The impact of full-sun cocoa monoculture on deforestation and ecosystem services in Agnibilekrou, Ivory Coast

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Preface

As a citizen of Ivory Coast, I believe that working on a topic that crystallizes the attention of all public institutions was relevant. Every Ivorian is to a certain extent affected by the cocoa industry. In Ivory Coast, it has been developing for decades, where one generation after another has kept producing cocoa, such that today Ivory Coast is the biggest cocoa producer in the world. Contributing to the livelihoods of nearly a million people, the cocoa industry is a pillar of the Ivorian economy. Considering that Ivory Coast would be the focus of my thesis, the cocoa industry and the environmental consequences of cocoa production were something worth investigating.

Researching ways to improve the state of the industry and mitigate the consequences of cocoa production the country's natural capital was the main focus when choosing this research topic. Being able to contribute to a positive change that would benefit all affected parties would be quite an achievement. I worked on this study in the hope that a national industry that is renowned around the world would take heed of the findings, and promote means of producing cocoa that is respectful of the environment.

Through this research, I was also fortunate to visit rural parts of Ivory Coast that I seldom had to chance to visit. Agnibilekrou is a department I had the chance to visit a couple of times before. The trip from Abidjan to Agnibilekrou shows the differences in terms of ecosystems, where the dense forest in the southern part of the country turns into a savanna approaching Agnibilekrou in the center of the country. Working outdoors is something that I have always valued, and being able to explore the outside world and see firsthand the consequences of cocoa production was an important part of this thesis for me. Nevertheless, it was also a good learning experience to conduct different interviews and review articles which are relevant skills to have in the field of environmental sciences.

As part of this journey, I would first and foremost like to thank Dr. Odile Angoran who paved the way and gave access to governmental institutions that could not have been accessible without her help, notably the Ministry of Agriculture and Rural Development and the Coffee-Cocoa Council. I would also like to thank Mr. Kombo N'Guessan for his help in arranging meetings and interviews with farmers in Kongodia. Further, I would like to thank Dr. Rudolf de Groot and Prof.dr.ir. Wim de Vries for their guidance and advice provided every step along the way to finalizing this thesis.

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Tables and Figures

Acronyms

AFD:	French Development Agency
ANADER:	National Agency for Support to Rural Development
CBA:	Cost-benefit analysis
CCC:	Coffee-Cocoa Council
CNRA:	National Agronomic Research Center
CSR:	Corporate social responsibility
DPSIR:	Driver, Pressure, State, Impact, Response
GDP:	Gross domestic product
FIRCA:	Interprofessional Fund for Agricultural Research and Council
ICRAF:	World Agroforestry Center
n.a.:	Not applicable
NGO:	Non-governmental organization
PES:	Payment for ecosystem services
REDD+:	Reducing Emissions from Deforestation and Forest Degradation in Developing Countries
SEP-REDD+:	Permanent executive secretariat for REDD+
SODEFOR:	Forest Development Corporation
SOM:	Soil organic matter
UN:	United Nations
UN-REDD:	The United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries
USGS:	United States Geological Survey
VPA-FLEGT:	Voluntary Partnership Agreement-Forest Law Enforcement, Governance and Trade

Summary

Global cocoa demand has steadily increased in the past decade, notably in Asia where chocolate consumption boomed. To meet this growing demand, cocoa producing countries have taken measures to increase their production. Cocoa production, like any other land-use, has environmental consequences. Trade-offs between cocoa plantations, and other land-uses exist. All land-uses utilize and value ecosystems differently. Ecosystems are interconnected communities of biological organisms living in the same physical environment. Depending on the ecosystem, different land uses can be favored.

Ivory Coast is the biggest cocoa producer in the world, by producing nearly a third of the world's production. To plant cocoa, primary and secondary forests have to be cleared. Primary and secondary forests are ecosystems that have benefits they provide to society called ecosystem services. They contribute to the welfare and wellbeing of people and organisms that depend on them. Once cleared and replaced with a cocoa plantation, the forest loses its ecosystem services and the plantation provides different services. Since the 1960s, Ivory Coast has lost most of its forest cover and has opted for full-sun cocoa monoculture to quickly maximize yields. Planting cocoa in full-sunlight reduces competition for resources, but is unattainable as cocoa yields have evidently been declining. Hence, other cocoa production systems, such as agroforestry systems and subsistence forests, ought to be investigated, to understand the environmental consequences of land-use change from a subsistence forest to a cocoa plantation and analyze the benefits each cocoa production system can provide.

Therefore, this thesis aims to investigate the impact of full-sun cocoa monoculture on deforestation and ecosystem services in Agnibilekrou, which was one of the first departments in Ivory Coast to plant cocoa. The research questions focus on the industry's stakeholders, the ecosystem services provided by the three considered land-uses (i.e. full-sun cocoa monoculture, subsistence forest, and agroforestry system), how cocoa drives deforestation and affect the original ecosystem services, and what is a sustainable cocoa industry.

To answer these questions, interviews, literature review and observations provided data. Fieldwork was done between July 2017 and August 2017. Firstly, stakeholders were identified to see which institutions and stakeholders were relevant to the industry. The Agnibilekrou Department was visited on two occasions to talk to thirteen cocoa farmers from Kongodia, a village in the department, and visit their plantations. The chairman of the farmers' cooperative in Kongodia was also interviewed. Moreover, five policy makers from the Coffee-Cocoa Council and the Ministry of Agriculture and Rural Development were also interviewed.

The resulting information was organized in a cause-effect DPSIR conceptual framework, which links drivers, pressures, states, impacts and responses, and is used to better understand environmental problems and increase awareness by communicating. I focused on the states and impact compartments, and used different methods to answer each research questions. Firstly, an impact assessment assesses the sustainability of a considered project. Potential environmental impacts, the design of mitigation measures and the implementation and monitoring fort these measures are identified. Stakeholder participation happens throughout the impact assessment. This tool was used in this thesis to assess the potential environmental impacts of land-use change. Twenty-five studies were reviewed to quantify those environmental impacts. Secondly, an ecosystem service analysis determined which ecosystem service each land-use option can provide. The Economics of Ecosystems and Biodiversity (TEEB) classification was used to select ecosystem services. TEEB also helped link economics and ecology, and highlight how ecosystem services benefit human well-being.

My research showed that converting a subsistence forest to a cocoa plantation strongly reduces annual carbon sequestration (from 2-6 ton C per ha to 0.80-1 ton C per ha) and the soil's carbon stock (from 115-400 ton C per ha to 25-90 ton C per ha). Vegetation removal increases the likelihood of drought due to less retained soil water (from 347-465 mm to 200-300 mm). This also leads to more annual soil losses (from 0-1.2 ton per ha to 20-90 ton per ha). Furthermore, vegetation loss deteriorates biodiversity (from 160 plant species to 116 plant species). All these factors cause full-sun cocoa monocultures to decrease their annual productivity over time (from 2-4 ton per ha in the 1960s to 250-560 kg per ha today). Furthermore, my calculations show that cocoa plantations are responsible for the loss of 15% of forest cover in Ivory Coast.

Agroforestry systems can annually sequester more soil carbon (0.25-3.5 ton C per ha) due to increased vegetation. The additional trees and the cocoa trees provide additional income and the tree leaves add to the litter layer that recycles nutrients back into the system and improve the soil's fertility (10-230 ton C per ha). Simultaneously, water retention increases compared to full-sun cocoa monocultures (265-375 mm), and erosion is negligible (i.e. similarly to subsistence forests). The ecological benefits contribute to increasing annual cocoa production (0.5 - 1 ton per ha).

Over time (10-15 years), agroforestry systems have been found to produce as much, if not more than full-sun cocoa monocultures, due to the increased shade that provides protection and additional nutrients. Moreover, the crops planted in combination with cocoa provide additional income and help to reduce poverty and food insecurity.

Ivory Coast's policies are aligned with those findings as the Ivorian REDD+ strategy aims to bridge the gap between agriculture and forestry. Moreover, the 'Cacao ami de la foret' policy shifts the focus from cocoa to a broader approach that also includes environmental protection. Nevertheless, these policies have been poorly implemented and monitored. The transition to a cocoa industry that does not cause deforestation and land degradation is in its initial stage in Ivory Coast. Funding is needed to study tree species' utility to apply in agroforestry systems, disseminate such information and make agroforestry smallholder farmers' standard.

My results are supported by scientific literature, despite the lack of sufficient and specific data from Agnibilekrou Department. The collaboration of cocoa growers and policy makers can create a viable solution to improve the cocoa industry. This thesis helps increase awareness amongst rural farmers and government officials about the possibilities of sustainable cocoa production and hopefully foster a faster transition towards a sustainable cocoa industry.

1. Introduction

1.1 Background

African countries have been at the forefront of the global cocoa (*Theobroma cacao*) production. Indeed, during the 2011/2012 campaign, the continent accounted for 71.4% of the global production, with Ivory Coast (or Cote d'Ivoire) providing 36.4% of that amount (Wilson *et al.* 2015). As a rapidly growing commodity, cocoa based goods are putting a great amount of stress on natural ecosystems. The demand for cocoa has increased globally, notably in Asia that saw a boom in consumption by 31% between 2007 and 2013. Between 2002 and 2010, consumption of chocolate products increased by 10% in European countries, the United States, Brazil, Japan and Australia (International Cocoa Organization, 2012). The global annual growth in consumption of the commodity is expected to be 2% over the coming years (Oberthür *et al.* 2015). Besides, the sector directly contributes to the livelihoods of over 800 000 households in Ivory Coast (Interview 1, email communication, September 5, 2017). The cocoa industry has been instrumental in shaping the growth of Ivory Coast. With the increasing demand for cocoa, Ivory Coast has been responding by remaining a world leader in cocoa production. The question that remains is whether this trade-off is of value to the country as a whole, accounting for future generations who will need fertile arable land to be able to meet their own needs.

Ivory Coast has three distinctive climatic zones: a dense and humid forested area in the South, a savannah in the North and a transition zone in the center of the country (Thomas, 2003). The forested area, which attracts the greatest flow of people, is where agriculture is done due to the fact that the soil and climatic conditions make it a favorable place for such activity as opposed to the more arid northern area. Agriculture has been the main economic activity in Ivory Coast since the 1960s and a major driver of its early prosperity. The country's first president, Felix Houphouet-Boigny, launched a policy with the motto "the land belong to those who develop it" that encouraged people to migrate towards forested zones and clear the forest to produce cocoa (Ruf, 2001). Today, 2 300 000 hectares are used to grow cocoa nationwide, which represents nearly 7% of the country's land area (Interview 1, email communication, September 5, 2017). In 2015, the coffee-cocoa industry contributed to 14% of the country's GDP (JNCC, 2016). Cocoa has for some time been an essential crop for Ivory Coast and its economy.

Yet, Ivory Coast, world leader in cocoa production, has witnessed deforestation on a wide scale, and cocoa production has been the major driver (Ruf *et al.* 2015). Through a study by Kone *et al.* (2016) using remote sensing and multi-temporal data, comparing images of previous years and more recent years, the forest cover and extent of deforestation in Ivory Coast could be established. Results showed that the country lost more than 80% of its forest cover since its independence in 1960 (Kone *et al.* 2016). This loss has been essentially due to agriculture, but also demographic pressure induced by migration, as well as illegal logging activities (Kone *et al.* 2016). As agriculture is a pillar of the Ivorian economy, the country has focused the use of its fertile land to produce crops, notably cocoa. Since 1980, the state of deforestation in Ivory Coast had been deemed critical based on certain indicators, notably the percentage of national forest cover and the annual deforestation rate, which were respectively 14% and 7% (Grainger, 2013).

1.2 Problem Statement

The increasing demand for cocoa, notably in Asia, since the 2000s (Oberthür *et al.* 2015) has been met with an increase in production in Ivory Coast. There is only a finite amount of land hence to increase production there needs to be more land allocated for cocoa production or intensification of production. Intense cultivation and deforestation helped increase production, yet

annual productivity has stagnated at about 450 kg per ha during the past decade, while the productivity of the soil has steadily declined to low levels (Andres *et al.* 2016).

Full-sun cocoa farming is the method of cultivation most prominent in the humid and sub humid regions of Ivory Coast (Tondoh *et al.* 2015). It involves growing the cocoa trees in full-sunlight with no shade, to maximize the yield in a shorter amount of time. However, this land-use option brings about different problems related to the adequate functioning of the ecosystem. Over time, full-sun cocoa monoculture become less productive and plantations are abandoned (Tondoh *et al.* 2015). According to different studies, the conversion of a forest to a full-sun cocoa plantation can result in forest degradation, loss of biodiversity, greenhouse gas emissions, reduced soil quality leading to low yields and food insecurity (Tondoh *et al.* 2015; Zapfack *et al.* 2002).

Considering the importance cocoa represents for the Ivorian economy, the government must ensure a steady production that continues to generate revenue. But considering the ecological drawbacks of full-sun cocoa monoculture, other land-use options should be considered for the future of the Ivorian cocoa industry. Other methods of producing cocoa, such as agroforestry systems, do exist and have been implemented in different countries with somewhat similar climatic conditions as Ivory Coast. In the savanna-forest interface of Cameroon, cocoa has successfully been produced in agroforestry systems (Jagoret *et al.* 2012). Furthermore, rural populations in Ivory Coast also use the forest for subsistence purposes, to feed their families (Interview 7, personal communication, August 18, 2017).

A trade-off between these three land-use options exists with respect to cocoa supply, but also to the regulation of ecological processes that are crucial for the proper functioning of the ecosystem. With a finite amount of land, land-use decisions should help meet the country's economic goals, but shouldn't be ecologically detrimental in the long run.

1.3 Study Area

Cocoa has had a long standing history with Ivory Coast, going all the way back to the colonial era. But it was not until after the First World War that most cocoa stands were planted on an industrial scale. 13 regions across the southern half of the country have been planting cocoa, out of the country's 31. The region of Indénié-Djuablin (Figure 1), encompasses the Bettie, Abengourou and Agnibilekrou Departments, which are precursors in the Ivorian cocoa industry (Ross, 2017). The latter will be the department this thesis will focus on.

1.3.1 Location

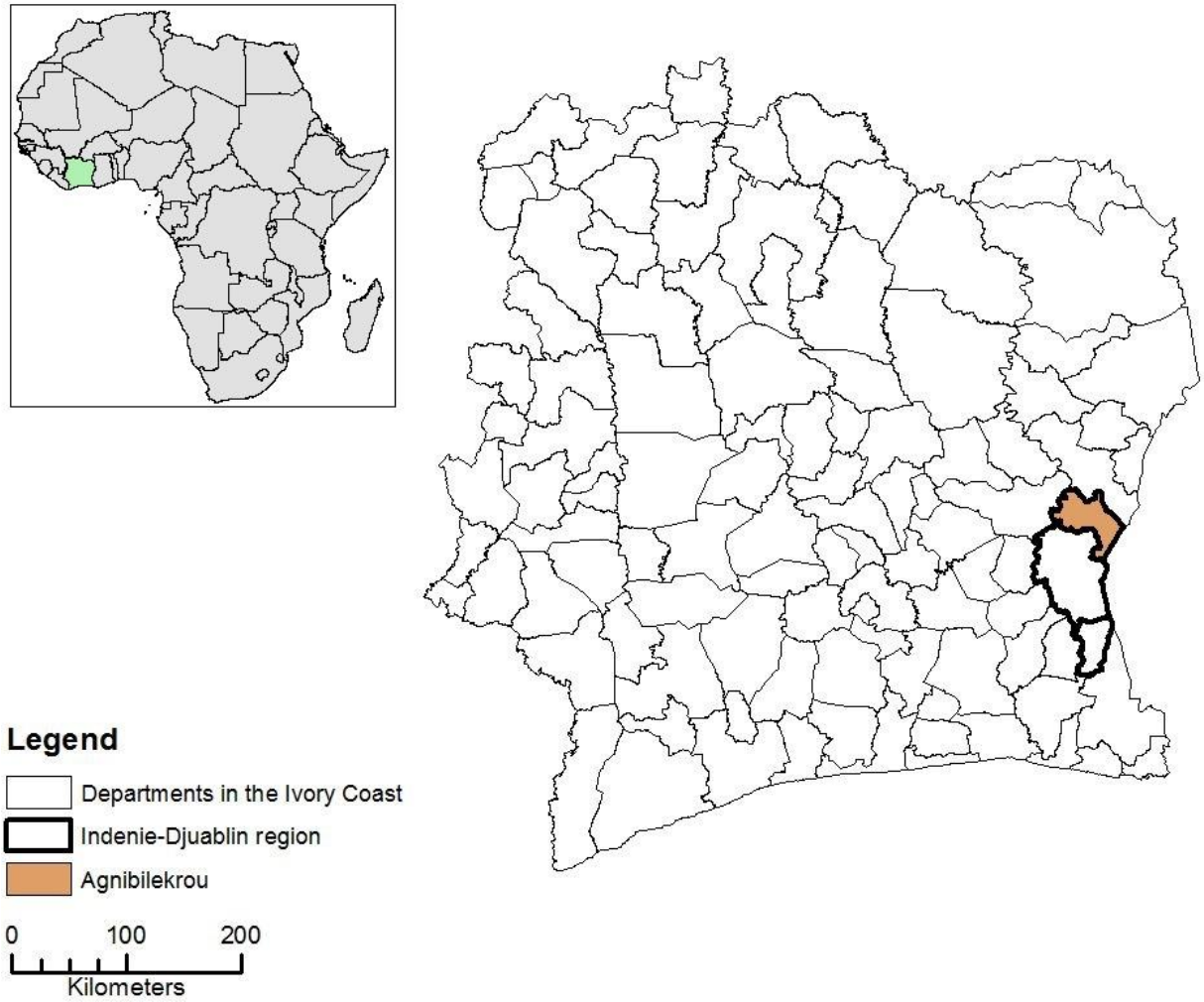


Figure 1: *GIS location map of the Indénié-Djuablin region, Ivory Coast with the Agnibilekrou, Abengourou and Bettie Departments (Shape files from Geofabrik and Map Library)*

