilian agroforestry. One example of this is obstacle b. (Logic of production and infrastructure of market) concerning the logistics of transporting food products from producers to consumers. The spatial configuration of the process of getting the food from the farm is crucial. Obstacle c. (Labour intensity and shortage of qualified labour) is another example of an item with a strong spatial component, as access to labour force often is challenged by distance and transport options. Opportunity p. (Organisation of farmers) is a more ambiguous case as the widespread access to digital communication to a certain extent lessen the importance of spatial distribution of the farmers. At the same time, it is obvious that digital communication cannot replace physical presence in all types of interactions.

Figure 15. A volunteer from the NGO Re-ação demonstrates how to prepare a banana palm for soil fertilisation and hydration in Brasília (own photo). This type of interaction is difficult to replace with digital communication.

Hörisch's (2015) critique of the inadequacy of the MLP's strong focus on the regime as the main lever to enhance sustainability transitions is also relevant in this context. Particularly in the case of large established firms of the regime versus small start-ups and entrepreneurs at the niche level or between the two, he argues that smaller companies and organisations are more likely to be pro-active and radical in terms of sustainability. While I have not been able to find any source analysing the distribution of farmers and companies working with agroforestry in Brazil, the interviews and literature suggest that the majority of agroforests in Brazil are managed by small-scale and family farmers. The mechanisms stabilising socio-technical regimes (discussed in chapter 3.2) result in lock-ins and make this level more resilient to change and less open to new ideas. This is particularly present in obstacle b. (Logic of production and infrastructure of market) where value and production chains, physical infrastructure and market structure of modern food production were mentioned repeatedly in interviews. Obstacle h. (Lack of adequate machinery and equipment) is another example where well-established companies are path dependent but where entrepreneurs and innovative small-scale farmers are experimenting and breaking paradigms.

Finally, it is productive to consider the differences between the uneven socio-political context of Brazil, broadly considered a developing country, and the urban European contexts where most empirical MLP studies have been done. The various institutional malfunctions mentioned by Ramos-Mejía et al. (2018) are an essential parameter to understand the extent and pervasiveness of for example obstacle d. (Conventional thinking in agricultural education and extension), f. (Lack of support and incentives in public policies), g. (Additional costs and difficulties of financing agroforestry) and i. (Political influence of agribusiness). The blurred lines between personal, industry and public interests in the legislative and executive branches of the political sphere in Brazil are notorious[6] and newly elected president, Jair Bolsonaro, is known for his tight link to the agribusiness as elaborated in obstacle i. (Political influence of the agribusiness, in chapter 5.1). This scenario is not directly comparable to the institutional context of many of the countries where the MLP has been applied (not to say that corruption and strong lobbying does not exist in these countries) and this will inevitably affect the dynamics between landscape, regime and niche.

[6] Brazil ranks 105 in 180 countries in Transparency International's corruption perception index of 2018 (Brandão, n.d.) and large corruption scandals such as Mensalão and Lava Jato have made it apparent how deeply rooted corruption is in the country.

Figure 16. Jair Bolsonaro in 2016, declaring his support for more favourable policies for the agribusiness at the Pareci SuperAgro fair in the state of Mato Grosso (Parecis SuperAgro, 2016, April 11).

5.4 Transition or no transition?

Agroforestry in Brazil can be understood as a niche innovation which to a certain extent is gaining momentum. The established agricultural regime in Brazil is under pressure from landscape level changes and some internal tensions are apparent. However, the regime still seems fairly stable, and the agroforestry niche has currently not gathered a full momentum. Yet, there is a potential for transition, but it is difficult to pinpoint the exact circumstances of a transition, particularly while it is happening. As Bilali, Hauser, Berjan, Miseckaite & Probst (2017, p. 1011) point out, “Many rural development initiatives are the sites of novelties and niches development, but it is not clear under which conditions they induce a transition”. Furthermore, Smith (2007) reminds us that sustainability transitions are not clean cuts, but rather a continuous and incremental process of regime-niche translations. Power relations are not equal between the two levels and regime actors will often cherry pick elements from a niche once they begin appearing profitable.

Rather than a smooth transition from one regime technology to the one-to-one adoption of a niche innovation, certain practices and concepts from the niche are gradually included in the regime, which might cause a transition in the long run (Smith, 2007). As mentioned in chapter 3.2, niches rarely are coherent and harmonious entities. Within a niche, one is likely to find tensions between idealistic groups and individuals strongly committed to radical sustainability and more pragmatic individuals willing to make compromises and help translating the niche technology into the regime bit by bit (Smith, 2007). This scenario is very apparent within the Brazilian agroforestry community where multiple ideologies, opinions on system complexity and strategies for proliferation coexist under the agroforestry term.

Considering the dawning global (CGIAR, n.d.; Field et al., 2014; United Nations, 2015; World Bank, 2019) and national (Embrapa, 2018; MAPA, n.d.) recognition that agriculture must become more sustainable, it seems likely that a sustainability transition will eventually occur in Brazilian agriculture. The pro-agribusiness position of the current Brazilian government, however, is likely to slow down this transition, but unlikely to cancel it altogether. The pace and scope of the transition are still very unknown and the same goes for the role of agroforestry as a niche innovation altering the Brazilian agriculture regime.

6. Taking a step back

Throughout the thesis, I have presented the environmental unsustainability of contemporary agriculture and the potential of agroforestry to mend this. I have identified obstacles and opportunities related to a larger adoption of agroforestry in Brazil and I have suggested the usefulness of understanding agroforestry as a niche innovation in a potentially unfolding sustainability transition within Brazilian agriculture. In this chapter, I first discuss the necessity of looking beyond production-side solutions to food security before reflecting on the implications of this thesis and on how to potentially take it further.

6.1 Questioning Malthus and seeing beyond yields

By the end of the century we will likely be more than 11 billion people on the planet (UNDESA, 2017) and future food security is one of the primary challenges facing humanity. The second of the sustainable development goals (SDGs) is named 'Zero Hunger' (United Nations, 2015) and the goal is contextualised in dire descriptions of a future characterised by climate change induced suffering and scarcity. Both the World Bank (World Bank, 2019) and the CGIAR (CGIAR, n.d.) give similar attention to the challenge of feeding the world and paint similarly sinister pictures of the challenges awaiting us. A common theme for these global institutions is that they talk about the issue primarily as a demographically driven phenomenon: the population will continue to grow and so will the overall global development level, making future food demand a simple equation based on combined projections for development and population growth.

This is a neo-Malthusian framing of the tensions between human activities and the carrying capacity of the planet. The analysis adopted by the global institutions (CGIAR, United Nations, World Bank), based on the Malthusian understanding of a demographically driven scarcity, sees the solution to the problem primarily as increased yield per hectare. We need massive investments in agricultural technology innovations to increase agricultural output "in harmony with the natural environment" (CGIAR, n.d.) and while "supporting people-centered rural development" (United Nations, 2015). The neo-Malthusian analysis has elaborate critics in academia (e.g. political ecology) and amongst activists (e.g. the environmental justice movements), but I will contain myself to question its conclusions. Because, while a more productive (and simultaneously environmentally friendly and socially just) agriculture is urgently needed, this is not and should not be considered the only variable for feeding the world.

There are, at least, two other main variables that deserve careful attention in the global effort to guarantee future food security, namely dietary behaviour and food waste. First, the strong attention given to yields per hectare, the amount of food produced in a given unit of productive land, seems to miss the point, as more food produced does not necessarily mean more mouths fed. As argued by Cassidy, West, Gerber, & Foley (2013), a more useful parameter would be the number of people fed per hectare rather than yields in total numbers. According to their calculations, available food calories could increase with 70 % (feeding an additional 4 billion people) if the current crop production were allocated exclusively for direct human consumption. This is mainly due to the enormous energy loss associated with conversion from plant to animal protein and calories[7], as illustrated in figure 17. In a recent research overview, Godfray et al. (2018) concluded that it seems clear that we will see a substantial increase in the demand for meat. These estimates are based on current dietary behaviour and it is crucial to recognise that such behaviour can be influenced and altered with significant implications for the global food security, bearing in mind the findings of Cassidy et al. (2013). Second, a FAO report from 2011 (FAO, 2011) found that an estimated one third of all food grown for human consumption is wasted or lost globally[8]. It seems rather futile to produce more food if we throw it out instead of feeding it to people.

	Dairy	Eggs	Chicken	Pork	Beef
Calorie conversion efficiency (%)	40	22	12	10	3
Protein conversion efficiency (%)	43	35	40	10	5

Figure 17. Feed conversion efficiencies in calories and protein showing the great loss associated with particularly beef but also other types of meat (Cassidy et al., 2013).