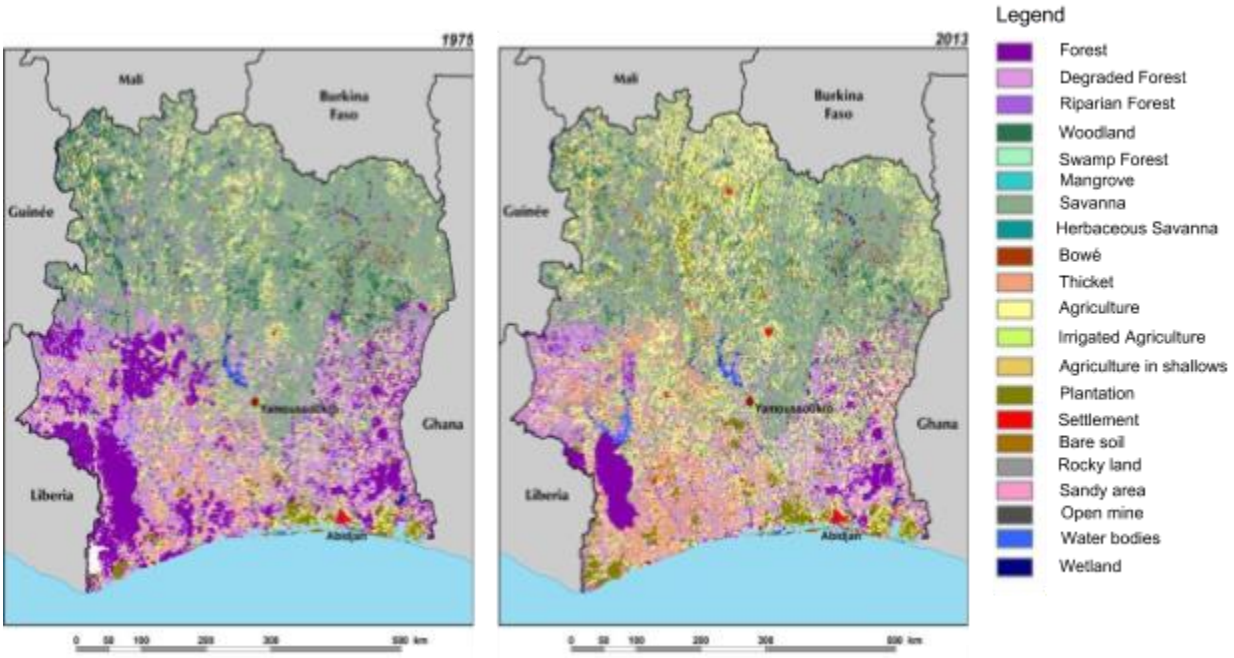
The Agnibilekrou Department has been the pioneer in the development of an industry that elevated Ivory Coast. Cocoa farming is done in the villages in the vicinity of Agnibilekrou, the seat of the department. For this thesis, Kongodia, a village situated 10 kilometers away from the city of Agnibilekrou was the base for data collection. This particular village was chosen because it was possible to contact the chairman of the farmers' cooperative who facilitated contacts with farmers from the village. In Kongodia, like in the 31 other villages in the department, cocoa farmers are smallholder farmers that own their own land and grow cocoa on family size plantations (between 1 and 4 ha) (Interview 6, personal communication, August 28, 2017). The village is home to about 100 farmers who for the most part practice full-sun cocoa monoculture to maximize their profits (Interview 7, personal communication, August 18, 2017). However, farmers are being exposed to other growing methods and techniques, amongst which agroforestry is becoming popular nowadays. Cocoa trees are planted with a mix of rubber and teak trees that provide additional raw material (i.e. rubber and timber). Nitrogen fixing trees have also been tested in those agroforestry system, notably with *Albizia sp*, to improve the soil quality and recycle nutrients with the added litter layer (Interview 3, personal communication, August 10, 2017; Del Greco *et*

al. 2012). Moreover, small areas (about 4 ha) around each village in the department, have mainly been left uncultivated for traditional reasons. The subsistence forest is still used for personal family food production. The three cited types of land-use (subsistence forest, full-sun monoculture, agroforestry system) can all be found in Kongodia. Based on the information found in that particular village and through literature, a representation of cocoa production in Agnibilekrou and Ivory Coast can be derived.

Considering the deep-rooted relationship the region has had with cocoa production over many decades, the impact of this industry could be adequately established in that area. Moreover, the state of deforestation in the Indénié-Djuablin region has been documented, thus providing information to establish a link between deforestation and declining yields.

1.3.2 Land-Use Change

Kone *et al.* has determined that since 1960, Ivory Coast has lost 80% of its forest cover due to increasing pressure from the agricultural sector and the cocoa industry (Kone *et al.* 2016) (Figure 2). With the reduction in forest cover, repercussions on the climate of the country ensued. A study by Spracklen *et al.* (2012) in the Amazon determined that when forests are cleared, the lack of vegetation reduces evapotranspiration which leads to reduced humidity in the atmosphere, thus repressing precipitation. In the region of Indénié-Djuablin where Agnibilekrou is located, the forest cover decreased from 435 000 ha to 45 000 ha between 1960 and 2000, representing a 90% reduction (Kone *et al.* 2014). Ecosystems, such as a primary or secondary forest, provide different benefits to society. Those benefits are called ecosystem services and contribute to people's welfare and wellbeing (de Groot *et al.* 2010). Considering the reduction in forest cover, the contribution of the cocoa industry to deforestation and the loss of ecosystem services ought to be investigated.



[1]***Figure 2:*** *Maps of land cover in Ivory Coast, comparing 1975 to 2013. (Adapted from USGS)*

[1] Maps obtained from the United States Geological Survey [eros.usgs.gov]

1.4 Research aims and questions

This research aims to investigate the impact of full-sun cocoa monoculture on deforestation and ecosystem services in Agnibilekrou specifically and Ivory Coast in general. The purpose is to understand the environmental consequences of overexploitation of natural resources to meet a growing demand. This aspect was investigated throughout this thesis to point out the consequences associated with full-sun cocoa monocultures.

Although economic activities are crucial for the development of Ivory Coast, they have to be sustainable to preserve natural capital. A comparison of three land-use options (i.e. a subsistence forest, a full-sun cocoa plantation, and a cocoa agroforestry system) revealed the potential benefits and trade-offs that could be gained by each system. Those three systems were described in terms of the benefits that they can provide to the people, with respect to provisioning, regulating, cultural and habitat services. Hence a comparison of those benefits would help determine what land-use option would be best suited to protect the environment and cocoa production.

Therefore, the research questions are:

RQ1: Which stakeholders are involved in the Ivorian cocoa industry?
RQ2: What are the ecosystem services of a subsistence forest, full-sun cocoa monoculture and agroforestry systems in Agnibilekrou?
RQ3: How does the cocoa industry contribute to deforestation?
RQ4: How are the selected services affected by cocoa production (full-sun monoculture or agroforestry system)?
RQ5: What recommendations can be given for a sustainable cocoa industry?

1.5 Thesis Outline

Firstly, an overview of the methodology outlines the conceptual framework used to carry out this research, but also gives a detailed overview of the methods used to collect and analyze the data gathered (Chapter 2). Secondly, there is a description of the major stakeholders involved in the Ivorian cocoa industry to understand its structure. The power, influence and how all stakeholders work for the betterment of the cocoa industry is given based on the interviews conducted with those stakeholder as well as information gained through literature (Chapter 3). This chapter lays the foundation for policy recommendations. Knowing the activities and institutional power of relevant stakeholders, plausible recommendations can be formulated. Thirdly, a description of three land-use options (subsistence forest, full-sun monoculture, agroforestry system), and the services that they each provide is presented in three tables and described (Chapter 4). Those services are quantified for comparison between the different land-uses. Later, the effect of each land-use option on deforestation and ecosystem services is presented (Chapter 5). This section gives a more qualitative comparison of the different land-uses to establish a wholesome comparison of their benefits and sustainability prospects. Moreover, an analysis of the policy goals of the REDD+ strategy and “Cacao Ami de la Foret” policy show the implications for the future of the cocoa industry while providing recommendations (Chapter 6). The recommendations are focused on research but include added policy. Lastly, a discussion about assumptions and limitations of this thesis shed light on its shortcomings and put the results in perspective to justify the credibility of my results (Chapter 7). It is then followed by a conclusion of the objectives set out at the beginning where I will summarize the benefits of each land-use and show that agroforestry systems can contribute most to a sustainable cocoa industry (Chapter 8).

2. Methodology

2.1 Conceptual Framework: DPSIR

A research study requires a conceptual framework to link all the different variables and connect them to each other. For the particular problem that this study is attempting to tackle, the DPSIR framework was used to map out the thought process behind the research. This framework was first developed for structuring and reporting of environmental problems (Giupponi, 2002). It elicits a causal chain between drivers, pressures, states, impacts and responses. It is used to classify factors that affect environmental problems and provide policy relevant information for decision makers on policy that have a certain environmental impact, current or future. The ecosystem services that people depend on for their well-being, are impacted by environmental change drivers, which have to be understood and managed in the appropriate way based on their environmental and social impact. The DPSIR framework can bring together different disciplines and helps to formulate indicators that can be used to set goals and promote progress, to better manage environmental systems (Rounsevell *et al.* 2010). Interactions between individual factors are not considered in the framework. Nevertheless, this framework can help better understand the problem. Both state and impact were the main focus of this thesis. Driver and pressure provided context, while the response focused on the prospect of agroforestry. The methods listed between the compartments were used to answer the research questions, and explained in the following sections of this chapter.

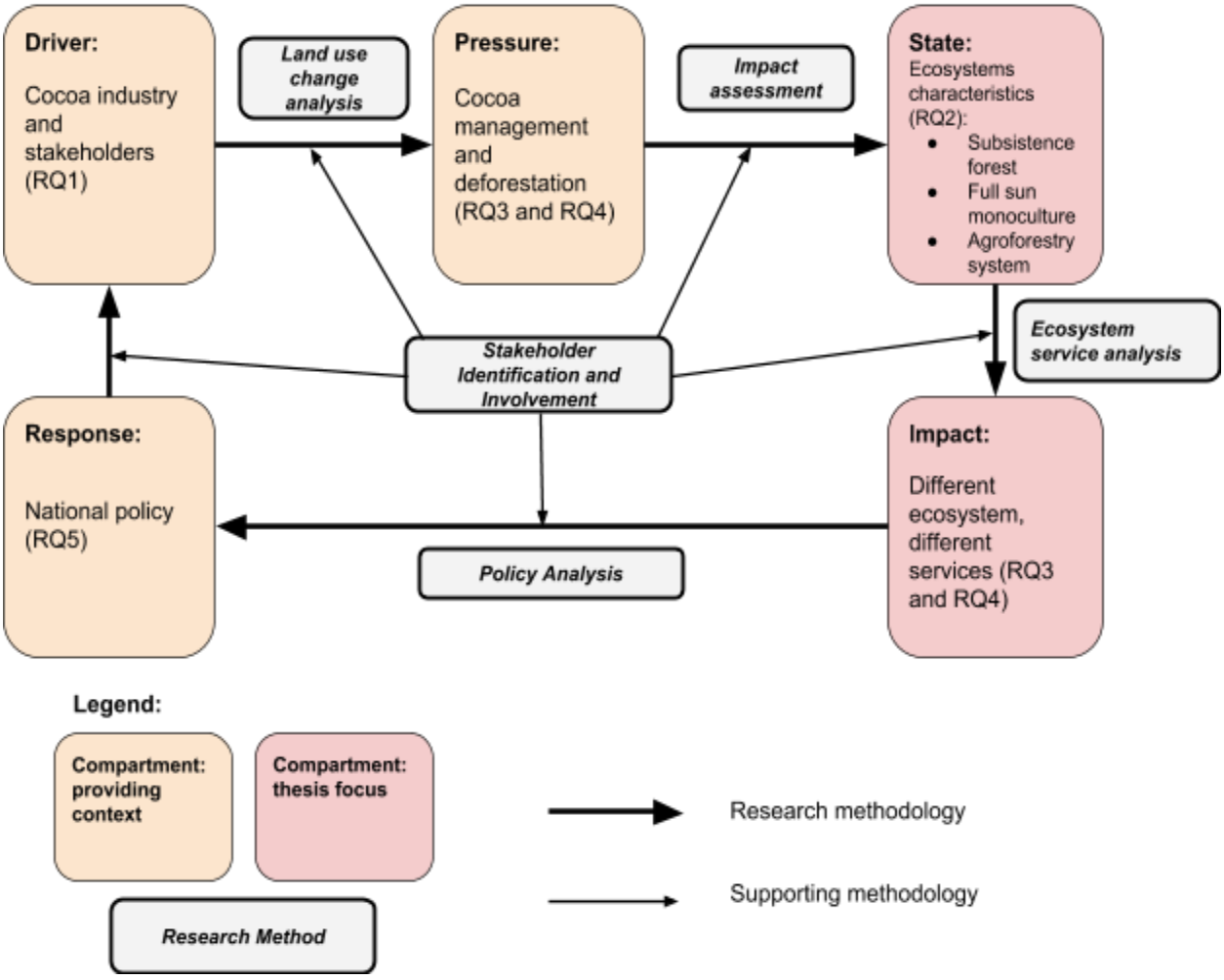


Figure 3: *DPSIR framework for the environmental problem (i.e. loss of ecosystem services) linked cocoa production in Ivory Coast*

The different components of the DPSIR framework are elaborated below based on full-sun cocoa monoculture in Ivory Coast:

- Drivers: The driving force is an underlying cause which leads to a pressure (Giupponi, 2002). With the increasing demand for chocolate and other cocoa based products, policy makers in Ivory Coast have been inclined to promote the cultivation of land towards the production of cocoa (Ruf, 2001). The economic factor is a considerable element to take into account as the cocoa industry represents a prominent component of the Ivorian economy, contributing to 40% of the country's export (Interview 1, email communication, September 5, 2017). Organizations that wield institutional power have for objective the increase in production and productivity in the Ivorian cocoa industry, accentuating the driving aspect of the demand for cocoa.
- Pressures: Driving forces lead to pressure on the environment (e.g. pollution emissions, exploitation of resources etc.) (Giupponi, 2002). They represents the human activities that help meet the need. By promoting agriculture in the country, deforestation has taken up 80% of the Ivorian forest cover (Kone *et al.* 2016). Vast areas of forest and all the benefits they deliver are cleared to make way for wide scale full-sun cocoa plantations that have

for only purpose the production of cocoa, neglecting other important services that the people and future generation will depend on.

- States: The pressure affects the state, which represents the quality of environment, and the ability to support biotic and abiotic organisms (Giupponi, 2002). By clearing a forest to make way for cocoa, a change in the state of the ecosystem occurs. A subsistence forest is replaced by a cocoa plantation. Nowadays in Ivory Coast, cocoa is mainly grown through full-sun monocultures (Tondoh *et al.* 2015), but agroforestry systems have been researched and are becoming more common. These three land-use options were investigated through this thesis.
- Impacts: The change in state has an impact on human well-being, the quality of the ecosystem, biodiversity etc. expressed with respect to the environmental harm (Giupponi, 2002). With deforestation and the intensity of production that has occurred over decades, the quality of ecosystems has been greatly impacted, leading to a reduction in productivity. Nevertheless, different impacts would ensue depending on the land-use option (i.e. whether it is a subsistence forest, a full-sun monoculture, or an agroforestry system). Each would provide different ecosystem services and benefit people as well as the surrounding environment differently.
- Responses: The responses are the efforts by society to mitigate or alleviate the problem (Giupponi, 2002). Other options do exist to somewhat meet the financial goals while preserving the integrity of the environment. Full-sun cocoa monoculture is continually becoming less productive, but agroforestry systems for instance can provide new benefits. The Ivorian government has opted to join the REDD+ efforts to help combat deforestation. Other policies such as the “cacao ami de la foret” policy put in place has also been aligned with the REDD+ strategy.

The DPSIR framework is useful to link the cause and origins of environmental problems to the appropriate response by displaying the environmental consequences of those problems. With this research, the DPSIR framework was used as a starting point to have a general overview of the issues that may arise with cocoa production.

2.2 Research Methods

In order to answer to the different research questions posed, a few methods were used for data collection and analysis.

2.2.1 Stakeholder Identification and Involvement

The acknowledgment of the stake of different stakeholder (individual, organization, etc.) and their ability to influence decision making is the rationale behind the stakeholder analysis (Brugha *et al.* 2000). Stakeholders are those actors who are or could potentially be affected by a project directly or indirectly (Varvasovszky *et al.* 2000). Compiling data on different stakeholders helps understand the reasoning behind the decision making process (Brugha *et al.* 2000). Depending on the power each stakeholders wields, it is possible to understand why certain decision have been favored to the detriment of others. As society in general has become increasingly aware of the ubiquitous nature of environmental risk, all stakeholders realize that they ought to be involved in the decision making process in order to protect their interests. To determine the relevance of stakeholders, it is important to know their position, networks, interrelations and other characteristics (Brugha *et al.* 2000). Furthermore, an understanding of the socio-political context is important to have an overview of these interrelations and the way decisions are taken (Varvasovszky *et al.* 2000).

In Ivory Coast, there has been a clear trade-off between environmental protection and cocoa production. Looking at policies that have been put in place for over half a century, stakeholders who wield institutional power have been promoting cocoa production, greatly benefiting the cocoa industry, but detrimental to small farmers and villagers who have to deal with declining soil productivity in the long run. All stakeholders in the cocoa industry have different power and influences.

The Ministry of Agriculture and Rural Development, as well as the Ministry of Economy and Finances came together to create the Board of Regulation, Stabilization and Development of the Coffee-Cocoa Sector (the Coffee-Cocoa Council or CCC), which is an organization under their guardianship, and tasked with amongst other things improving the productivity of both coffee and cocoa, as well as regulate and stabilize the industry (Interview 2, personal communication, July 26, 2017). In the Agnibilekrou Department, all cocoa farmers are smallholder farmers (Interview 7, personal communication, August 18, 2017). Despite the incentive they have to keep producing cocoa, alternatives have to be presented that account for the prosperity of not only their children, but also for the environment itself. Measures have been put in place to protect and preserve the land that the farmers depend on, for instance through organizations such as CNRA (the National Agronomic Research Center) and ICRAF (World Agroforestry Center) that do research, as well as ANADER (the National Agency for Support to Rural Development) that focuses on training farmers on new and improved techniques. The information on the different stakeholders was gathered primarily through literature review, but interviews were used when possible.

2.2.2 Impact Assessment

An impact assessment is a method used to ensure that projects under consideration are done in a sustainable way and will not result in any negative effects on the environment and society (Jay *et al.* 2007). The assessment is done prior the beginning of the project to help decision makers determine whether it is sound to move forward. It involves the assessment of potential environmental and social problems, the elaboration of mitigation measure that include public participation, and the establishment of a management plan (Jay *et al.* 2007).