[7] A small, but growing, part of available calories is used as biofuel feedstock, further reducing net available food (Cassidy et al., 2013).
[8] This proportion is still maintained at FAO's website, see: http://www.fao.org/food-loss-and-food-waste/en/

In my thesis I have focused on the production side, i.e., a better way of producing food. But it is crucial to recognise that meeting future food demand is far more complex than a simple equation based on contemporary tendencies and future projections. A better production is of great importance, but it is not the only and entire answer to feeding the world.

6.2 Implications and possibilities for further research

To understand what stands in your way is an important step in planning how to achieve a given goal. At the same time, to diagnose a situation and point out problems is not necessarily sufficient to advance. With my research question, I attempted to create an overview of the current agroforestry situation in Brazil, both in terms of what is currently impeding further adoption as well as what could stimulate it. Tables 2 and 3, synthesising the main findings of my research, are one attempt to answer the question I pose. For people already engaged with agroforestry in Brazil or for people curious about getting involved, this answer offers an overview of what to be aware of as potential challenges to take into consideration as well as forward paths to pursue to further the Brazilian agroforestry agenda. I hope that the thesis can be of use and inspiration for one or several people who are engaged with sustainable agriculture and/or agroforestry, in Brazil or beyond.

In terms of limitations to the research, it could potentially have strengthened the depth of the explanatory power of the analysis if I had been able to include a more heterogeneous range of stakeholders. In particular, it could have been fertile to include the perspectives of farmers who are not currently involved with agroforestry to gain more insights from within the current agricultural regime. It would also be interesting to do a similar research in other countries in the region to understand what the differences and similarities are. Even in an entirely different context, such as Scandinavia, it would be productive to study obstacles and opportunity and highly interesting to analyse what seems to be common across climatic, cultural and socio-political divisions and what seems to be particular.

7. Conclusions

In the context of the urgent need for a more sustainable agriculture, I have investigated the main obstacles to and opportunities for a wider adoption of agroforestry in Brazil, considering agroforestry a promising agriculture system causing less environmental degradation than current practices. I have strived to make a sustainability science research that is problem-driven (Brazilian agriculture is unsustainable), solution-oriented (identifying obstacles and paths forward for a more sustainable agriculture) and normative (Brazilian agriculture should be more sustainable). The results of this thesis are primarily tables 2 and 3, showing an overview of obstacles impeding a wider adoption of agroforestry in Brazil as well as opportunities for the future. The tables are based on 18 interviews with stakeholders in Brazil and 57 literature sources which together provide my answer to my research question.

Using the sustainability transitions approach and the multi-level perspective, I have analysed Brazilian agroforestry as a niche innovation. It has the potential to influence the agriculture regime and possibly even the socio-technical landscape in Brazil, eventually being part of a larger sustainability transition within Brazilian agriculture although it is uncertain if this will happen and at what pace. As such, my results are relevant to sustainability science in their contribution to understand circumstances of one particular transition towards a more sustainable society. It is important to be aware that my results are not *the* answer to my research question but rather *an* answer. Brazil is a vast country and there is certainly a lot of literature and countless stakeholders that I have not been able to include in my research. The obstacles and opportunities I have identified are a part of an answer to what is impeding and what could stimulate more agroforestry in Brazil and the analysis of a possible sustainability transition in Brazilian agriculture is one way of interpreting the situation.

Finally, I discussed the importance of seeing beyond production-side solutions for food. Although my particular research is dealing with production-side improvements, it is of paramount importance to include factors such as dietary behaviour and food waste and losses in the discussion of sustainability and future food security. Whether agroforestry will trigger a sustainability transition in Brazilian agriculture remains unclear, but the analysis shows certain indications that it could be the case. The burning enthusiasm and competence of the people I interviewed, as well as the steadily growing body of knowledge about and experience with agroforestry, makes me confident that agroforestry systems will increase in number, scale and quality throughout Brazil in the coming years.