For a given project, the impact statement starts with screening and scoping the environmental impact to identify the potential environmental problems that may arise. Then a proposal is prepared with the preparation of the impact assessment with a detailed analysis of the environmental impacts, the design of mitigation measures along with a management plan and monitoring. Stakeholders' participation occurs throughout this whole process. Furthermore, an appraisal is conducted to identify threats and opportunities from a social, legal and environmental perspective. Once the appraisal done, the management plan can be implemented, and monitored especially after the impact assessment has been concluded.

When making a land-use choice a trade-off has to be made. With respect to the cocoa industry in Ivory Coast, forest ecosystems and the benefits they provide have been neglected for the more profitable full-sun cocoa production. The production of cocoa has evident impacts on ecosystems, especially related to soils and their functions. Depending on the land-use option chosen, there are different consequences incurred by the ecosystem. Having a clear overview of the impacts that each land-use type has on the ecosystem would be an essential asset in the decision making process. Once the forest has been clear for cocoa to be produced in an intensive manner, new impacts are derived from such land-use option. Agroforestry systems also have a different set of impacts on ecosystems as opposed to the two previously cited land-use options. A comparison of these land-use options is essential in determining the impact of cocoa production, but also for the sake of looking at agroforestry as a solution for the preservation of natural capital.

The utility of the impact assessment is to anticipate negative consequences and prevent them from happening beforehand through the development of mitigation measures. Nevertheless, this method can be used to look at the consequences of land-use change, accounting for both social and environmental factors, when land-use is replaced with another one. This thesis only focused on the screening and scoping of the environmental impact to identify the different problems that occur with land-use change in the cocoa industry. 25 scientific articles from Latin America, West and Central Africa were reviewed to assess and quantify the environmental changes resulting from land-use change.

2.2.3 Ecosystem Service Analysis

Ecosystem services have been defined as the benefits society derives from nature (de Groot *et al.* 2010). Those services represent the direct and indirect contribution of the natural environment to human well-being. An ecosystem service analysis is a tool used to understand the benefits provided by a given ecosystem. The Economics of Ecosystems and Biodiversity classification recognizes four categories of ecosystem services: provisioning services which are the products obtained from nature, regulating services which are benefits derived from the regulation of ecological processes, habitat services which provide habitat for species and protects the gene pool, and finally cultural services which are the nonmaterial benefits gained from nature (de Groot *et al.* 2010). That same classification lists 22 services across those four categories (Table 1). The selection of the ecosystem services that were the focal point of this thesis were based on Table 1.

The quantification of ecosystem services is dependent on the capacity of an ecosystem to provide a service (i.e. potential), and the actual use of the service (de Groot *et al.* 2010). Different benefits can be obtained from ecosystems depending on the management practices put in place. This tool was used to determine which benefits a forest ecosystem, a full-sun cocoa monoculture, as well as an agroforestry system can provide.

There are different services provided by the forest, prior to being destroyed. Non-timber forest products can be harvested from a forest such as bush meat, or precious metals such as gold, while crops are grown; the forest ecosystem stores carbon in the soil and recycles nutrients to maintain the productivity of the soil which is essential for its adequate functioning, the water retention capacity is essential in preventing droughts that are amongst the consequences of deforestation, a litter layer is instrumental in protecting the soil from erosion, organic matter contributes to the aggregation of soil colloids reducing erosion potential, retains cations, and conserves nutrients in their organic form preventing leaching (Lavelle *et al.* 2001); the maintenance of genetic diversity in and on the soil for biodiversity; the people have cultural beliefs attached to the forest. Those services were selected based on information gathered through interviews with farmers in Kongodia and at the CCC in Abidjan (the economic capital of Ivory Coast) with the Technical Secretary of Public Private Partnership Platform. Their lack thereof can explain the trend that farmers in Kongodia have witnessed over the last few years with declining yield.

By knowing what various ecosystem services a forest can provide, an understanding of the consequences of the loss of said services can be derived. Assessing the different services provided by a subsistence forest, a full-sun cocoa monoculture plantation and a cocoa agroforestry system is an essential part of this thesis to understand the different impacts of management practices. The assessment of the ecosystem services was both qualitative and quantitative, done through interviews and literature review.

Table 1: *TEEB ecosystem services categories (Based on de Groot et al. 2010). An asterisk indicates the ecosystem services that were further elaborated through this thesis*

Services category	Service	*Examples*
Provisioning Services	Food*	Crops, cocoa, livestock
	Water	Drinking water
	Raw materials*	Timber, fossil fuels, minerals
	Genetic resources	Medicine, crop improvement
	Medicinal resources	Biochemical products (proteins etc.)
	Ornamental resources	Domesticated animals
Regulating Services	Air quality regulation	Canopy cover
	Climate regulation*	Vegetative cover
	Moderation of extreme events	Windbreaks
	Regulation of water flows*	Natural irrigation
	Waste treatment	Compost
	Erosion prevention*	Vegetative cover
	Maintenance of soil fertility*	Soil organic matter content
	Pollination	Pollinator
	Biological control	Seed dispersal
Habitat Services	Maintenance of life cycles of migratory species	Nursery service
	Maintenance of genetic diversity*	Habitat
Cultural Services	Aesthetic information	Design inspiration
	Recreation and tourism	Camping
	Inspiration for culture, art and design	Landscape photography
	Spiritual experiences*	Mourning
	Information for cognitive development	Research

Water retention capacity

Water retention is an essential service for cocoa production given the importance of irrigation. In order to determine the water retention capacity of the different land-use options, precipitation minus total evapotranspiration (Equation 1) was the chosen approach. It gives the net amount of water entering the soil.

$$R = P - ET \quad \text{EQ1}$$

R (mm) represents the amount of water that could be held in the soil, P (mm) the annual precipitation and ET (mm) the total annual evapotranspiration.

Regarding the total annual evapotranspiration, the formula by Zhang *et al.* (2001) was used. This approach uses precipitation and potential evapotranspiration in an equation with the plant available water coefficient w (See Equation 2) (Zhang *et al.* 2001).

$$\frac{ET}{P} = \frac{1+w\bullet\frac{E_0}{P}}{1+w\bullet\frac{E_0}{P}+\frac{P}{E_0}} \qquad \text{EQ2}$$

ET (mm) represents the total evapotranspiration, P (mm) the annual precipitation, E_0 (mm) the potential evapotranspiration and w represents the difference in the way plants use the water in the soil for transpiration.

2.3 Data Collection and Analysis

Field work was conducted between July 2017 and August 2017 in Ivory Coast. The Agnibilekrou Department was visited to interview farmers and see plantations.

2.3.1 Literature Review

Data collection

Having an overview of previous research is an essential step in any academic project as it reveals the extent of the knowledge already gathered, but also exposes the areas that still lack information and need to be investigated further (Webster *et al.* 2002). To bring about progress in the Ivorian cocoa industry, what has been done before has to be fully uncovered. Only then, can new and improved measures be sought out to better the prospect of the cocoa industry in Ivory Coast when it comes to ecosystem services. Gathering and compiling data on previous research provides clarity on the context at hand, both social and ecological, and sets a good basis to build upon. Nonetheless, the literature reviewed ought to be justifiable and logical (Kumar, 2014). There has to be a distinct reasoning behind choosing a certain study over another. The information gathered has to provide insight on how to answer the different research questions this thesis is attempting to expend on.

However, a literature review is more than solely a gathering of data and synthesis of previous research. According Levy *et al.* a literature review should analyze and synthesize quality literature, provide a foundation for the topic, provide a foundation for the selected methodology, and show that the research will contribute something new to the available body of knowledge (Levy *et al.* 2006). The literature review helped guide how to conduct this research to achieve the desired results. It is necessary to formulate research problems and contextualize the findings (Kumar, 2014). Putting the end product of the research in the appropriate context will reveal what was the contribution to the current body of knowledge. The literature review is therefore a continuous process that has to occur prior the beginning of the research, but afterwards as well.

Data analysis

Google Scholar and the Wageningen University and Research library (i.e. Web of science database) were used to find scientific articles and government reports to review. They were selected based on key search terms (e.g. ‘cocoa production Ivory Coast’, ‘deforestation Ivory Coast’, ‘cocoa agroforestry’ etc.), their published date (no older than 2000 preferably selected), and their geographical area of focus (Ivory Coast, Africa and Latin America). Articles on ecosystem services provided by tropical forests and agroforestry systems were also reviewed to

provide a baseline understanding of the former and future states of the forest, prior to being cleared and after being converted to an agroforestry system from a full-sun monoculture.

TEEB classification (de Groot *et al.* 2010) provided a basis on which the selection of relevant ecosystem services could be made. The selected ecosystems services were further elaborated in Tables 3, 4 and 5 that give quantitative information about the services provided by a subsistence forest, a cocoa monoculture as well as an agroforestry system. The services quantified included carbon sequestration, nutrient cycling (organic matter content), erosion prevention, water retention capacity and genetic biodiversity. It was done through literature review. Water retention capacity was quantified using Equations 1 and 2. Provisioning services were also quantified in terms of the cocoa yields obtained from the different ecosystems.

Moreover, articles regarding precipitation, and the climatic conditions of the eastern central regions of Ivory Coast (Indénié-Djuablin and Iffou regions) (Otchoumou *et al.* 2012) where cocoa is predominantly grown in the country and where Agnibilekrou is located were reviewed as well. So was climatic data from the World Bank used to create a graph for annual rainfall in Ivory Coast over the past 60 years using Microsoft Excel (Figure 7). Furthermore, a study by Brou (2009) looked at the annual average precipitation all over Ivory Coast during every decade from 1950 to 2000. That data was used to look at the evolution of the climate with deforestation, but was also used for water retention capacity calculations (Equation 1 and 2).

The status of deforestation in the Indénié-Djuablin region has also been reviewed (Kone *et al.* 2014). Data on cocoa production and productivity obtained from the Kongodia cooperative and the CCC were used to create comparative tables using Microsoft Excel. This was done to establish the link between deforestation, the current climatic conditions as a result of the aforementioned deforestation, and cocoa production. Furthermore, maps from the USGS (United States Geological Survey) were compared to see the land cover change over the past half century. This falls in line with the land-use analysis used to link driver and pressure from the DPSIR model.

Ivory Coast's REDD+ strategy provided by the General Manager of the Ministry of Agriculture and Rural Development, was used in a policy analysis to understand the ideas behind the actual policy and the possible implications. There needs to be a clear understanding of the policies that have already been put in place, showing the country's preferred direction with respect to the cocoa industry. Only then can credible recommendations be given.

2.3.2 Interviews

Data collection

The interview is a tool used to collect data from people for different purposes and in different social contexts in a research setting (Kumar, 2014). However when it comes to empirical research, the information generated from an interview may lack objectivity (Qu *et al.* 2011). Even though there is a wide application of interview in the research field, whether structured or unstructured, there is a risk of oversimplification where the interviewee is not truthful or lacks the necessary expertise to deliver the required information (Qu *et al.* 2011). Regardless of the usefulness of the interview as a research tool, this risk has to be addressed for the sake of reliability and legitimacy in the collected data.

Interviews require skills with respect to listening and synthesizing information (Qu *et al.* 2011). The ability to take out relevant information and translating it in a concise way to contribute insight to the research is crucial. To get the necessary information, the questions have to be coherent. Open-ended question give the respondent freedom to express themselves (Kumar, 2014). The interview helps the interviewer see things from the perspective of the interviewee. The qualitative

research interview is meant to contribute theoretical and conceptual aspects to the body of existing knowledge based on the personal experiences of the interviewee (DiCicco-Bloom *et al.* 2006). The social context in which the interview is being conducted needs to be understood to interpret the information gathered. Depending on the stakeholder, the social context will unveil the reasoning behind their responses. Having a grasp on that aspect can bring clarity and weed out information that may be tainted with bias.

An unstructured interview is an appropriate tool to use when facts and concrete information are sought to find answers to the research questions (Kumar, 2014). Nevertheless, a qualitative understanding of the processes involved in cocoa production provided insight on the way to approach the generation of mitigation measures for policy makers. Based on the perception of the interviewees who are directly involved with the production of cocoa (i.e. the farmers for instance), an idea of how to improve the system can be found. It is advantageous to use with complex situations (i.e. agriculturally induced environmental degradation) that require in-depth knowledge and can be applied to different social groups in different contexts (Kumar, 2014).

Additionally, group interviews are used in qualitative research to obtain opinions about a given issue, through an open discussion between the interviewer and his/her target audience in which the interviewer plays the role of facilitator (Kumar, 2014). In a rural context where there are strong connections amongst the people, bringing them together is preferable as they would be more inclined to speak in the presence of their peers as opposed to a one on one with stranger. Considering time and cost, group interviews are a popular method to generate information from any given professional group (Kumar, 2014). The participants have to be selected based on their knowledge, capabilities, and the objective the researcher is attempting to achieve. The group ought to be of adequate size to prevent skewed data, but have a representative sample (between 8 and 10 people) (Kumar, 2014).

Data analysis

Interview questions were prepared beforehand, specifically for the CCC, the Ministry of Agriculture and Rural Development, and smallholder farmers in Agnibilekrou. Notes were taken during the interview to record the responses for future analysis. The 8 interviewees had their own set of questions relative to them. Specific questions were also prepared for the group interview with 11 farmers. Some questions overlapped between the different interviewees. The questions (Annex 1) were written based on the research questions and expanded in more detail. They were designed to provide information that would complement and rectify what could be found in the literature. For the sake of clarity and efficiency, the questions were emailed beforehand, but were subject to change and interpretation during the interviews. The recipients were three different members of the CCC and two from the Ministry of Agriculture and Rural Development. Those members were selected based on the positions they held in those institutions (the Deputy Director of Cash Crops, the Head Engineer in Agronomy and the General Manager of the Ministry of Agriculture and Rural Development, as well as Technical Secretary of Public Private Partnership Platform, the Director of Statistics Monitoring Evaluation and Public Studies of the CCC) as they would have access to relevant information. The ones who weren't able to meet answered the questions through email.

Concerning smallholder farmers, they were selected from Kongodia, a village 10 kilometers away from the city of Agnibilekrou. The chairman of the board of directors of the Kongodia cooperative helped set up interviews with two different farmers in the village, as well as a group interview with 11 farmers who were willing to participate in the discussion. More farmers in the other villages of Agnibilekrou could have been interviewed as well, but the lack of time and contact information made them difficult to access.

Many of the reviewed articles gave conflicting information regarding cocoa production, therefore interviews with the director of statistics of the CCC was necessary to supplement and rectify the gathered information. Hence, the data provided was used to create a graph of the cocoa production in Ivory Coast in a Microsoft Excel graph for clarity and interpretation.

The interviewees are representative of the relevant stakeholder along the value chain, from producers to governmental officials who deal with agricultural related issues.

Interview	Function
1	Deputy Director of Cash Crops of the Ministry of Agriculture and Rural Development
2	Head Engineer in Agronomy of the Ministry of Agriculture and Rural Development
3	Technical Secretary of Public Private Partnership Platform of the CCC
4	General Manager of the Ministry of Agriculture and Rural Development
5	Director of Statistics Monitoring Evaluation and Public Studies of the CCC
6	Farmer in Kongodia
7	Chairman of the board of directors of the Kongodia cooperative
8	Farmer in Kongodia
Group interview	11 farmers in Kongodia

2.3.3 Observations

Data collection

Observations are a means of gathering primary data, through watching and listening to an interaction or phenomenon (Kumar, 2014). Observations are more useful when it comes to study behavior as opposed to perception (Kumar, 2014). In order to ascertain the function of different tasks, observations are a useful tool for contextualization, especially in the agricultural field. For the sake of objectivity and to prevent bias, non-participant observation was the preferred method, where the researcher takes no part in the interactions but is solely present to observe and take note. The observations were conducted in the respondent's natural environments (i.e. cocoa plantations) where they spend a great deal of their time. Narrative recordings were conducted to take notes of a qualitative nature, describing the different processes that were discussed regarding cocoa production.

Nevertheless, the limitations of this data collection method have to be noted. As respondents are aware that they are being scrutinized, their instinctive behavior and responses may change. That is the Hawthorne effect (Kumar, 2014). Discussing farming techniques, yields, and the environment in general etc. with a researcher, smallholder farmers could potentially exaggerate or misconstrue facts. Considering the location of the data collection, with the declining yields, farmers' perception about the loss of ecosystem services may therefore be tainted with bias, and this was taken into account.

Cocoa plantations were located between 5 and 6 kilometers from Kongodia. They were accessed by motorbikes as the rough terrain made it difficult for cars to reach. They were full-sun cocoa monoculture plantations, belonging to five of the interviewed farmers. As they were in the vicinity of each other, it made it easier to visit them in a couple of days. Those plantations were selected based on their age, location, crop produced and production methods used to compare them and get a general sense of how cocoa is grown in Agnibilekrou. The plantations had to be a least 10 years of age, between 1 and 4 ha per plantation, and be full-sun cocoa plantations. Those are the characteristics of the optimally producing cocoa plantation based on information provided by the CCC (Interview 3, personal communication, August 10, 2017). The physical characteristics of the plantations (i.e. tree arrangement, litter layer, planting process etc.) were noted.

Data analysis

Observations were used as a supporting tool for the literature review. Pictures were taken with an iPhone to contextualize the findings from the literature. The farmers' perception could be seen and the reality of the field could be compared with the literature.

3. Main stakeholders involved in the Ivorian cocoa industry

3.1 Stakeholder matrix

In the cocoa industry of Ivory Coast, seven main different stakeholders can be identified. They range from governmental institutions to private citizens. It is relevant to have a full understanding of the different stakeholders involved in the Ivorian cocoa industry, if change has to be brought up. Hence, Figure 4 depicts the relationships between the different stakeholders. Said depiction remains somewhat basic as some institutions have more than one area of expertise, or have tasks and goals that could overlap with other institutions. The description of each stakeholder can be found in Annex 2, where they are all represented in terms of who they are, what they do, and projects that they work on.

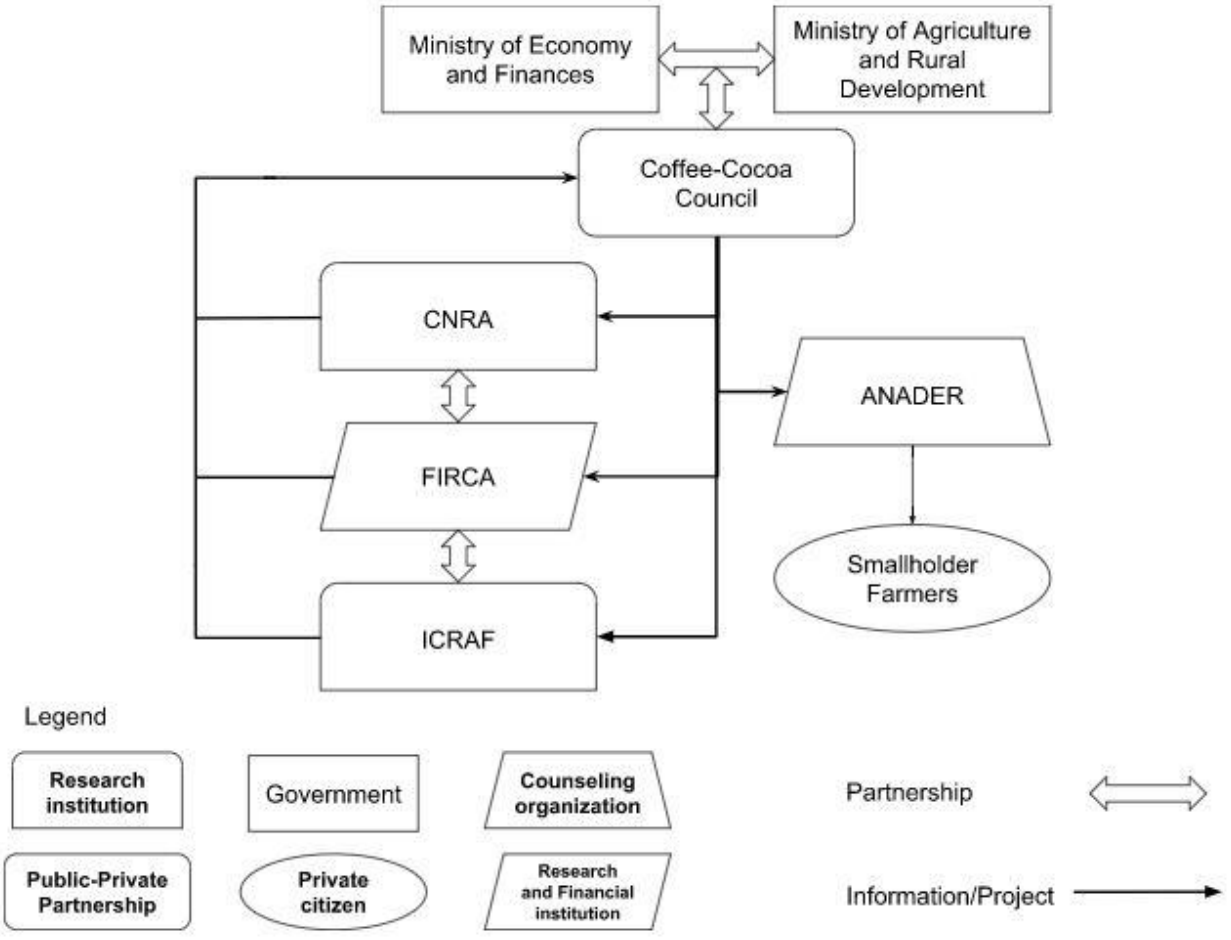


Figure 4: *Stakeholder interconnections of the cocoa industry in Ivory Coast*

The CCC is the key player concerning cocoa in Ivory Coast. This institution sets the purchasing price (Conseil Café Cacao, 2013), is there to ensure that farmers have an improved livelihood, but also ensure that production and productivity increase. It works to put together projects such as the “2QC” program (“Quantité, Qualité, Croissance”, Quantity, Quality, Growth) in partnership

with the CNRA, FIRCA and ANADER where the expertise of each institution is used to meet a common goal (The program itself is explained in Annex 2). Research institutions provide new and improved information and techniques for a better cocoa industry. The CCC with governmental backing with respect to finances and institutional authority, brings together said research and disseminates the generated information (via ANADER) to the local populations who are the ones growing the cocoa.

3.2 Link between Stakeholder and Ecosystem Services

Considering how important cocoa has been for the development of Ivory Coast, the government has always been trying to maximize the profits from this sector. Hence the provisioning of crops was the service holding the highest value with respect to the government. All aspect regarding cocoa production is redirected to the appropriate institution that deals with more specific issues. Based on government programs such as the aforementioned 2QC, the government showed that not only production, but improved productivity was also important. Those goals would be reached by working with the other involved institutions.

The CCC's chief goal is to improve the production and productivity of the cocoa sector through better governance and transparency of resource management. Therefore the service that was the most importance to the CCC was the crops provided by the ecosystem. Yet productivity is determined by ecological processes, so the CCC also takes into account regulating services, to ensure that production keeps going. Other institutions that work closely with the CCC, i.e. ANADER, the CNRA, FIRCA and ICRAF, all have to a certain degree the provisioning of crops as their primary service. As a partner of the CCC, their job is to first and foremost find ways to increase production, but also productivity. Thus, regulating services are important for all the aforementioned stakeholders. The CCC works predominantly on increasing production, while the other mentioned institutions work with the CCC to deal with regulating process and the productivity of the land.

ANADER focuses on counseling and the dissemination of information. Through the information they bring to farmers, the production of higher quality cocoa should follow. As the main problems faced are low yields and drought, the provisioning of crops, along with carbon sequestration, drought prevention and soil organic matter content are services that are valued by this organization. They deliver information on these issues to the farmers and research the best ways to incorporate a participatory approach to bring change in the system. FIRCA on the other hand generates funds for different projects that have for aim the enhancement of cocoa production, by tackling problems related to production techniques (FIRCA, 2015).

ICRAF, which focuses on agroforestry research, attempts to tackle many problems related to the regulation of ecological process that occur in plantations by growing trees. Their research is focused on how trees can benefit agriculture, i.e. in terms of carbon sequestration and nutrient cycling. But they also work on grafting to be able to increase yields, which is more related to the provisioning service (Pye-Smith, 2016). ICRAF is involved with all the selected ecosystem services, omitting the cultural service. The organic matter content of the soil is important to them in terms of soil fertility, so are weather patterns that indicate the extent of the dry season. Furthermore, biodiversity is also enhanced by shade trees that provide habitat for species in order to maintain the ecosystem (Pye-Smith, 2016).

The CNRA works to improve and rejuvenate old plantations by replanting better hybrid seeds and grow cocoa with multi-purpose trees (Interview 3, personal communication, August 10, 2017) that can also provide raw materials, recycle nutrients, prevent drought, deposit a litter layer, and sequester carbon in the soil. Nevertheless, the CNRA has focused most of its research on high-

yielding and disease resistant hybrid seeds that have been developed since the early 1990s, while research on agroforestry systems has been started in 1994 (Interview 3, personal communication, August 10, 2017). Hence, CNRA's activities are primarily focused on finding ways to increase the production of cocoa, while also working on improving ecological processes. Research lead to *Albizia sp* trees that have recently started being used in cocoa plantation for their nitrogen fixing abilities, the nutrients they provide through recycling and the aeration that their roots create in the soil (Interview 3, personal communication, August 10, 2017). Trees also have the added benefit of providing habitat to different species, even though that aspect isn't a focus point for the CNRA.

Local farmers, as far as they are concerned, care greatly about their plantations yields. They also value all other non-timber forest products they can obtain, such as bushmeat or timber for constructing material, even though the quantity of raw materials extracted is not significant (Interview 8, personal communication, July 29, 2017). Regardless, biodiversity should be maintained to ensure that future generations have access to the same resources. Nevertheless, to obtain great yields, the soil should be productive, hence the importance of regulating services. Throughout interviews with farmers, drought prevention and organic matter were the main issues brought up in terms of ecological processes. Vegetative cover was mentioned as an additional source of income with the use of leguminous crops such as peanuts. Even though drought was a recurrent topic with all the farmers, carbon sequestration and climate change were never mentioned by the farmers. With a low adult literacy rate (43.9% nationally (World Bank, 2017)), farmers didn't know much about carbon sequestration and climate change per se, but knew that their agricultural activities were partly responsible for the lengthening of the dry season. Lastly, only farmers received cultural benefits from the ecosystem as no other institution accounts for cultural value.

Table 2 was created to link each stakeholder to the ecosystem services they use and value. It elicits the use (i.e. whether or not the stakeholder affects the ecosystem service through its activities) and importance (i.e. the relevance (or value) of that service to the stakeholder). The table was filled based on information that was gathered through literature review as well as the stakeholders perspectives' gained through interviews. They can be found in Annex 1 (interview questions and answers) and Annex 2 (description of main stakeholders).

Different stakeholders influence ecosystem services differently. For this thesis, the "impact" and "influence" were the terms selected to describe the influence. A high "impact" means that the stakeholder actively affects the given service through their activities. The government or the CCC have both showed through their policies that an increase in cocoa production is essential, despite the desire to reduce deforestation and mitigate its effects. The provisioning of crops is therefore highly used by those stakeholders. On the other hand, local farmers and the CCC haven't done much with regard to erosion prevention. There are no government programs to help directly mitigate the effects of erosion, or do local farmers try to plant crops for the sole purpose of not leaving the soil bare. Hence those stakeholders have a low impact on those services. With respect to the "importance", it reflects the relevance of the given service depending on the stakeholder. Through the various interviews and literature review, stakeholders' perception of certain ecosystem services became more apparent. Farmers thought that soil fertility and drought prevention were pivotal issues, while carbon sequestration wasn't even mentioned. Carbon sequestration and SOM are connected, hence their high use, but carbon sequestration was not relevant to the farmers as they lacked knowledge about this service. Therefore based on the stakeholders' perception of the selected services, their relative importance was assessed with respect to the stakeholders. "n.a." was used when there was a lack of information.

Table 2: *Stakeholders' relative impact and importance to the ecosystem services with respect to the cocoa industry based on their perspectives*

Main Stakeholder		Ecosystem Services							
		Crops	Raw Materials	Carbon sequestration	Erosion prevention	Drought prevention	SOM*	Habitat	Spiritual experience
Government	Impact		n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Importance		n.a.		n.a.			n.a.	n.a.
CCC	Impact		n.a.					n.a.	n.a.
	Importance							n.a.	n.a.
Local Farmers	Impact								
	Importance								
ANADER	Impact		n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Importance							n.a.	n.a.
CNRA	Impact								n.a.
	Importance								n.a.
FIRCA	Impact			n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
	Importance							n.a.	n.a.
ICRAF	Impact							n.a.	n.a.
	Importance								n.a.

*: Soil organic matter

Impact

high

moderately

not significant

n.a.: not applicable

Importance

high

moderate

not significant

n.a.: not applicable

4. Ecosystem services provided by three different land-use options

4.1 Subsistence Forest

The Agnibilekrou Department (170 000 ha) dedicates about 30% of its area for plantations, 40% for settlements and 30% remains partially cultivated or completely uncultivated (Interview 7, personal communication, August 18, 2017). Portions of the subsistence forest remain uncultivated for cultural reasons. Ancestors of the villagers are buried in forest patches that have forbidden access (Interview 7, personal communication, August 18, 2017). The government hasn't classified any area as protected land in the entire department, so other than cultural reasons and land tenure, the land in the department could potentially be cultivated. The partially cultivated parts of the forest, are used by the villagers for their personal consumption where they catch bushmeat and grow various crops such as legumes, onions, okra, cassava etc. (Interview 7, personal communication, August 18, 2017).

Besides, the forest maintains all the ecosystem services it provides, which are elaborated in Table 3. Not all ecosystem services are mentioned, only the selected ones for the sake of comparison with the other land-use options. Quantification of regulating and habitat services were determined through literature. The provenance of the data is explained in footnotes in each section of the table. Data on production and cultural services were obtained from interviews conducted in Agnibilekrou.

Table 3: *Ecosystem services provided by a subsistence forest*

Ecosystem Services		Subsistence Forest	Reference
Provisioning	Food	Bushmeat [Greater cane rat (*Thryonomys swinderianus*); Monitor lizards (*Varanus*); Tree squirrels (*Sciuridae*); Brown rat (*Rattus norvegicus*)], small subsistence agriculture (not significant in terms of quantity)	(Interview 7, personal communication, August 18, 2017)
	Raw material	Wood mainly used as construction material and fuel. Some precious metals have been found but in very small amounts	(Interview 7, personal communication, August 18, 2017)
Regulating	Climate regulation	2-6 ton C per ha[2]	(Bonan, 2008), (Fan *et al.* 1990), (Malhi *et al.*., 1998)
	Water retention capacity	347-465 mm[3]	See equation 1 and 2
	Erosion	Soil losses: 0-1.2 ton per ha[4]	(Bruijnzeel, 2004), (Lal, 1985), (Blanco *et al.* 2010)
	Maintenance of soil fertility	Carbon stock: 115-400 ton C per ha[5]	(Palm *et al.* 2004), (Nasi *et al.* 2002), (Bationo *et al.* 2007)
Habitat	Maintenance of genetic diversity	160 plant species[6]	(Zapfack *et al.* 2002)
Cultural	Spiritual experience	About 4 ha of forest adjacent to each village are sacred.	(Interview 7, personal communication, August 18, 2017)

[2] Annual values representative of dense, moist rainforests. Data from the Amazon basin.
[3] Rainfall data used to make calculations were from Agnibilekrou, Ivory Coast.
[4] Annual data for soil losses corresponds to the humid region of Ivory Coast, and Brazil.
[5] These values are representative of undisturbed and managed forests. Data from Indonesia (Southeast Asia), Cameroon (central Africa) and Senegal (West Africa).
[6] Regarding the quantification of biodiversity as it pertains to maintenance of genetic diversity, the study by Zapfack et al. was meant to shed light on the impact of land conversion on plant biodiversity. Three quadrants (625 m^2) in three different zones comprising different land-use in each (primary forest, secondary forest, fallow, crop field, cocoa field) were selected within the semi-deciduous rainforest of Cameroon (which has climatic similarities with Ivory Coast, therefore relevant for value transfer). Plant species were recorded in the different land-use types. The selected land-use types for this study were primary forest and cocoa field.

4.2 Full-sun cocoa monoculture

Figure 5: *Full sun cocoa monoculture in Kongodia, Agnibilekrou, Ivory Coast. Trees are aligned with no other crops competing for resources.*

Full-sun cocoa monoculture is the way cocoa is predominantly grown in Agnibilekrou and Ivory Coast (Tondoh *et al.* 2015). Primary and secondary forests are cleared and burned manually to make way for cocoa to be produced, with at times some understory crop used as an additional source of food and income, such as cassava for instance (Tondoh *et al.* 2015). Mainly, cocoa is grown alone on small scale (between 1 and 4 ha) family owned plantations in rows of trees separated by about 2.5 meters (Interview 8, personal communication, July 29, 2017) (Figure 5). The lack of other crops is meant to reduce competition and favor cocoa in order to maximize the yields in a short amount of time. Fertilizers have been used more often in the past decade (750 kg per ha of Urea or 50 kg per ha NPK), but some older farmers prefer not to as Agnibilekrou was a densely forested area in the past and the soil still remains somewhat fertile from their perspective (Group interview, personal communication, July 30, 2017). Harvesting starts in October, at the beginning of the agricultural campaign and ends around April before the raining season starts over again. In 2013, the national production average was about 580 kg per ha, which is aligned with the findings in Agnibilekrou (FAOSTAT, 2016).

After roughly 25-30 years of exploitation, plantations are abandoned due to a considerable decrease in production, and production shifts to a new location (Tondoh *et al.* 2015). The plantations that are too old are replaced with Hevea or Cashew trees (Interview 7, personal communication, August 18, 2017). Historically, production zones have shifted in Ivory Coast, starting from the eastern and central eastern regions in the 1950 (where Agnibilekrou is located), to the southwest nowadays (Tondoh *et al.* 2015).

Full-sun cocoa monoculture brings many ecological problems, notably forest degradation, biodiversity loss, poor soil quality with low yield. The quantification of those problems has been presented in Table 4. The data for regulating and habitat services was derived from literature. Data on production and cultural services were obtained from interviews conducted in Agnibilekrou.

Table 4: *Ecosystem services provided by a cocoa full-sun monoculture*

Ecosystem Services		Full-sun monoculture	Reference
Provisioning	Food	Cocoa (about 500 kg per ha), 250-560 kg per ha range.	(Interview 8, personal communication, July 29, 2017), (FAOSTAT, 2016), (Andres *et al.* 2016)
	Raw material	n.a.	
Regulating	Climate regulation	0.80-1 ton C per ha[7]	(N'Gbala *et al.* 2017)
	Water retention capacity	200-300 mm[8]	See equation 1 and 2
	Erosion	Soil losses: 20-90 ton per ha[9]	(Hartemink, 2006), (Lal, 1985)
	Maintenance of soil fertility	Carbon stock: 25-90 ton C per ha[10]	(Gockowski *et al.* 2011), (Jacobi *et al.* 2014), (Wade *et al.* 2010)
Habitat	Maintenance of genetic diversity	116 plant species[11]	(Zapfack *et al.* 2002), (Gockowski *et al.* 2011)
Cultural	Spiritual experience	n.a.	n.a.

4.3 Agroforestry system

Since 1994, before the creation of the CCC, the CNRA had been working on research to use agroforestry systems to produce cocoa (Interview 3, personal communication, August 10, 2017). Nevertheless, they still remain a novelty in Agnibilekrou, as well as the rest of the country. The push towards such system stems from the declining productivity of full-sun cocoa plantations that have not been producing as well as in past years. The CNRA's hybrid seeds have helped foster a bump in production, but haven't tackled the problem at the root cause (i.e. degraded and dry soils deprived of nutrients and organic matter as well as decreasing rainfall).

As of today in Agnibilekrou, an estimated 2 to 5% of the cocoa producers in the department have opted for an agroforestry system to grow cocoa (Interview 7, personal communication, August 18, 2017). Those plantations have similar characteristics to the full-sun monoculture plantations. They are small scale (between 1 and 4 ha) family owned plantations and relatively old (about 15 years). Those old plantations are being revamped with new combinations of trees proposed to the locals

[7] Annual data representative of the semi-deciduous forest area in the central region of Ivory Coast.
[8] Rainfall data used to make calculations were from Agnibilekrou, Ivory Coast.
[9] Annual data for soil losses corresponds to arable land in the humid region of Ivory Coast.
[10] Data representative of full-sun cocoa monocultures in Cameroon, Bolivia
[11] Data representative of cocoa plantations in Cameroon and Ghana

by the CCC through technicians from ANADER (Interview 7, personal communication, August 18, 2017). Hevea and Teak trees are commonly used in combination with cocoa in the region. The trees are planted 3 meters apart from each other, with rows separated by 2.5 meters (Interview 6, personal communication, August 28, 2017).