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Appendices

Appendix 1. Table of sources behind table 1

Benefit	Sources
Soil conservation	Aguiar et al., 2010; Atangana et al., 2014; Béliveau et al., 2017; Carvalho et al., 2005; Coelho, 2017; Hombegowda et al., 2016; Lasco et al., 2014a; Lasco et al., 2014b; Souza et al., 2011; Moraes et al., 2011; Pompeu et al., 2017; Quandt et al., 2018; Sacramento et al., 2013; Salim et al., 2018; Sharma et al., 2016; Souza et al., 2016; Wilson & Lovell, 2016
Increased soil fertility	Moraes et al., 2011; Moreira et al., 2018; Selecky et al., 2017; Wilson & Lovell, 2016; Guteta & Abegaz, 2015; Aguiar et al., 2010; Coelho, 2017; Leite et al., 2014; Duarte et al., 2013; Hombegowda et al., 2016; Didonet, 2015; Salim et al., 2018; Lasco et al., 2014a; Lasco et al., 2014b; Atangana et al., 2014, Sharma et al 2016
Carbon sequestration and fixation	Atangana et al., 2014; Coelho, 2017; Moraes et al., 2011; Jose & Bardhan, 2012; Salim et al., 2018; Selecky et al., 2017; Seoane, 2012; Sharma et al., 2016; Souza et al., 2016; Torres et al., 2014; Torres et al., 2017; Wilson & Lovell 2016; Duguma et al., 2017; Hombegowda et al., 2016; Lasco et al., 2014a
Biodiversity promotion and conservation	Atangana et al., 2014; Clough et al., 2011; Carvalho et al., 2005; Coelho, 2017; Moraes et al., 2011; Leakey, 2014; Souza et al., 2016; Wilson & Lovell, 2016; Guteta & Abegaz, 2015
Biological pest control	Atangana et al., 2014; Coelho, 2017; Moraes et al., 2011; Leakey, 2014; Salim et al., 2018; Sharma et al., 2016; Deltour et al., 2017; Resende et al., 2014; Lasco et al 2014b
Resilience of production systems and livelihoods	Altieri et al., 2015; Carvalho et al., 2005; Coelho, 2017; Moraes et al., 2011; Sharma et al., 2016; Wilson & Lovell, 2016; Lasco et al., 2014a; Lasco et al., 2014b
Increased productivity	Atangana et al., 2014; Coelho, 2017; Moreira et al., 2018; Sagastuy, 2018; Pompeu et al., 2017; Quandt et al., 2018; Guteta & Abegaz, 2015; Lasco et al., 2014b
Water conservation and improvement	Carvalho et al., 2005; Moraes et al., 2011; Quandt et al., 2018; Sharma et al., 2016; Souza et al., 2016; Lasco et al., 2014a; Lasco et al., 2014b

Diversification of products and income	Moraes et al., 2011; Sagastuy, 2018; Salim et al., 2018; Sharma et al., 2016; Hombegowda et al., 2016; Lasco et al., 2014b
Microclimate regulation	Souza et al., 2011; Moreira et al., 2018; Pompeu et al., 2017; Guteta & Abegaz, 2015; Lasco et al., 2014a; Lasco et al., 2014b
Food security	Canuto et al., 2017; Didonet, 2015; Leakey, 2014; Quandt et al., 2018; Lasco et al., 2014b

Appendix 2. List of bibliographical references for literature used in literature review. Listing literature sources on Brazil, Other countries and Global / regional tendencies.

Brazil:

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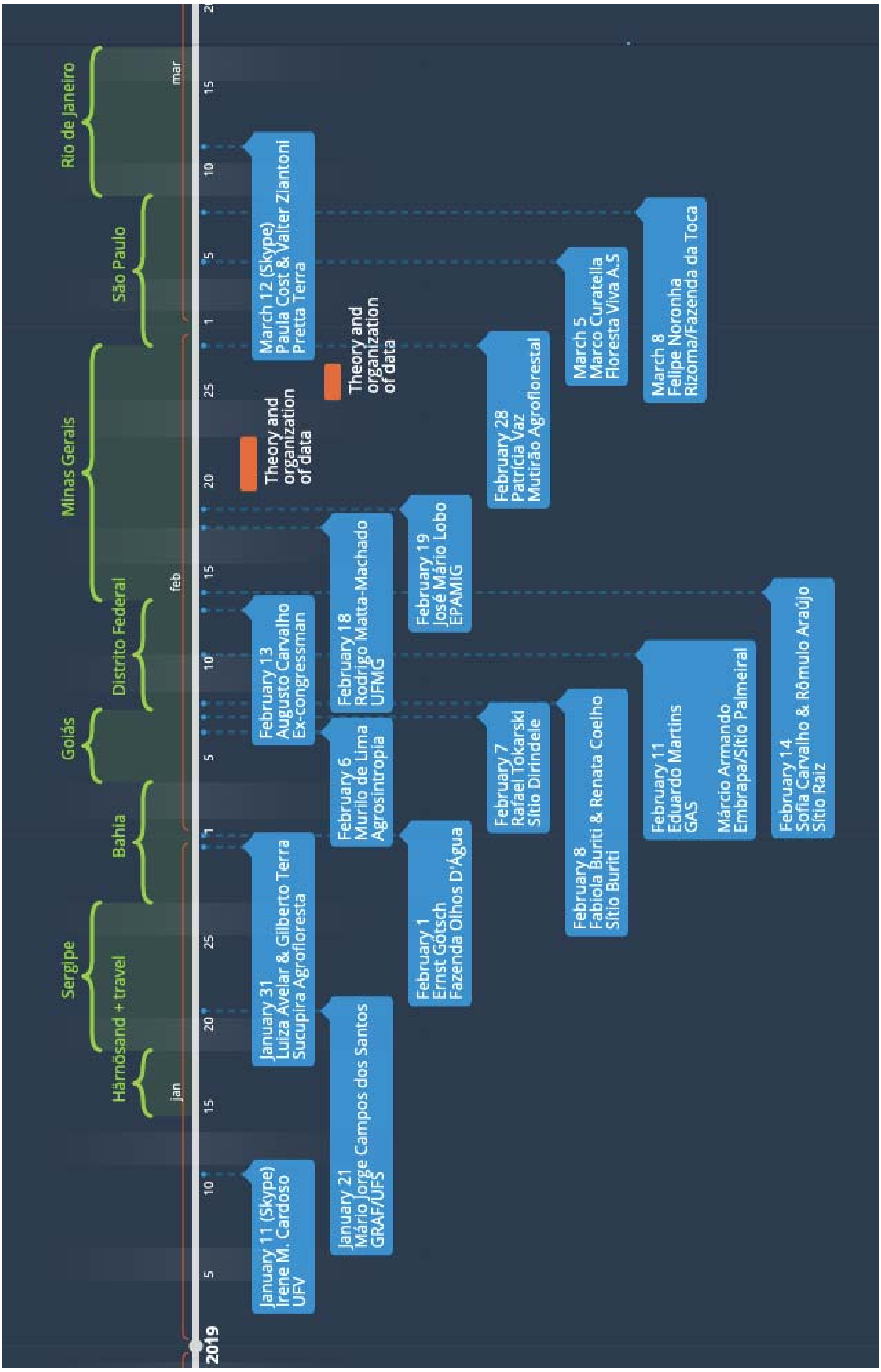
Appendix 3. Itinerary in Brazil.



Appendix 4. Interview guide for semi-structured interviews with agroforestry stakeholders in Brazil

Guia de entrevista

Introdução
Meu nome é Asger Mindegaard, sou estudante no curso de mestrado em estudos ambientais e ciências da sustentabilidade da Universidade de Lund na Suécia.
Estou realizando uma pesquisa para entender os principais obstáculos e as principais oportunidades em relação a uma maior adoção de práticas agroflorestais no Brasil. Eu gostaria de entender isto a partir da experiência de pessoas que estão trabalhando com agroflorestas, de uma forma ou outra, para criar uma síntese de conhecimento diversificado sobre a questão. A intenção é que esta síntese sirva como uma visão global dos desafios e das possibilidades para quem já trabalha na área ou para quem quer entrar. A pesquisa faz parte da minha dissertação de mestrado.

Informações práticas
A informação recolhida na entrevista será utilizada somente para a minha dissertação de mestrado, significando que não será utilizada para fins econômicos. A dissertação estará publicamente acessível na internet.

O/a entrevistado/a é livre para decidir não participar em qualquer momento antes, durante ou depois da entrevista.

As perguntas que eu gostaria de cobrir durante a entrevista encontram-se na segunda página deste documento.

Se você tiver alguma dúvida ou pergunta sobre a pesquisa, pode entrar em contato comigo no e-mail: malabares91@gmail.com.

Nome (entrevistado): ....

Organização/fazenda: ....

Função: ....

Eu quero ficar anônimo: sim ...... não ......

Eu dou a minha permissão para o uso da informação da entrevista na pesquisa

Data: .... de ...., 2019

Assinatura: ....