In the early 2000s, the CNRA started promoting the use of *Albizia sp* trees in agroforestry system for the benefits they provide in terms of nitrogen fixation (Del Greco *et al.* 2012), but also for the nutrients they recycle in the soil (Interview 3, personal communication, August 10, 2017). The trees provide leaf litter to the ground, which reintroduces nutrients in the system. Furthermore, the tree roots allow improved aeration in the soil. Additionally, shading from the trees reduce evapotranspiration thus limiting the likelihood of a drought. Indeed, during the 2007-2008 campaign, plantations with at least 30% shade were able to survive a drought as opposed to the full-sun monoculture plantations (Interview 3, personal communication, August 10, 2017). Overall, the shading didn't improve the yields, but prevented them from declining by protecting the plantations.

Table 5 gives an overview of the ecosystem services that could be provided by an agroforestry system. Data for regulating and habitat services was derived from the literature. Data for production and cultural services were derived from interviews with the CCC and farmers in Agnibilekrou.

Table 5: *Ecosystem services provided by a cocoa agroforestry system*

Ecosystem Services		Agroforestry system	Reference
Provisioning	Food	Cocoa (between 500 kg and 1 ton per ha)	(Interview 3, personal communication, August 10, 2017)
	Raw material	Rubber from *Hevea brasiliensis* and timber from Teak trees (*Tectona grandis*)	(Interview 6, personal communication, August 28, 2017), (Interview 7, personal communication, August 18, 2017)
Regulating	Climate regulation	0.25-3.5 ton C per ha[12]	(Dixon *et al.* 1994), (Albercht *et al.* 2003), (Isaac *et al.* 2005), (Nair *et al.* 2014), (Luedling *et al.* 2011)
	Water retention capacity	265-375 mm[13]	See equation 1 and 2
	Erosion	Soil erosion is negligible in perennial crop systems[14]	(Hartemink, 2005), (Tscharntke *et al.* 2011)
	Maintenance of soil fertility	Carbon stock: 10-230 ton C per ha[15]	(Mbow *et al.* 2014), (Palm *et al.* 2004), (Dixon *et al.* 1994), (Luedling *et al.* 2011)
Habitat	Maintenance of genetic diversity	128 plant species[16]	(Bhagwat *et al.* 2008), (Zapfack *et al.* 2002)
Cultural	Spiritual experience	n.a.	n.a.

[12] Annual data representative of West and Central Africa.

[13] Rainfall data used to make calculations were from Agnibilekrou, Ivory Coast.

[14] Once the canopy cover has been established, the soil is protected. Erosion in cocoa plantations is very low except on steep slopes (Hartemink, 2005).

[15] Data representative of the Congo basin for agroforestry systems during 50 year rotations.

[16] Bhagwat et al. was used for data. Species richness in agroforestry systems was determined by compiling data from 36 studies comparing species richness in 12 types of agroforestry systems (9 taxa, 14 tropical countries) with the species richness in adjacent forest reserve. The results were percentages that represented the proportion of species found in the agroforestry system, relative to that of the neighboring forest. With respect to this thesis, only data regarding plant species from Bhagwat et al. was used to be able to be consistent with Zapfack *et al.* (2002). Results showed that 112% of lower plants, 64% of herbaceous plants and 64% of tree species from adjacent forests were found in the agroforestry systems surveyed. Hence, 80% (Noble *et al.* 1997) of the plant species in a tropical forest can also be found in an adjacent agroforestry system. Zapfack *et al.* (2002) surveyed 160 plant species in the primary forest, which would mean 128 of those plant species could potentially be found in an adjacent agroforestry system.

4.4 Synthesis

Table 6 summarizes the quantification of the selected ecosystem services depending on the land-use option. It compares the land-use options relative to one another in terms of the ecosystem services they provide.

Table 6: *Comparison of the quantification of the environmental impacts of the three land-use options (subsistence forest, full-sun monoculture and agroforestry system) on the selected ecosystem services (See Tables 3, 4 and 5 for references)*

Ecosystem Services	Subsistence Forest	Full-sun monoculture	Agroforestry system
Provisioning[17]			
Food	Negligible	250-560 kg per ha	0.5-1 ton per ha
Raw Material		n.a.	Rubber, Timber (Negligible)
Regulating[18]			
Climate Regulation[19]	2-6 ton C per ha	0.80-1 ton C per ha	0.25-3.5 ton C per ha
Water retention capacity	347-465 mm	200-300 mm	265-375 mm
Erosion[20]	0-1.2 ton per ha	20-90 ton per ha	Negligible
Maintenance of soil fertility	115-400 ton C per ha	25-90 ton C per ha	10-230 ton C per ha
Habitat[21]			
Maintenance of genetic diversity	160 plant species	116 plant species	128 plant species
Cultural[22]			
Spiritual experience	About 4 ha of forest adjacent to each village are sacred	n.a.	n.a.

[17] Data for provisioning services was obtained from interviews conducted in Agnibilekrou.
[18] Data for regulating services was obtained from literature.
[19] Annual values
[20] Annual values
[21] Data for habitat services was obtained from the literature.
[22] Data for cultural services was obtained from interviews conducted in Agnibilekrou.

5. Effect of cocoa production on deforestation and selected ecosystem services

5.1 Trends in cocoa production and yield

Cocoa trees produce the most during the first decade in a full-sun monoculture (Schneider *et al.* 2017). Jacobi *et al.* (2015) studied cocoa yields from different systems in Bolivia and concluded that on 10 to 15 year old plantations, agroforestry systems (423 kg per ha) were able to yield more than full-sun monocultures (350 kg per ha). Based on the information received from the CCC, full-sun cocoa plantations reach their optimal production in about 10 years, after which the plantations start declining in productivity (Interview 3, personal communication, August 10, 2017). From that point on, an agroforestry system would become the preferred option as Jacobi *et al.* (2015), and Jagoret *et al.* (2012) have shown that in the long run, agroforestry systems have the ability to produce more than the full-sun monocultures. Indeed, they increase food security for the local population through the added crops grown in combination with the cocoa and provide ecological benefits (Table 10). Furthermore, shade trees can help buffer droughts and other extreme climatic events, protecting cocoa plantations.

In 1985, all the cooperatives of the Agnibilekrou Department came together to keep track of cocoa production in the department. Averaged estimates of the yields from the entire department were determined based on the production from each decade going back to 1980 (Table 7) (Interview 7, personal communication, August 18, 2017). Furthermore, Table 8 compares cocoa production in Agnibilekrou and nationwide over the same time frame.

Table 7: *Cocoa yield evolution in Agnibilekrou (Based on Interview 7, personal communication, August 18, 2017)*

Time period	Cocoa yield (kg per ha)
1980 - 1990	800
1990 - 2000	500
2000 - 2010	300
2017	< 300

Table 8: *Cocoa production evolution in Agnibilekrou and in Ivory Coast (Based on Interview 7, personal communication, August 18, 2017; CCC)*

Decade	Agnibilekrou cocoa production (Ton)*	Ivory Coast cocoa production (Mega Ton)
1980	1500 - 2000	6
1990	2000 - 3000	10
2000	2000	13
2010 - 2016	< 1500	10

*Production in Agnibilekrou is influenced by the differences in cocoa prices between Ivory Coast and Ghana. If prices are better in Ghana then that's where the producers will sell their produce. Cooperatives

only count production as the cocoa sold through the cooperative, not in another department or country, therefore the actual production could slightly vary (Interview 7, personal communication, August 18, 2017).

The CCC has kept extensive records of the cocoa produced in Ivory Coast from every agricultural campaign going back to 1960. Said production has been represented in Figure 6 to show the evolution on cocoa production at the national scale.

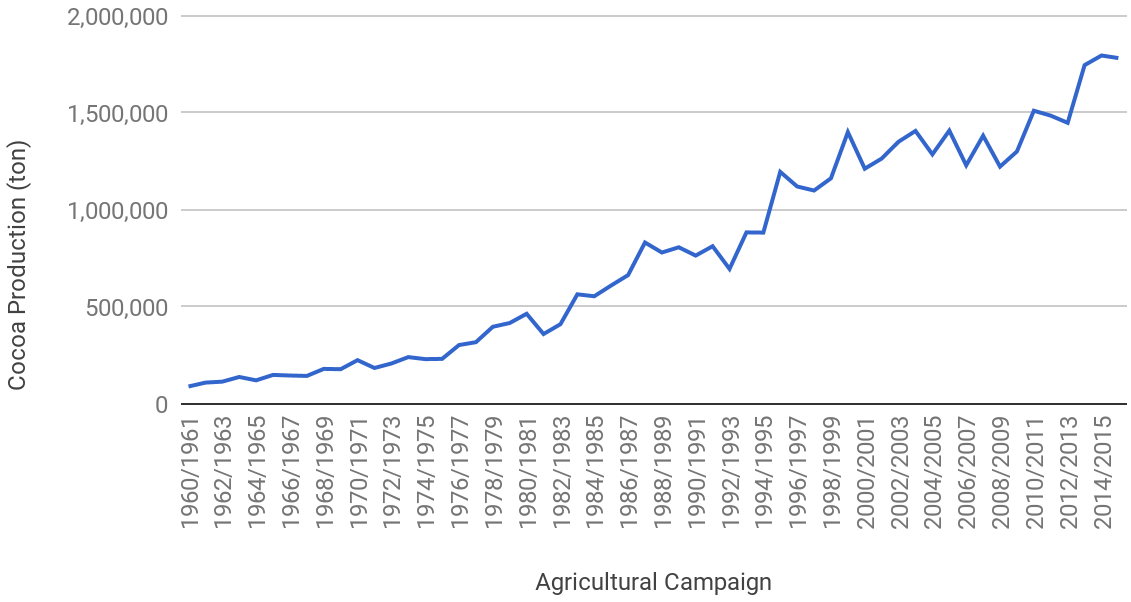


Figure 6: *Line graph representation of the Ivorian cocoa production (in tons) from 1960 to 2015. (Data obtained from the CCC)*

Reduction of production during the 2015-2016 campaign by 14% compared to the previous agricultural campaign was attributed to climate change with a bad distribution of precipitation in the cocoa production area, which affected cocoa production qualitatively and quantitatively (JNCC, 2016). Farmers in Agnibilekrou have also noticed the same trends. Production of cocoa is directly linked to precipitation and climate patterns from the farmers' perspective (Group interview, personal communication, July 30, 2017). According to them, declining production is due to poor rainfall. In spite of the high-yielding hybrid seeds developed by the CNRA, the yields still remain poor, as the climate (i.e. rainfall) is an increasingly important factor.

5.2 Effect on Deforestation and rainfall

The country's annual rainfall from 1960 to 2015 is presented in Figure 7. It declined from an average of 1470 mm in the 1960s to 1290 mm after the 1990s. A study by Brou (2009) determined the average annual precipitation all over Ivory Coast between 1950 and 2000. The values were separated by decade. In the 1960s, Agnibilekrou had an average annual precipitation between 1400 and 1200 mm, while by the 1990s, the average annual precipitation dropped between 1200 and 1000 mm (Brou, 2009). Along with the loss of forest cover, precipitation also decreased over time nationwide and in Agnibilekrou. Spracklen *et al.* (2012) study demonstrated that loss in forest cover leads to a reduction in precipitation.

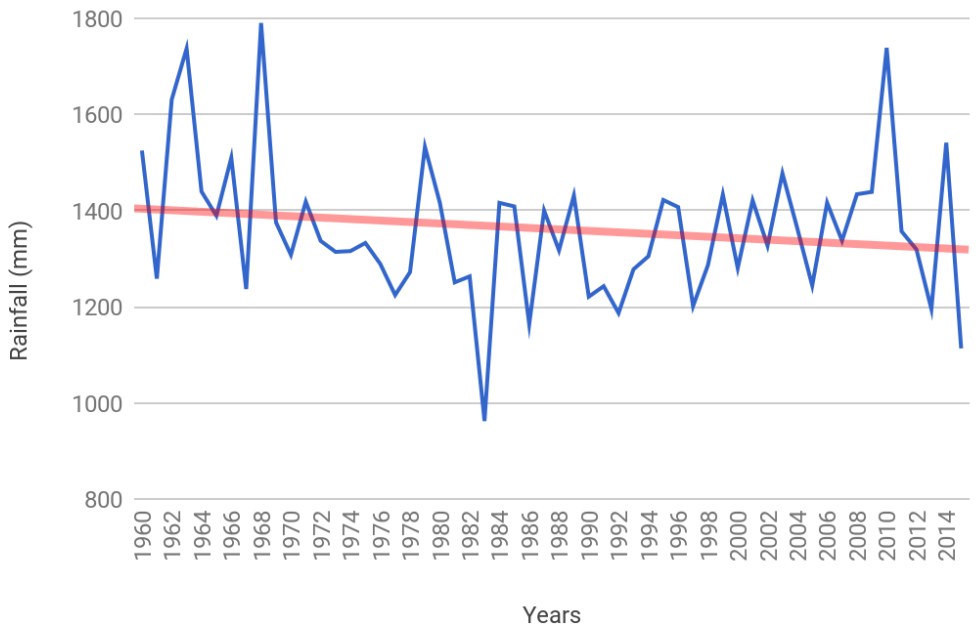


Figure 7: *Ivory Coast annual rainfall (mm) trend from 1960 to 2015. (Data obtained from the World Bank Group)*

Figure 7 is representative of the slight decline in annual rainfall at the national scale. However, it is not necessarily representative of a decline in rainfall that could be exclusively attributed to cocoa farming. The main causes of deforestation were found to be the expansion of slash-and-burn agriculture, increasing urbanization, the harvesting of forests for firewood, wildfires, illegal small-scale gold mining, and poverty in rural areas that leads to overexploitation of available resources (World Bank, 2018). Nevertheless, the cocoa industry has been reported as being a major contributor to deforestation. In 2015, 65% of Ivory Coast's land was used for agriculture, representing nearly 21 000 000 ha out of a total 32 246 000 ha (FAOSTAT, 2017). The country saw a strong decline in forest cover where it dropped from 12 to less than 4 million ha between 1960 and 2010 (World Bank, 2018). That decrease corresponds with the steady increase cocoa production has had over the same timeframe (Figure 6). Of the area used for agriculture, cocoa plantations account for 2 300 000 ha (11%) (Interview 5, email communication, September 5, 2017). A report by Fobelets *et al.* (2016) determining the actual price of cocoa from Ivory Coast found that 57% of cocoa cultivated land come from primary forest. Hence the cocoa industry is responsible for the loss of nearly 1.3 million ha of primary forest which corresponds to about 15% of the total forest lost.

5.3 Effect on Water Retention Capacity

Water retention was one of the most important services when interviewing farmers. Droughts have been a major cause for declining yields as there is a lack of water for irrigation. Hence, the effect of cocoa production on water retention was determined for the three different land-uses.

Data on potential evapotranspiration for Agnibilekrou was not available due to lack of research in that department. Nevertheless, Brou's (2009) study on the analysis of climate data of Ivory Coast calculated the average potential evapotranspiration from 1977 to 2000 in seven different location

in the country using Penman's[23] method (Penman, 1948). None of them were in Agnibilekrou, however, one was in Abengourou, located 56 km south of Agnibilekrou in the neighbouring department. Both departments are in the Indénié-Djuablin region (Figure 1), and share similar climatic conditions, thus allowing for value transfer. The average potential evapotranspiration in Abengourou from 1977 to 2000 was 1409 mm (Brou, 2009). This value was used for calculation for the three land-use options.

Studies have shown that the loss of forest cover causes a reduction in precipitation (Spracklen *et al.* 2012; Avissar & Werth, 2005). Hence, P values were different for each land-use type as the deforestation that lead to the land-use had effects on precipitation for that land-use. In the 1960s, the region of Indénié-Djuablin had a forest cover of 435 000 ha (Koné *et al.* 2014), and an average annual precipitation ranging from 1600 to 1400 mm during that decade in Agnibilekrou (Brou, 2009). These precipitation values were used for the subsistence forest as cocoa plantations weren't as widespread yet. In 2000, the region had a forest cover of 45 000 ha (Koné *et al.* 2014), and an average annual precipitation ranging from 1200 and 1000 mm during the 1990s (Brou, 2009). These precipitation values were used for the full-sun monoculture since by 2000 the region had lost 90% of its forest cover. As there was a lack of data on agroforestry systems, the average of the two previous precipitations (i.e. average annual precipitation ranging from 1400 to 1200 mm) was used because agroforestry systems are agricultural production systems, like the full-sun monoculture, but promote afforestation making them similar to a forest as well. With the increased trees and vegetation in the agroforestry systems, precipitation would increase compared to a full-sun monoculture.

Equation 2 was used to calculate the total evapotranspiration from precipitation, potential evaporation and a plant available water coefficient w. w values range from 0.5 to 2.0 depending on the vegetation. Larger values of w promote evapotranspiration (Zhang *et al.* 1999). The best fit w value of forests was determined to be 2.0, while short grass and crops have a best fit value of 0.5 (Zhang *et al.* 2001). A bare soil has a w lower than 0.5 (Zhang *et al.* 2001). Tree crops have a higher evapotranspiration than annual crops (Mommer, 1999). No specific w value for cocoa plantations or agroforestry systems could be found, hence they were arbitrarily set at 1.3 and 1.7 respectively. Zhang *et al.* (2001) arbitrarily set the w value for mixed vegetation to 1.0 because no data could accurately separate herbaceous and forest cover (Zhang *et al.* 2001). Both full-sun monoculture and agroforestry system have tree crops, thus share similarities with forests in terms of evapotranspiration, hence the relatively high w for both land-use options. Despite the presence of trees, full-sun cocoa monocultures lack vegetative cover, hence a w lower than the forest. Agroforestry systems on the other hand have more vegetative cover due to the added trees and crops planted in combination with the cocoa trees, hence a w closer to that of the forest. The forest w was set at 2.0.

From the potential evapotranspiration and w values, along with equation 2, the total evapotranspiration could be determined for the three different land-use options. Hence, using equation 1, the water retention capacity of the three land-use options could be determined (Table 9).