Perguntas que eu gostaria de cobrir durante a entrevista

a. Para começarmos, você pode se apresentar? Seu nome, idade, o que faz?

b. O que são sistemas agroflorestais para você? Principais vantagens e desafios?

c. Como você se interessou por sistemas agroflorestais e como está envolvido/a com agrofloresta hoje?

d. Na sua opinião, quais são os maiores obstáculos para que tenhamos mais agroflorestas no Brasil?

e. Na sua opinião, quais são as maiores oportunidades para que tenhamos mais agroflorestas no Brasil?

f. No final da minha pesquisa, eu quero apresentar uma síntese do que os entrevistados identificaram como obstáculos e oportunidades. Qual seria um formato útil para apresentar essa síntese?

g. Tem alguma outra coisa que você gostaria de acrescentar/comentar que eu tenha esquecido de perguntar? Há algo que acha que eu deveria ter perguntado?

Appendix 5. Table of interviews with agroforestry stakeholders in Brazil. The interviews were conducted between January 19 and March 18, 2019 in the states of Sergipe (SE), Bahia (BA), Goiás (GO), Distrito Federal (DF), Minas Gerais (MG), São Paulo (SP) and Rio de Janeiro (RJ) as well as on Skype and WhatsApp.

Date, location, state	**Name**	**Organisation, company, institution**	**Relation with agroforestry**
Jan. 7, Skype	Irene M. Cardoso	Federal University of Viçosa, (UFV)	Researcher and associate professor at the soil department
Jan. 21, UFS (SE)	Mário Jorge Campos dos Santos	Federal University of Sergipe, (UFS)	Researcher and associate professor at the department for forest science
Jan. 31, their farm (BA)	Luiza Avelar & Gilberto Terra	Sucupira Agroflorestas	60 hectares of agroforest, courses and consultancy in agroforestry and silviculture
Feb. 1, his farm (BA)	Ernst Göetsch	Olhos d'Água	A few hectares of agroforest, courses and consultancy in syntropic agriculture which he developed
Feb. 5, his house (GO)	Murilo de Lima	AgroSintropia	Consultancy in syntropic agriculture
Feb. 7, his house (GO)	Rafael Pereira Tokarski	Sítio Dirindele	Courses and consultancy in agroforestry
Feb. 8, their house (GO)	Fabiola Buriti & Renata Coelho	Sítio Buriti	600 m^2 of agroforest, unrelated fulltime jobs on the side
Feb. 11, his house (DF)	Eduardo Martins	Grupo de Agricultura Sustentável (GAS)	Organic farmer and co-organiser of the GAS network working on sustainable large-scale agriculture
Feb. 11, Shopping Boulevard (DF)	Márcio Silveira Armando	Embrapa (Brazilian Agricultural Research Corporation)	Researcher and project developer, 25 years of contact with syntropic agriculture
Feb. 13, Torteria di Lorenza (DF)	Augusto Carvalho	Federal deputy in congress for six mandates until January 2019.	Former president of the environmental commission of the Chamber of Deputies, organised public hearing with Ernst Götsch in the Congress
Feb. 14, their farm (DF)	Sofia Carvalho & Rômulo Araújo	Sítio Raíz	3 hectares of syntropic agriculture
Feb. 18, UFMG (MG)	Rodrigo Matta Machado	Federal University of Minas Gerais, (UFMG)	Researcher and assistant professor at the institute of biology
Feb. 19, Padero bakery (MG)	José Mário Lobo	EPAMIG (Agricultural Research Corporation of Minas Gerais)	Researcher in agroecology working with sustainability indicators, former large-scale farmer
Feb. 28, her farm (MG)	Patrícia Vaz	Núcleo Diversitah and Mutirão Agroflorestal	Courses, consultancy, research and production related to syntropic agriculture since 1992

Mar. 5, Shopping Iguatemi (SP)	Marco Curatella	Floresta Viva S/A	Co-founder and associate in Floresta Viva S/A with 165 hectares of agroforest
Mar. 8, Fazenda da Toca (SP)	Felipe Noronha	Rizoma	Research and development of 50 hectares of agroforestry at Fazenda da Toca
Mar. 12, Whatsapp	Paula Costa & Valter Ziantoni	Preta Terra	Consultancy, education and communication of agroforestry systems
Mar. 18, Whatsapp	Agrofloresta do Futuro	Agrofloresta do Futuro	Technical and economic consultancy focused on investors and education in agroforestry