[23] Penman's equation was developed to calculate potential evapotranspiration using meteorological data. $E_o = ((\Delta/\gamma)*H + E_a)/((\Delta/\gamma) + 1)$. E_o (mm/day) is the potential evapotranspiration, H the heat budget, E_a the mass transfer, and Δ/γ an empirical parameter dependent on temperature.

Table 9: *Water retention capacity of three different land-use options*

Variables	Land-use options		
	Subsistence forest	Full-sun monoculture	Agroforestry
P (mm)	1400	1000	1200
w	2.0	1.3	1.7
ET (mm)	1050 - 1135	800 - 900	935 - 1025
R (mm)	347 - 465	200 - 300	265 - 375

The subsistence forest has the highest amount of water retained in the soil (R), between 347 and 465 mm, hence this land-use option can retain the greatest amount of water. Agroforestry systems have the second highest R, between 265 and 375 mm, while the full-sun monoculture had the lowest value for R, between 200 and 300 mm. The lack of precipitation in a full-sun monoculture reduces the amount of water going in the soil, thus reduces the amount that could potentially be retained. Subsistence forests on the other hand have a higher precipitation due to more vegetation. The litter layer and soil organic matter increases water holding capacity (Machmuller *et al.* 2015). This explains the subsistence forests' highest water retention capacity compared to the other land-use options. Agroforestry systems also have more soil organic matter than full-sun monocultures due to the added trees and crops planted in combination with cocoa, giving this land-use option a higher water retention capacity than full-sun monocultures.

Researchers from the CNRA working on a soil mapping project started in 2012, The Cocoa Fertilizer Initiative, attempting to improve soil fertility in key growing regions, concluded that an annual rainfall below 1200 mm was not favorable to grow cocoa (Kassin *et al.* 2017). Based on said research, cocoa production would not be suitable in Agnibilekrou today considering the low rainfall.

5.4 Effect on other Ecosystem Services

5.4.1 Effect on Climate Regulation

Tropical forests are one of the biggest carbon sinks on the planet. Subsistence forests can sequester the greatest amount of carbon compared to the other two land-use options. Relatively, a subsistence forest can sequester up to 100% more carbon than an agroforestry system, and up to 600% more carbon than a full-sun monoculture (Table 6).

Converting a primary or secondary forest to a plantation results in a great loss of the original carbon stock, and reduces the climate regulation capacity of the land. Indeed, with less carbon sequestered in the soil, full-sun cocoa plantations contribute to climate change. Forested areas can mitigate climate change by stocking greenhouse gases in their soil and biomass. By removing the vegetation, not only is carbon emitted from the soil, but the ecosystems loses its capacity to store the same amount of carbon as it previously could. Large areas of unshaded cocoa trees that used to have a tropical forest will sequester carbon at much slower rate.

Soil carbon and soil fertility are linked. Carbon is needed for the mineralization of nutrients in the soil. Without this process, nutrients wouldn't be available to plants, therefore not contribute to the soil's fertility. Hence, carbon sequestration can help improve the soil's fertility while contributing to the mitigation of climate change.

5.4.2 Effect on Erosion

Removing vegetation from a primary or secondary forest leaves the soil bare. It exposes the soil's top layer to rainfall or wind erosion, which would cause a loss of essential nutrients. Under a vegetative cover, soil nutrients remain on the soil and contribute to the soil's fertility. Plant roots keep the soil from being washed away by runoff, and the canopy reduces both rainfall velocity and impact. The vegetation is crucial in maintaining nutrients. Without the soil's nutrients, plants (i.e. cocoa trees) won't be able to yield as much as they would be able to on a fertile soil.

Subsistence forests and agroforestry systems have negligible erosion due to their vegetation (Table 6). The added vegetation from agroforestry systems provide protection for the soil in the form of windbreaks, and also by reducing surface runoff with the litter layer. The tree cover reduces the loss of nutrients, increasing soil fertility by nearly 30% in an agroforestry system compared to a full-sun monoculture (Table 6).

5.4.3 Effect on Soil Fertility

Cocoa production has an evident impact on the soil's organic matter content depending on the land-use. That is an indicator for the life support function of the soil, the soil organic carbon and soil microbes who are essential for the mineralization of nutrients, thus necessary for nutrient cycling. Microbes need carbon as an energy source for decomposition of organic matter and mineralization. Without nutrient cycling, the soil loses its fertility and cannot yield the same outputs as it previously could due to the lack of essential nutrients that are necessary for growth.

Full-sun monocultures have the lowest soil fertility (Table 6), hence are the land-use option that could yield and produce the least. As production of cocoa is the most important service, full-sun monoculture is not the most appropriate land-use to meet the desired goals based on the evidence. Agroforestry systems have an increased tree cover that provides a litter layer that decomposes to deliver essential plant nutrients. An agroforestry system can have up to twice as much carbon stocked compared to a full-sun monoculture (Table 10), thus increasing fertility.

5.4.4 Effect on Genetic Diversity

Clearing the forest to change the land-use to a full-sun cocoa plantation will result in a loss of about 30% of plant species (Table 6). An agroforestry system loses about 20% of plant species compared to the subsistence forest (Table 6).

Conservation of plant and animal species in an ecosystem is important. Different species can depend on one another for survival, in a predator-prey relationship, or by creating a corridor to link fragmented habitats.

In rural areas of Ivory Coast such as Agnibilekrou, populations often use plant species as medicine. Reduction in forest cover reduces the amount of plant species that are used by the locals. Some of those species can provide additional income to local populations, helping alleviate poverty.

5.4.5 Effect on Spiritual experience

Only the subsistence forest had any cultural significance. Once the forest is cleared and replaced by a cocoa plantation, the cultural value is lost. Full-sun monocultures and agroforestry systems have for primary purpose the production of crops. They don't have any space allocated for a graveyard.

5.5 Comparison between 3 cocoa production systems

Table 10 gives the assessment of the environmental and social impacts of the different land-use options on the selected ecosystem services. Along with Table 6, Table 10 gives a better understanding of the consequences of the land-use change.

Table 10: *Interpretation of the impacts of three land-use options (subsistence forest, full-sun monoculture and agroforestry system) on the selected ecosystem services*

Ecosystem Services	Subsistence Forest	Full-sun monoculture	Agroforestry system
Provisioning			
Food	Resources extracted from the forest hold no quantitative significance on the count of the small amount that is used. Timber is used as construction material while bushmeat and small subsistence agriculture provide food for the villagers. Those activities do not disrupt the functioning of the ecosystem [(Interview 7, personal communication, August 18, 2017)].	Conversion of a forest to a full-sun cocoa plantation results in ecological disadvantages with respect to soil quality, resulting in low yields over time. After 10 to 15 years, agroforestry systems can produce up to twice as much as a full-sun monoculture [(Tondoh *et al.* 2015), (Interview 3, personal communication, August 10, 2017)]	Improved production of food, timber, and increased income from products grown in the intercropping system. Cocoa production could reach 1.5 ton per ha by 2023 using agroforestry systems. Shade trees can buffer extreme climatic events (i.e. drought, windstorm etc.) that affect plant growth [(Garrity *et al.* 2004), (Pye-Smith, 2016), (Mbow *et al.* 2014)]
Raw Material			
Regulating			
Climate Regulation	Tropical forests are a big carbon sink and can sequester large amounts of carbon, containing about 25% of the world's carbon. [(Bonan, 2008)]	Between the 1980s and 2000s, the forest cover of Ivory Coast was reduced by 1.25 million ha (48%), mainly due to industrial agriculture. The region of Indenie Djuablin, where Agnibilekrou is located, lost 391 450 ha (about 90%) of its forest cover between 1960 and 2000. As a result of primary forest being converted to cocoa plantation, there is a loss of 61% of the original SOC [(Kone *et al.* 2014), (Kone *et al.* 2016), (Chiti *et al.* 2014)]	Agroforestry systems have the potential to mitigate greenhouse gas emissions by stocking carbon through the added vegetation, but carbon sequestration values have been based on generalizations, hence do not constitute scientifically prominent data. [(N'Gbala *et al.* 2017), (Nair *et al.* 2014)]
Water retention capacity	Recycle huge amounts of water preventing droughts, storing water to deliver it to plants. The forest with its vegetation, soil and litter act as a sponge that soaks rainfall. Once the forest has been removed, the sponge effect dissipates resulting in a diminished water yield.[(Fenton, 2012), (Nasi *et al.* 2002)]	Reduction in precipitation due to reduced evapotranspiration caused by deforestation and the removal of the forest cover. Increases the length of the dry season in Agnibilekrou by 2 months (Starts in November and ends in April instead of February). Reduction in water availability dampens production. [(Lima *et al.* 2014), (Interview 8, personal communication, July 29, 2017), (N'Gbala *et al.* 2017), (Spracklen *et al.* 2012)]	Shade from the trees reduces evaporation and runoff, increase precipitation and water availability, improved soil structure for water infiltration with tree roots. [(Mbow *et al.* 2014), (Spracklen *et al.* 2012), (Ellison *et al.* 2012), (Garrity *et al.* 2010), (Vaast *et al.* 2014)]

Erosion prevention	Tree roots prevent the soil and its nutrients from being washed or blown away. [(Fenton, 2012), (Nasi *et al.* 2002)]	Once the vegetation has been removed, the forest soil becomes vulnerable, soil aggregates lose their stability, and the soil could potentially lose sediments and nutrients to heavy rainfall. [(Maass *et al.* 2005), (Fenton, 2012)]	Shade trees provide protection from raindrop impacts, reduce surface runoff velocity and improve infiltration by increasing the soil surface roughness with a litter layer. [(Tscharntke *et al.* 2011)]
Maintenance of soil fertility	Left intact, the forest recycles the nutrients it creates itself and doesn't require any external input. Trees and branches maintain soil quality by providing organic matter in a closed loop system. [(Fenton, 2012)]	Conversion from a primary forest to a perennial cropland results in the loss of about 30-35 ton per ha of SOC in about 30 years (roughly the amount of time for a cocoa plantation to be abandoned), reducing the productivity of the soil over time. [(Grace *et al.* 2014), (Guillaume *et al.* 2015)]	Using nitrogen fixing trees, such as *Albizia sp*, to increases nutrient availability in the soil. Leaf litter in combination with decaying roots and biomass provide additional organic matter. [(Albercht *et al.* 2003), (Garrity *et al.* 2010)]
Habitat			
Maintenance of genetic diversity	Source of ideas for biomimicry that could help solve human problems, genetic storage in case of extreme events. Plant species in rural areas are often used for medication. [(Fenton, 2012), (Nasi *et al.* 2002)]	Expansion of agricultural land causes a significant loss of forest species (plants, invertebrates and vertebrates) when the tree cover is reduced. [(Norris *et al.* 2010)]	Conservation of above and below ground biodiversity. Creation of forest corridors to reduce habitat fragmentation, allowing dispersal of seeds. Additional source of income to help with forest management and alleviation of poverty and food insecurity [(Garrity *et al.* 2010), (Mbow *et al.* 2014), (Vaast *et al.* 2014), (Bhagwat *et al.* 2008)]
Cultural			
Spiritual experience	The locals have been burying their ancestors in patches of forests (about 4 ha) that are considered sacred. [(Interview 7, personal communication, August 18, 2017)]	n.a.	n.a.

6. Policy Analysis and Implication for the future of cocoa production

6.1 Description of two important Policies

In recent years, Ivory Coast has taken steps towards improving the state of its environment and forest cover. Indeed, in 2012, the country signed a decree that lead to the creation of the National REDD+ Commission to be part of the solution in reducing greenhouse gas emissions caused by deforestation (Conseil Café Cacao, 2017). Furthermore, at the 2014 climate summit, Ivory Coast signed the New York Declaration on Forests to cut down natural forest loss in half by 2020, and eradicate it by 2030 (Climate Summit, 2014). At the United Nations Conference in 2014, president Alassane Ouattara of Ivory Coast, declared that the country intended to transition to a "zero deforestation agriculture" by 2017. This policy was developed by the Ministry of Health, Environment and Sustainable Development in collaboration with Ministry of Agriculture and Rural Development.

All these measures taken to reduce deforestation show the desire to shift to a more environmentally friendly cocoa industry (Conseil Café Cacao, 2017). Hence the development of a national policy, "Cacao Ami de la Foret", and the country's participation in the international mechanism REDD+, to tackle the many problems that have been brought up throughout this thesis with respect to cocoa production.

This thesis has revealed the ecological consequences of land-use change with respect to the cocoa industry in Ivory Coast. The aforementioned policies have certain implications, both socially and environmentally. Nevertheless, those policies cannot solve all problems. The following sections give the main guidelines of those policies to understand their aim. Furthermore, certain recommendations could improve the results sought by the policies to work towards a sustainable cocoa industry.

6.1.1 "Cacao Ami de la Foret" policy

"Cacao ami de la Foret" was first developed in 2015 with SEP-REDD+ as an integral part of the "zero deforestation agriculture" policy presented at the COP21 in Paris (Conseil Café Cacao, 2017). SEP-REDD+ is a permanent executive secretariat for REDD+ that is tasked with the day to day planning, mobilization of financial resources, technical support and participation in the national REDD+ mechanism. This project was first established to promote the development of a sustainable cocoa production that is compatible with environmental protection, biodiversity conservation, as well as economic and social development of all stakeholders in the value chain (i.e from producers to sellers), where the end goal is to ensure long term security of revenue for all stakeholders involved in the industry.

The Ivorian government is fully aware of the importance a crop such as cocoa represents for the country's economy. Yet, the consequences of deforestation have been increasingly evident, thus the shift towards an environmental conservatism approach to cocoa production. One of the main aspects that has been brought up with this policy is the fact that agroforestry systems can increase revenue for producers while preserving the environment (Conseil Café Cacao, 2017). There is therefore a way to merge both environmental protection and cocoa production, through such policy.

The Cacao Ami de la Foret policy is elaborated in more detail in Annex 3.

6.1.2 The Ivorian REDD+ strategy

Since June of 2011, Ivory Coast has been a participant in the REDD+ mechanism. REDD+ (Reducing Emissions from Deforestation and Forest Degradation in Developing Countries) is a process that bring together different parties affected by deforestation to help fight it and mitigate the consequences of climate change (Ministry of Agriculture and Rural Development, 2016). In Ivory Coast, this process is led by the Ministry of Health, Environment and Sustainable Development, with technical and financial support from Forest Carbon Partnership Facility and UN-REDD, as well as the French Development Agency (AFD) (Ministry of Agriculture and Rural Development, 2016). Table 11 gives an overview of the strategic aim of the REDD+ mechanism.

Table 11: *REDD+ strategic axes in Ivory Coast (Ministry of Agriculture and Rural Development, 2016)*

Factors influencing Deforestation	Indirect					Direct		
	Agricultural expansion; Lumbering; Production of firewood; infrastructure expansion (Transport, Habitat); mining exploitation; Wildfire					Weak governance; Price of agricultural products; Demographic expansion; Political crisis; Lack of a landscape management scheme; Political will based on agricultural production		
Strategic Axes	Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅴ	Ⅵ	Ⅶ	Ⅷ
	Zero deforestation agriculture with a public-private partnership	Development of a sustainable energy strategy	FLEGT*, sustainable management and conservation of protected forests, areas, and sacred forests	Afforestation and restoration of degraded land	Mining exploitations respectful of the environment	Development of a national payment for ecosystem services system	Territorial development relaunch and land securitization	National planification and structural reform for a green economy

*: Forest Law Enforcement, Governance and Trade

The Ivorian REDD+ strategy is elaborated in Annex 4

6.2 Policy Analysis

This section puts the policy that were referenced in this thesis into context, to analyze what would be their practical implications for the cocoa industry in Ivory Coast, along with recommendations.

6.2.1 Implications

Since Ivory Coast's independence, cocoa production has steadily increased, making the country the biggest cocoa producer in the world by volume (Beg *et al.* 2017). Until the 1990s, production was increasing at a steady pace. It started slowing down from that point on (Figure 6). Despite many studies showcasing the negative ecological impacts of full-sun cocoa production (Andres *et al.* 2016; Tondoh *et al.* 2015; Dawoe *et al.* 2014), and information from cocoa farmers in Agnibilekrou (Group interview, personal communication, July 30, 2017) concluding that the soil is less productive over time, cocoa production still increased. Since 2000, national production has increased from 1.2 to 1.8 tons per year, while farmers experienced declining yields and income

(Pye-Smith, 2016). This increase in production regardless of ecological factors is due to use of high-yielding hybrid seeds developed by the CNRA in the 1990s and used in plantations ever since (Interview 3, personal communication, August 10, 2017). Nevertheless, declining yields have caused a change in policy. Based on the "Cacao ami de la foret" policy along with the country's REDD+ strategy that have been developed in the last few years, the economic aspect is not the only factor to account for anymore.

The primary objective of the referenced policies is to reduce deforestation caused by agriculture. This is done through the improved management of protected forests and lands. With the help of the private sector, public institutions can ensure that all relevant stakeholders are involved, and that the management of the protected forests includes the participation of locals. Smallholder farmers receive support to help with the productivity of their land, but also have to contribute by vacating illegally occupied land. Furthermore, the restoration of degraded land and afforestation help restore the forest cover. The National Forest Development Fund, backed by the National REDD+ fund is meant to finance afforestation efforts. Additionally, the development of a national payment for ecosystem services system encourages farmers to invest in agroforestry and afforestation, to gain ecological, but also monetary benefits.

Looking at the policies that have now been put in place, the Ivorian government has opted to promote a cocoa industry that does not cause deforestation, and that helps improve the lives of the smallholder producers that heavily depend on agriculture for their subsistence and income. Agroforestry systems have the potential to eradicate the erosion that is quite extensive with full-sun cocoa monocultures (20 to 90 ton of soil/ha/year (Lal, 1985)) while it is negligible under agroforestry systems (Hartemink, 2005; Tscharntke *et al.* 2011). As the REDD+ strategy focuses on the incorporation of trees in agriculture, the issue of soil erosion posed by the current state of cocoa production systems can be tackled. Moreover, agroforestry systems have the potential to retain 30% more water than full-sun monocultures, reducing the likelihood of drought, which has been determined to be a main reason for declining yields.

Studies have also shown that agroforestry systems can actually produce more than full-sun cocoa plantation in the long run (Jacobi *et al.* 2015; Jagoret *et al.* 2012). Hence a switch to such system would be economically and environmentally beneficial. As the cocoa industry is a pillar of the Ivorian economy, using a system that can potentially produce nearly twice as much cocoa (250-560 kg per ha in full-sun monoculture, against 500 kg - 1 ton per ha in agroforestry systems) and isn't detrimental for the environment would provide stability and security for the industry. The incorporation of a PES scheme (REDD+ strategic axis VI) showcases the government's desire to invest in agroforestry. With this shift in production system, the Ivorian cocoa industry can remain the most productive in the world in the near and further future. Cocoa production will keep increasing, without causing any additional environmental problems (i.e. longer dry period and lack of soil fertility)

6.2.2 Governmental Policy Recommendations

Despite these policies, there still lacks concrete information about what has been done to this day. In theory, the chosen policies will improve the cocoa industry for all stakeholders in the value chain. With improved environmental conditions, more cocoa can be produced under better conditions. Yet there is a lack of evidence that anything has actually been done. Officials at the CCC haven't commented on their progress to meet the new policy goals in spite of multiple requests. The fact that such policies are being considered for implementation and the government's decision to ratify the Paris agreements show progress. Ivory Coast's cocoa industry is still at the initial stage of the transition it is going through.

Transitions are a fundamental transformation process in society that occur over a generation or more (Rotmans *et al.* 2001). Cocoa farming has been done in full-sun monocultures for decades, and such systems are what farmers have been accustomed to. Making the change to a new system on a wide scale will take some time. Farmers have to be educated on new techniques and tree combinations that they could use. They would need to have a better understanding of the benefits added trees can provide and see the added value they can obtain. Once the dissemination has been effective enough, agroforestry plots will steadily become more common, until eventually becoming the norm. But such transition can only be effective with strong governmental support.

Farmers are only now becoming more aware and willing to try such systems on their land to produce cocoa. Other than the added income they could receive through the production of additional crops (i.e. cashew nuts or rubber), farmers don't have any other incentive to switch to a different production system. With a subsidy from the government, farmers will have the capital to fully participate in REDD+ afforestation efforts (REDD+ strategic axis IV). The PES scheme (REDD+ strategic axis VI) meant to provide investment opportunities for smallholder farmers is definitely a step in the right direction. With additional support from the government, more farmers would see a benefit in switching to a different production system.

Research has been mainly focused on high-yielding hybrid seeds, but has to shift to agroforestry in cocoa plantations. The National Forest Development Fund and the National REDD+ fund already allocate funds for afforestation efforts. Some funds could be provided to the CNRA to conduct research and experiments to test different tree combinations in cocoa plantations. Participation from smallholder farmers would make the results more practical and facilitate implementation.

7. Discussion

This thesis was faced with different limitations in assessing the impact of cocoa production on deforestation and ecosystem services and assumptions had to be made to fill in the gaps caused by a lack of data. Below, an overview is given of those shortcomings.

7.1 Literature reviews

Lack of specific data

Finding specific climatic data on Agnibilekrou was challenging as very little research had been conducted on forestry and climate change in that particular department. Only two studies (i.e. Kone *et al.* 2014; Brou, 2009) provided data. Literature on locations with similar climatic conditions, like Cameroon or the Amazon basin were used to assess the characteristics of the investigated land-use systems in Ivory Coast. Climate data (i.e. annual rainfall) for the country could be obtained which was helpful for comparison with what could be attributed to Agnibilekrou. Nonetheless, actual annual rainfall for Agnibilekrou would have been preferable.

Nevertheless, the data gathered was aligned with the literature that had been reviewed with respect to decreasing yields (Tondoh *et al.* 2015; Andres *et al.* 2016; FAOSTAT, 2016), and cocoa production (Interview 5, email communication, September 5, 2017). Having the ability to have access to governmental records from the CCC was an asset to the study. Smallholder farmers' day to day experience when it comes to declining soil fertility could be backed by literature (Grace *et al.* 2014; Guillaume *et al.* 2015). Previous studies have shown that the conversion of forest to perennial croplands results in a great loss of carbon from the soil, hence reducing the fertility of said soil. This thesis also concluded that such land use change can result in a loss of up to 80% of the soil's fertility. Therefore despite the low availability of data, the results remain reliable.

Plant available water coefficient

With respect to the water retention capacity, the formula by Zhang *et al.* (2001) was used to quantify the service. The equation uses precipitation, potential evapotranspiration and a plant available water coefficient w that ranges from 0.5 to 2.0 (Equation 2). Precipitation data could be obtained for Agnibilekrou over multiple decades. However only an average value for potential evapotranspiration from 1977 to 2000 in Abengourou (neighboring department to Agnibilekrou (Figure 1)) was used due to lack of better data. Furthermore, the plant available coefficient of a cocoa plantation or agroforestry system could not be found. Since forest have a w of 2.0 (Zhang *et al.* 2001), the values for a cocoa monoculture and a cocoa agroforestry system were arbitrarily set at 1.3 and 1.7 respectively since no w value have been set for those two land uses.

7.2 Stakeholder Interviews

Stakeholder availability

The CNRA's headquarters being outside of Abidjan, in Divo, 155 km away, was difficult to access. They were contacted through email, but didn't reply due to a strike that the organization was having. This institution could have provided a great deal of information on the research they have been conducting on agroforestry systems, but also on hybrid seeds that are now commonly used in Ivorian cocoa plantations. Nonetheless, the CCC which works closely with the CNRA had relevant information about the aspects that were sought, but couldn't give statistical information on research. In spite of that, considering the time frame, the most relevant stakeholders (i.e. the CCC, local farmers in Agnibilekrou and Ministry of Agriculture and Rural Development) were therefore targeted.

Having access to and communicating with public institutions was a challenge given the socio-political climate of Ivory Coast. Being able to meet with a government official or people from any of the relevant institutions was already an achievement. As environmental issues are seemingly a high priority in appearance (i.e. Paris agreement, presentation of the "Cacao ami de la foret" at the COP21, etc.), concrete action is lacking. Based on the interviews at the CCC and the Ministry of Agriculture and Rural Development, the mitigation of the environmental problems caused by cocoa production pales in comparison to the monetary gain that stands to be made. The literature review has demonstrated that cocoa can viably be produced in agroforestry systems, and the government through the president has stated the country's desire to fight climate change and reduce the environmental impact of cocoa production (Ministry of Agriculture and Rural Development, 2016). Yet, there lacks information regarding the application of the different proposed measures.

Interviews in Agnibilekrou

Moreover, data on cocoa production for the department was also difficult to find, as the cooperatives came together only in the 1980s to track the department's production, and the recorded data has only been done on paper. A lot of the information obtained from Kongodia lacked precision as mostly ranges could be provided with respect to yields and overall production. The information pertaining to ecosystem services was derived from the perspective of cocoa farmers. Many estimates were made in terms of the land-use present in the department, considering that not all farmers in the department registers with the cooperative of their respective village. Besides, of the 31 villages in Agnibilekrou, only Kongodia was surveyed as there was a couple of contacts among the farmers there already established. Having the ability to talk to more farmers in the many other villages of the department would have painted a clearer image of cocoa production in Agnibilekrou. Not enough data was gathered from the field visit and farmer interviews for a statistical analysis. Nonetheless, the data that was gathered was aligned with government reports on production. Furthermore, results from studies on regulating services and land use change were corroborated by farmers in Kongodia. They were aware of the ecological benefits that agroforestry systems could provide (i.e. litter layer, nutrient cycling, shade, additional source of income) (Albercht *et al.* 2003; Garrity *et al.* 2010), and the changing climatic conditions that are marked with longer dry seasons and low rainfall (Spracklen *et al.* 2012; UNdata, 2010).

7.3 Implications

The aim of this thesis was to assess the ecosystem services that could be obtained from three land-use systems (subsistence forest, full-sun cocoa monoculture and agroforestry systems) and determine how cocoa production impacts the ecosystem services and affects deforestation. To answer these questions, data on Ivory Coast and Agnibilekrou was required. The availability of data and information represented the main limitation. Regardless, the obtained results are aligned with literature.

This thesis also provides farmers' perspectives on ecosystem services in Agnibilekrou. Research looking at actual cocoa growers' views with respect to ecosystem services had not been done in one of the oldest cocoa producing regions in the world. The limited contacts those farmers have with researchers and government agencies helps maintain the status quo. The information from the department coming from local farmers, will help develop a participatory approach for a transition in the cocoa industry of Agnibilekrou and Ivory Coast. Farmers will have more information and more skills that will help meet the government's environmental and economic goals.

8. Conclusions

RQ1: Which stakeholders are involved in the Ivorian cocoa industry?

As the primary industry of Ivory Coast, the cocoa industry brings together a wide range of stakeholders from governmental institutions to local farmers. The CCC has the most influence in the Ivorian cocoa industry as this institution sets the purchasing price and actively works to improve production and productivity with the help of other national institutions such as ANADER, the CNRA and FIRCA. Their work involves research, financing and dissemination of information. Other than governmental institutions, smallholder farmers represent the other main stakeholder, as they are the ones producing the cocoa. The industry contributes to the livelihoods of close to a million people, and represents 11.5 % of the current GDP, emphasizing its importance for the country.

RQ2: What are the ecosystem services of a subsistence forest, full-sun cocoa monoculture and agroforestry systems in Agnibilekrou?

Different methods are used to grow cocoa. Today, full-sun cocoa monoculture is the primary method of production, where subsistence forests that are used by local populations are replaced with unshaded cocoa plantations to maximize yields. Agroforestry systems which have been researched in the past are now becoming less of a novelty for farmers. Those three aforementioned land-use options were the focus of this thesis. Based on literature review and interviews, it was determined that those land-use options could provide the following ecosystem services: food and raw materials, climate regulation, water retention, erosion prevention, maintenance of soil fertility, maintenance of genetic diversity as well as spiritual experience.

RQ3: How does the cocoa industry contribute to deforestation?

Ivory Coast lost 80% of its forest cover since its independence in 1960. That lost was mainly due to the expansion of agricultural land. Cocoa plantation now occupy 2 300 000 ha or 7% of the country's land area. A study determined that 57% of cocoa plantations come from primary forest. Hence based on calculation, le cocoa industry is responsible for nearly 15% of the deforestation of the last 50 years.

RQ4: How are the selected services affected by cocoa production (full-sun monoculture or agroforestry system)?

Full-sun monoculture was the land-use option that had the worse values on essentially every single ecosystem service that was quantified compared to the other two land-uses. Converting a subsistence forest to a cocoa plantation results in a decrease of many regulating services that the productivity of the land depends on. There is a decline in annual carbon sequestration (from 2-6 ton C per ha to 0.80-1 ton C per ha), carbon stock (from 115-400 ton C per ha to 25-90 ton C per ha), a higher likelihood of drought due to less retained soil water (from 347-465 mm to 200-300 mm), more annual soil losses (from 0-1.2 ton per ha to 20-90 ton per ha), a decline in biodiversity (160 plant species to 116 plant species). The annual productivity of this land-use decreases over time due to erosion and the decline of organic matter (from 2-4 ton per ha in the 1960s to 250-560 kg per ha today).

Agroforestry systems can annually sequester more carbon in the soil due to more vegetation (0.25-3.5 ton C per ha). The increased number of trees planted in combination with cocoa can provide additional income, and the leaves from those trees add to the litter layer that recycles nutrients back into the system, improving the soil's fertility (10-230 ton C per ha). Furthermore water retention increases compared to full-sun monocultures (265-375 mm), and erosion is

negligible similarly to subsistence forests. The ecological benefits contribute to increasing annual cocoa production (0.5 - 1 ton per ha). The findings from Agnibilekrou were consistent with what could be found in the literature for the whole country.

RQ5: What recommendations can be given for a sustainable cocoa industry?

The country's policies that have been developed in recent years have been geared towards environmental protection and conservation. Theoretically, these measures would improve the industry for all stakeholders on the value chain, but there is no evidence that anything has been done. The goal of transitioning to a 'zero deforestation agriculture' by 2017 was encouraging, but results are yet to be seen. Transitions take time, and the Ivorian cocoa industry is still in the initial stage of its transition towards an improved cocoa production that accounts for ecological factors. Further research on trees to use in agroforestry systems with the participation of farmers would help improve the implementation of agroforestry. Furthermore, changing a production system that has been in place for decades takes effort. The government ought to implement a subsidy to give farmers the incentive to switch to a new system, and strengthen the relationship between policy makers and farmers.

The aim set out at the start of this thesis was achieved. The research conducted concluded that agroforestry systems would be beneficial for the cocoa industry. Nevertheless, this thesis can help increase awareness amongst farmers and politicians to foster a sustainable Ivorian cocoa industry.

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Annex 1

Interview questions

Interview 1, the Deputy Director of Cash Crops of the Ministry of Agriculture and Rural Development
Interview 2, the Head Engineer in Agronomy of the Ministry of Agriculture and Rural Development
Interview 3, the Technical Secretary of Public Private Partnership Platform of the CCC
Interview 4, the General Manager of the Ministry of Agriculture and Rural Development
Interview 5, the Director of Statistics Monitoring Evaluation and Public Studies of the CCC
Interview 6, farmer in Kongodia
Interview 7, the chairman of the board of directors of the Kongodia cooperative
Interview 8, farmer in Kongodia
Group interview, with 11 farmers in Kongodia

Question	Answer	Respondents
Plantation Owners/Farmers		
Production		
What is the land tenure status? Does the land belong to the people or is it more of a rental agreement with the government? Are the land management decision autonomous?	The land belongs to the local. They decide to do whatever they see fit with their land in terms of management	Interview 6
How is cocoa produced in Agnibilekrou (what type of farms)?	Small family size full-sun plantations (between 1 and 4 ha). Only a few farmers have plantations over 10 ha	Group interview
		Interview 6
		Interview 7
How many cocoa farmers are there in Agnibilekrou? (estimate)	There are 25 cooperatives in the department, with a total of about 3000 farmers. Kongodia has about 100	Interview 7
How long has cocoa been produced in this area?	Since the 1950s	Interview 8

Why was cocoa first produced in the area?	A government subsidy from the French colonial government encouraged many farmers to grow cocoa	Interview 8
What were the initial yields?	Between 2 and 4 ton per ha	Interview 8
What are the current yields?	Lower than 1 ton per ha, closer to 500 kg per ha	Interview 8
		Group interview
Have there been any upgrades in the way cocoa is produced (mechanized, artificial inputs, etc.)?	Everything is still very archaic. Clearing is done manually (no mechanization)	Interview 6
How much cocoa do you sell? For what price/kg?	Currently, cocoa is sold between 700 Fcfa/Kg and 1 100 Fcfa/Kg	Interview 8
		Interview 6
What do you believe is affecting productivity/soil fertility?	The lack of rain is making it difficult to irrigate the plantations	Group interview
		Interview 8
		Interview 6
How much fertilizers is used in the production of cocoa?	Depending on the farmers: ● Many still use fertilizers for their plantations (50 kg of NPK/ha or 750 kg of Urea/ha) ● Some don't use chemical fertilizers but manure instead for its low cost	Group interview
How do you think governmental policies and regulations influence land management options?	The government creates protected spaces where no anthropogenic activity can occur, but there aren't any in the department	Group interview
What in your opinion is responsible for the declining yields?	Depending on the farmers: ● Extended dry seasons ● Poor soils, no forest cover, same plantation being exploited for 2 or 3 decades ● Lack of labor	Group interview

	• State gives land to loggers that clear everything in non-protected lands	
Agroforestry		
Are you aware of different production methods such as agroforestry systems?	Planting rubber trees in combination with cocoa has been done in the region. Legumes such as peanuts, have been planted as subsistence agriculture	Interview 6 Group interview
Have governmental institutions (the CNRA for instance) tried to implement agroforestry systems in the region?	They have just started disseminating their information on different tree species to use in agroforestry systems. It is still a novelty. Most farmers rather stick to what they know	Group interview
Would you be willing to implement such system even if it leads to lower yields in the near future?	If there is more financial help from the government there could be some change but reluctantly	Group interview
Ecosystem services		
What non-timber forest products are extracted from the forest?	Mainly bush meat and wood for construction material. Some gold can be found in some places but in very small amounts	Interview 7
Are there cultural beliefs and values attached to the forest?	Each village in the department has a piece of land of about 4 ha they don't touch because their ancestors are buried there	Interview 7
Are the people willing and open to clear large forested areas? Or are there incentives that drive them to make such decisions?	People want to make money, that's their main focus	Interview 6
How has the soil been impacted over the years, notably with respect to erosion?	Leaf litter from the trees planted in combination with the cocoa provides protection for the bare soil	Group interview
How has soil fertility fluctuated over the past decades? Has it noticeably declined?	Before, you barely needed to dig to sow seeds. Now, you need to dig a 40 cm hole, fill it up with humus, then wait until the first rain before	Interview 8

	sowing	
How has the climate changed over the years?	The big raining season use to be between February and July, but now it's from April to June	Interview 8
Coffee-Cocoa Council		
Production		
How is cocoa produced in Ivory Coast (what type of farms)?	Mainly smallholder farmers with family size plantations (2-4 ha)	Interview 1
		Interview 2
When cocoa became a pillar of the Ivorian economy, how much cocoa was produced?	90 000 tons during the 1960/1961 campaign	Interview 5*
What are the production levels of today?	About 1 800 000 tons at the end of the 2015/2016 campaign	Interview 5*
How much is cocoa sold for in Ivory Coast?	1 100 Fcfa/Kg as of the 2016/2017 campaign	Interview 5*
Who buys the cocoa? Who sells it?	Agricultural cooperatives bring together farmers who sell their produce to exporters such as Cargill and Olam	Interview 1
		Interview 2
To what extent does cocoa contribute to the Ivorian economy?	About 11.5% of the country's GDP and 40% of all exports	Interview 5*
		Interview 1
Agroforestry		
Have there been any other methods of growing cocoa than full-sun monoculture (i.e. Agroforestry)?	The CNRA has been doing research on trees to use in agroforestry system since 1994	Interview 3
Has such program been implemented already?	The CNRA distributes hybrid cocoa seeds already. They are also slowly introducing these new agroforestry systems using *Albizia sp* trees	Interview 3

How far has the research on such program gone?	It's been already over 20 years now, but implementation is only slowly starting now	Interview 3
Have such systems been successful? Have they been able to meet previous yields?	They can't produce the same yields, but they are less susceptible to drought thanks to the added shade	Interview 3
Can such system be productive in terms of the country's goals to remain a world leader?	Research is being done on hydrologic stressors and diseases (mainly swollen shoot). With agroforestry systems, plantations receive 30% shade which is ideal to reduce drought risks	Interview 3
Would such system be feasible on the national scale?	Any afforestation project falls in line with the government's plan	Interview 3
Ministry of Agriculture and Rural Development		
Production		
Which stakeholders are involved in the cocoa production?	The Ministry of Agriculture and Rural Development and the Ministry of Economy and Finances created the CCC which is tasked with the development and stabilization of the cocoa industry.	Interview 2
Which institutions work on research to help meet the government's goals?	The CCC works tightly with the CNRA and ANADER to reach rural population and disseminate new information and technology	Interview 2
How is cocoa sold?	Start selling on October 1st, the beginning of the agriculture campaign, until September 30th of the following year	Interview 2
Policy		
What has Ivory Coast done to mitigate the problems related to agriculture and deforestation?	Ivory Coast joined REDD+ in 2011, and renewed its strategy in 2016	Interview 4*
What does the future of the cocoa industry entail for Ivory Coast?	The government is also developing a new policy "Cacao ami de la foret", to combine agriculture and	Interview 4*

	forestry	

* Provided additional documents during the interview

Annex 2

Stakeholder Description

Ministry of Economy and Finances/Ministry of Agriculture and Rural Development

Prior to the independence, the colonial regime introduced a subsidy in 1956, giving cocoa farmers 7 000 Fcfa/ha to encourage them to produce. That subsidy increased to 8 000 Fcfa/ha by 1957. Nevertheless, this subsidy was discontinued after the independence in 1960, but had already created a boom where many farmers switched to cocoa production in mass (Interview 8, personal communication, July 29, 2017). Ever since, the cocoa industry has been under the tutelage of the Ministry of Economy and Finances, as well as the Ministry of Agriculture and Rural Development. It is an agricultural activity that represents a substantial contribution of the Ivorian economy. Hence, the creation of the CCC to take care of all cocoa related matters. Nevertheless, only the ministries can wield constitutional power to bring change in the system. Cocoa ought to keep providing for the country, from a financial standpoint, but has to be done so such that agriculture isn't compromised in the long run. Therefore, different institutions work together on projects to create a cocoa industry that is profitable and sustainable for the country.