Appendix 6. Table of sources behind Table 2

	Obstacle	Interviews	Literature
a	Complexity of agroforestry and knowledge gap	Lima, Armando, Lobo, Curatella, Costa & Ziantoni, Agrofloresta do Futuro, Götsch, Noronha	Bendahan et al., 2018; Campello et al., 2006; Macedo & Venturin, 2006; Henkel & Amaral, 2008; Miccolis et al., 2016; Nascimento et al., 2016; Sales et al., 2013; Souza et al., 2012; Padovan et al., 2016a; Sagastuy 2018
b	Logic and infrastructure of production and market	Cardoso, Lima, Buriti & Coelho, Martins, Lobo, Curatella, Noronha, Costa & Ziantoni, Agrofloresta do Futuro	Carvalho et al., 2005; Moraes et al., 2011; Hoch et al., 2012; Miccolis et al., 2016; Padovan et al., 2017; Porro & Miccolis, 2011; Sales et al., 2013
c	Labour intensity and shortage of qualified labour	Santos, Lima, Tokarski, Buriti & Coelho, Vaz, Curatella	Didonet, 2015; Macedo & Venturin, 2006; Miccolis et al., 2016; Nascimento et al., 2016; Padovan et al., 2017; Bendahan et al., 2018; Sales et al., 2013
d	Conventional thinking in education and extension	Avelar & Terra, Götsch, Armando, Martins, Carvalho, Carvalho & Araújo, Lobo, Santos	Padovan et al., 2017; Porro & Miccolis, 2011
e	Lack of consumer awareness and appreciation	Tokarski, Buriti & Coelho, Carvalho & Araújo, Machado, Lobo, Vaz, Costa & Ziantoni	Miccolis et al., 2016; Padovan et al., 2017; Sales et al., 2013
f	Lack of support and incentives in public policies	Cardoso, Vaz	Coelho, 2017; Belarmino, 2017; Nascimento et al., 2016; Padovan et al., 2017; Porro & Miccolis, 2011; Miccolis et al., 2016
g	Additional costs and difficulties of financing agroforestry	Avelar & Terra, Buriti & Coelho, Curatella, Tokarski	Moraes et al., 2011; Miccolis et al., 2016; Padovan et al., 2017; Porro & Miccolis, 2011
h	Lack of adequate machinery and equipment	Götsch, Lima, Armando, Vaz, Curatella, Noronha, Costa & Ziantoni	
i	Political influence of agribusiness	Cardoso, Martins, Carvalho, Machado, Lobo	
j	Production disconnected from nature	Götsch, Martins, Armando, Carvalho & Araújo	Mattos, 2006
k	Erosion of traditional knowledge and rural culture	Butiti & Coelho, Carvalho & Araújo, Machado, Santos	

Appendix 7. Table of sources behind Table 3

	Opportunity	Interviews	Literature
l	Research in agroforestry	Carvalho & Araújo, Machado, Lobo, Noronha, Avelar & Terra	Moraes et al., 2011; Nascimento et al., 2016; Padovan et al., 2016a; Porro & Miccolis, 2011; Carvalho et al., 2005; Souza et al., 2012
m	Agroforestry in education and extension	Lima, Armando, Lobo, Curatella	Bendahan et al., 2018; Moraes et al., 2011; Macedo & Venturin, 2006; Gonçalves et al., 2016; Porro & Miccolis, 2011; Sagastuy, 2018
n	Promotion of mind-shift	Götsch, Tokarski, Buriti & Coelho, Carvalho & Araújo, Machado, Vaz, Martins, Lobo	Mattos, 2006
o	Political support	Avelar & Terra, Carvalho & Araújo, Machado, Lobo	Moraes et al., 2011; Nascimento et al., 2016; Porro & Miccolis., 2011
p	Organisation of farmers	Avelar & Terra, Lima, Tokarski, Buriti & Coelho, Armando, Carvalho	Nascimento et al., 2016
q	Lead by example	Santos, Götsch, Lima, Martins, Carvalho, Buriti & Coelho, Armando	
r	Innovation of machinery and equipment	Götsch, Lima, Buriti & Coelho, Carvalho & Araújo, Lobo, Vaz	
s	Integration of agroforestry into land restoration efforts	Lima, Tokarski, Lobo	Miccolis et al., 2016; Nascimento et al., 2016
t	Good examples for inspiration and confidence	Santos, Avelar & Terra, Martins	Moraes et al., 2011