The Board of Regulation, Stabilization and Development of the Coffee-Cocoa Sector (Coffee-Cocoa Council)

Under the guardianship of the Ministry of Economy and Finances as well as the Ministry of Agriculture and Rural Development, the Coffee-Cocoa Council was founded the in December of 2011 (Conseil Café Cacao, 2013). This organization was created for the better governance and transparency of resource management, the development of a sustainable cocoa industry through better production and productivity. The general manager of the CCC is assisted by two deputy managing directors responsible for commercialization on the one hand, and production, durability and technical operations on the other (Conseil Café Cacao, 2013). Their job is to create a public-private partnership to improve the sustainability of coffee and cocoa with the private sector.

The CCC is responsible with setting the minimum price at which cocoa is purchased to ensure that producers are fairly compensated and increase their standard of living (Conseil Café Cacao, 2013). Furthermore, the CCC is solely responsible in determining who are the authorized buyers and exporters of cocoa in the country. Authorized farmers' cooperatives sell cocoa to authorized exporters with quotas to foster a healthy competition (Interview 2, personal communication, July 26, 2017). Quality control is among the CCC's tasks as well. Impromptu checkups in factories to check weights and prices are often conducted for the sake of transparency in the industry (Conseil Café Cacao, 2013).

For the improvement of the cocoa industry in Ivory Coast, the CCC has to play a pivotal role. Programs such as "2QC" ("Quantite, Qualite, Croissance", Quantity, Quality, Growth) done in partnership with other institutions, notably FIRCA, ANADER and the CNRA, has for objective to increase the revenue from cocoa and ensure that the country remains a leader in cocoa production, reduce rural poverty and strengthen the status of Ivory Coast on the global scale (JNCC, 2016). The estimated cost of this program was 456 billion Fcfa over 10 years, stressing the importance of such a program for the government (JNCC, 2016). It entails research for drought

and disease resistant plants, along with agronomic research dissemination. By 2030, the plan is to replant 800 000 ha out of the estimated 2 000 000 ha of cocoa in Ivory Coast with improved seeds (Ministry of Agriculture and Rural Development, 2014). Each year, 200 000 producers are trained with respect to good agricultural practices, notably relating to the regeneration of plantations (JNCC, 2016). Furthermore, a seed distribution campaign of high yielding early bloomers occurred during the past four agricultural campaigns, where 152 318 ha of cocoa had been replanted with upgraded seeds (JNCC, 2016).

National Rural Development Support Agency (ANADER)

Created in 1993 with a capital of 500 million Fcfa (divided between state and private sector respectively contributing 35 % and 65%), ANADER's aim was to improve agricultural counselling for producers all over the country (Ministère de l'Agriculture et de l'Elevage, 2017). By 1997, the organization's services were covering the entire country (Ministère de l'Agriculture et de l'Elevage, 2017). Partnerships made with research institutions focused on research oriented towards the producers to better cater to their needs. Said research is centered on a participatory approach based on the knowledge of the field and rural population (Ministère de l'Agriculture et de l'Elevage, 2017).

The aim of ANADER is to improve rural standard of living by means of professionalisation of producers by providing them tools and putting in place programs to ensure a sustainable and controlled development of the cocoa industry. The objectives are to increase the productivity and revenue for producers, improve the quality of cocoa, promote the formation of cooperatives as well as put in place studies (Pye-Smith, 2016). Practically speaking, agents from ANADER are the ones in contact with the rural populations, teaching them new techniques and methods and making sure that producers stay up to date with the most recent knowledge from the field (Interview 2, personal communication, July 26, 2017). To change the status quo when it comes to cocoa production, organizations such as ANADER that are in direct contact with the producers, play a key role to ensure that the sought measures are fully understood and put in place by the rural population, who are the ones growing cocoa in the first place.

National Agronomic Research Center (CNRA)

Founded in 1998, the CNRA brings together multiple research station all over the country working on means to increase the sustainability of production and productivity in the agricultural and agro-industrial sectors (CNRA, 2017). With respect to the cocoa industry, the research is heavily oriented towards the development of cocoa hybrid seeds that are characterized by their high yields and early bloom (Interview 3, personal communication, August 10, 2017). Different hybrids have been developed and can produce between 2.5 and 3 tons/ha and produce faster which is an improvement considering the current state of cocoa production (CNRA, 2017). Those hybrids have been developed and used since the 90s in Ivory Coast (Interview 3, personal communication, August 10, 2017). As yields have been decreasing over the past decades, the CNRA has chosen to tackle this issue by developing ways to increase the production from the available land, with the same methods. Farmers in Kongodia have used some of those hybrids provided by the CNRA and have been able to start harvesting within 18 months as opposed to 3 to 4 years which is the common timeframe (Interview 8, personal communication, July 29, 2017).

Through the aforementioned government program 2QC, CNRA's seeds have been distributed to producers since the 2004-2005 agricultural campaign. During the 2013-2014 campaign, the CCC had provided seeds developed by the CNRA to producers, allowing to replant 400 000 ha of

upgraded cocoa throughout the country (Ministry of Agriculture and Rural Development, 2014). The research that has been conducted by the CNRA has essentially been geared towards increasing cocoa production. Nonetheless, the genetically generated seeds are not only designed to be high-yielding. They also are pest and insect resistant (JNCC, 2016), as disease is another issue that farmers have to account for. This however wasn't in the scope of this research. Besides, the CNRA is working on research for better means of planting cocoa plantations with hybrid seeds, but also looking at the benefits that trees could bring in an agricultural context (JNCC, 2016).

World Agroforestry Center (ICRAF)

The World Agroforestry Center, or ICRAF, is the world's repository of agroforestry related science, headquartered in Nairobi, Kenya (Pye-Smith, 2016). The organization's objective is to ensure an equitable agricultural world where all parties can have viable livelihoods with healthy ecosystems to support them (Pye-Smith, 2016). ICRAF's research is based on the benefits that trees can provide to agriculture, and how practices and policies can be reshaped to account for trees and the benefits that they can deliver (Pye-Smith, 2016). Farmers are encouraged to grow different trees in association with the cocoa they grow for the sake of biodiversity, but also as an additional source of income.

ICRAF acknowledges the need for a cocoa industry in Ivory Coast that has improved yields, fosters biodiversity, and does not degrade the land. That reasoning lead to the Vision for Change program (V4C) that was launched in 2010. It brought together Mars Incorporated, the largest chocolate company, national institutions (CCC, FIRCA, CNRA and ANADER), as well as farmers (Pye-Smith, 2016). All those stakeholders could recognize that agroforestry systems, would be a more sustainable option as opposed to full-sun monoculture, which has been the standard in Ivory Coast. The program is aligned with the aforementioned government program 2QC which aims at restoring 40% of the country's orchards and increase cocoa yield up to 1.5 ton per ha by 2023 (Pye-Smith, 2016). Practically speaking, the V4C program attempts to foster an improved cocoa industry by using grafting to increase yields in a short amount of time, replacing old trees with improved hybrids, using good agricultural practices such as pruning, and helps in terms of education and community building (Pye-Smith, 2016).

Interprofessional Fund for Agricultural Research and Council (FIRCA)

FIRCA was founded in December of 2002 as an organization for the financing of progress in agriculture for Ivory Coast. It is meant to ensure the financing of programs related to the production of vegetable, livestock as well as forestry (FIRCA, 2015). The state and private sectors are brought together to determine the needs of the producers in a general assembly composed of 152 members from different agricultural sectors (coffee and cocoa having the most representative, followed by the cotton and palm oil sectors), and from the state (FIRCA, 2002). Those members represent producers, professional agro-counselling organizations, agribusiness and primary processing industries (FIRCA, 2002). FIRCA's financing is done through membership fees from the different members, but also public and private contribution that help fund the organization's various programs. Those funds are used for agronomy research, experimentation, technological research to improve agricultural production, dissemination of information, professional training as well as providing agricultural counselling to producers (FIRCA, 2015).

The West Africa Cocoa Livelihoods Program started in 2009 is an example of the programs funded by FIRCA. The aim of the program is to improve the livelihoods of smallholder farmers in Ivory Coast, Cameroon, Ghana, Liberia and Nigeria. It was initiated by the World Cocoa

Foundation, in partnership with the Bill & Melinda Gates Foundation, the Ministry of Economic Cooperation and Development of Germany, along with a dozen cocoa exporting companies. In Ivory Coast, FIRCA works on this projects with ANADER and plays the role of technical coordinator and fiduciary (World Cocoa Foundation, 2012). The activities included research on improved production techniques and technical formation of producers on innovative ways to grow cocoa (World Cocoa Foundation, 2012).

Local Farmers from Kongodia

Kongodia is a small village located in the Agnibilekrou Department. It is one of the 31 villages were cocoa production takes place in Agnibilekrou. As it is the case for the remainder of the department, the entirety of the cocoa production in Kongodia is done by smallholder farmers on small family owned farms (Interview 7, personal communication, August 18, 2017). Land tenure is not an issue as the land belongs to the locals. The practices conducted on the land they own is entirely their own choice in terms of land-use. Initially, coffee was predominantly grown in the region. Once demand for cocoa increased, it spiked an increase in the price, giving farmers an incentive to start growing cocoa (Interview 6, personal communication, August 28, 2017). Indeed, the price increased from 200 Fcfa/Kg in 1992, to 1100 Fcfa/Kg in 2017 (Interview 5, email communication, September 5, 2017).

Farmers all over the country come together in their respective localities to create cooperatives in order to pull all their resources together. The Agnibilekrou Department comprises of 25 cooperatives with over 3000 farmers (Conseil Café Cacao, 2014). Kongodia has its own cooperative with roughly 100 farmers (Interview 7, personal communication, August 18, 2017). 62% of the cocoa collected in the country is sold through cooperatives, as the one in Kongodia, to big corporations such as Cargill and Olam (Interview 1, email communication, September 5, 2017). Those cooperatives are therefore an important actor in the commercialization of cocoa. Nonetheless, farmers don't wield any institutional power. They do not have any power over the price of their merchandise and unfortunately don't have a seat at the negotiation table. They possess a great deal of information about the soil, fertility and cocoa production in general as cocoa is a generational business that has been going on for many decades, but that knowledge and their land are their only assets.

Annex 3

Cocoa Ami de la Forêt

The program has essentially two main axes (Conseil Café Cacao, 2017). The first one pertains to the separation between cocoa production and deforestation in rural areas:

- Geo-localization of cocoa producers and their parcels for traceability
- Increasing the yields of cocoa plantations by sustainable intensification of ecosystems
- Promotion of agroforestry to cocoa producing communities
- Rural afforestation with a participatory approach where rural communities have a say in the tree species selection

The second axis relates to the contribution to sustainable management of protected forests, parks, reserves and degraded forests in cocoa producing zones:

- Support for cocoa producing communities for the afforestation of fallow and deforested land around protected forests, parks, reserves and degraded forests
- Support for afforestation, restoration and conservation efforts in protected forests located in cocoa production zones

Annex 4

The Ivorian REDD+ strategy

Each axis of the country's REDD+ strategy has been explained in the following paragraphs based on the document provided by the General Manager of the Ministry of Agriculture and Rural Development. Only the axes that have been deemed relevant for cocoa production (I, III, IV, and VI) were further elaborated in terms of the action points that are meant to contribute to one or more strategic axis.

I. **Zero deforestation agriculture with a public-private partnership:** This axis is based on a public-private partnership between agro-industrial businesses and the public sector to reduce agricultural induced deforestation by 80%, by 2030, primarily in protected forests and areas:
    1. Risk/Opportunity evaluation of forests with cultural and ecological benefits
    2. Traceability of agricultural products and deforestation
    3. Support for smallholder producers to help them increase their productivity
    4. Support for the development of "sustainable territories" (one or more adjacent rural territories that do not experience net forest loss and have a minimum 20% forest cover) through payment for ecosystem services
    5. Restoration of protected forest illegally occupied by small cocoa farmers
    6. Private sector engagement with governmental partnership
    7. National and international dissemination
    8. Creation of a national platform on a zero deforestation agriculture to facilitate coordination between all stakeholders

    The aforementioned "Cacao ami de la foret" policy, aligned with the 2QC program (See Annex 2) showcase how the cocoa industry falls under the umbrella of the REDD+ strategy. With respect to this industry, the aim is to reduce the deforestation caused by cocoa production, gain private sector investments for sustainable cocoa production while improving the productivity of the value chain, and promote sustainable management of protected forests.
II. **Development of a sustainable energy strategy:** The aim of this axis is to create a sustainable value chain for the cooking energy source (i.e. firewood) by increasing the offer for biomass, through afforestation for the production of firewood, use of agricultural residue, and improvement in energy use efficiency.
III. **FLEGT, sustainable management and conservation of protected forests, areas, and sacred forests:** The aim of this axis is to ensure the preservation of protected lands and steadily restore degraded land through a new management. This is done through a participatory and inclusive approach that accounts for social and environmental factors related to the people living in and around those areas for subsistence purposes:
    1. Ensure legal and sustainable timber exploitation through the VPA-FLEGT[24] process
    2. Strengthening of the governance of protected forests and areas, through participative inclusion of all stakeholders (i.e. local communities, private

[24] Voluntary Partnership Agreement (VPA) is a legally binding trade agreement between the EU and a non-EU country exporter of wood, such that the wood sold in the EU meets the legal requirement of the country in which it is being sold.

sector of the wood industry, and the Ministry of Waters and Forests), and a comprehensive plan for the management of protected forests
3. Management of the expansion of agricultural lands inside protected forests
4. Development of partnership for the restoration of protected forests with the help of SODEFOR[25] and many other stakeholders (NGOs, Local communities, investors, etc.)
5. Emergency plan to preserve protected forests and well conserved areas
6. Increased security in parks and reserves
7. Sacred status and conservation for natural community forests that have cultural value

IV. **Afforestation and restoration of degraded land:** The aim of this axis is to increase the carbon stock by rehabilitating 5 000 000 ha of deforested and degraded land through afforestation, and the promotion of rural based agroforestry to reach a 20% national forest cover by 2040, while ensuring food security, poverty alleviation and the restoration of biodiversity:
    1. Organization of the institutional framework to put together policies for restoration of the forest cover
    2. Creation of an institutional mechanism for the production of seeds, the National Forest Seed Center
    3. Establishment of a national plant production system
    4. Development of rural plantations depending on their utilization, through agroforestry, and afforestation in rural areas, but also the promotion of urban forestry with communal forests, parks, etc.
    5. Protection and traceability of forest and afforestation, to prevent wildfires, but also for land tenure issues
    6. Traceability, guidance and development of partnership agreement for the harvesting and commercialization of timber, by registering forests, guidance to optimize a sustainable timber production, and commercial agreement between timber producing villagers and private companies
    7. Establishment of a financing mechanism for afforestation, the National Forest Development Fund that will be backed by the National REDD+ fund, developed and managed by the Ministry of Economy and Finances
    8. Strengthening of the timber industry for the adaptation of production tools to smaller diameter trees

V. **Mining exploitations respectful of the environment:** The aim of this axis is to develop a low carbon mining industry through the promotion of corporate social responsibility (CSR) among companies and gold washer cooperatives

VI. **Development of a national payment for ecosystem services system (PES):** The aim of this axis is to provide investment opportunities for smallholder farmers and rural communities to make beneficial investments in terms of agroforestry and afforestation, by investing in activities that protect and conserve the environment:
    1. Four different modalities for PES under the REDD+ strategy:
        a) Agroforestry
        b) Rural afforestation
        c) Assisted (initial manual maintenance) natural regeneration
        d) Forest conservation

[25] Forest Development Corporation (Société de Développement Forestier): Public company tasked with upkeep, maintenance, and valorization of forests under its responsibility

Each modality has its own time frame, monetary amount, payment calendar, payment conditions, as well as the expected benefit in terms of carbon sequestration

2. Establishment of a robust mechanism for the governance of the national PES system, handled by SEP-REDD+
3. Establishment of a national financing mechanism for the PES
4. Cooperation between Ivory Coast and Costa Rica for their experience setting up a PES mechanism

VII. **Territorial development relaunch and land securitization:** Ivory Coast lacks a harmonized national landscape management plan that guarantees sustainable development for sectors linked with land utilization, notably agriculture and forestry (mining and urbanization are also somewhat relevant). Hence, in 2008, the creation of the Regional Plan for the Development of the Territory that laid the foundation for the REDD+ strategy approach to land-use.

VIII. **National planification and structural reform for a green economy:** The aim of this axis is to create a favorable climate for the elaboration of national policies and measures aligned with sustainable development objectives that the country decided to achieve by ratifying the Paris climate agreements, and put the country on track towards sustainable development and green economy.