The potential of good agricultural practices in creating a living income for Ivorian cocoa farmers

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Abstract

Cocoa production continues to be associated with low incomes, low productivity, and poverty. Working in tandem with certification programs, cocoa traders, manufacturers, and retailers have started implementing their own interventions in the cocoa sector. In these interventions, large attention is paid to increasing productivity through the adoption of Good Agricultural Practices (GAPs). Increasing productivity is expected to decrease the gap to a living income. This thesis investigates this theory of change by analyzing farm-level data collected in Ivory Coast between 2016 and 2019, in scope of the CocoaAction program. This data is analyzed using relevant econometric regression models. The results show that GAP adoption decisions by farmers cannot be expected to increase with farm gate cocoa prices, and are positively influenced by appropriate training. The adoption of GAPs according to the CocoaAction framework do not necessarily result in higher yield. The majority of the farmers in the study are not earning a living income. Considering the complexity of farmer decision making, the uncertain role of GAPs on yield, and the stability of yield over the years, increasing yield cannot solely be relied on for increasing incomes. A higher minimum farmgate cocoa price has potential to decrease the gap but might worsen the competitive position of the Ivorian cocoa sector, and is likely out of scope for private interventions. For future interventions and research, it is recommended to further investigate and improve the role of GAPs in increasing yields and to increase knowledge on farmer decision making, whilst considering the resource constraints that farmers face.

Preface

This master thesis is the final part of my study in Environmental Economics and Natural Resources at the Wageningen University. I would like to thank Dr. Ir. C (Koos) Gardebroek, Matthew Bare, MSc. and Erika Seidenbusch, MSc. for their guidance and supervision throughout the entire process. Their great knowledge, expertise, flexibility and honesty have enabled me to get the most out of myself. I further want to thank my parents Heleen and Patrick and my brother Douwe, for their never-ending support, for always believing in me, and for providing me with the opportunity to write this thesis. Without them, I would not have been where I am now. Last, I want to give special thanks to Maurits, for his loving support and his ability to always put me back on my feet. This has been an exceptional period with exceptional, at times challenging, circumstances, and I am more than ever aware of the good health and circumstances I have been given.

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Chapter 1 Introduction

1.1 Background

Ivory Coast is the largest cocoa exporting country in the world, producing about 40% of the global supply. It reached a supply peak in 2016/2017 due to favorable weather conditions when they produced 1,690,000 tons of cocoa (Ingram et al., 2017). That Ivory Coast has become the world's largest cocoa producer is the result of a government policy to stimulate cocoa production in the 1970s. This policy became successful due to the favorable conditions: large virgin forests were abundant, as well as labor due to migration from the North (Wessel and Quist-Wessel, 2015). In 2017, cocoa beans, paste, and butter formed 53% of the Ivorian exports (OEC, 2020). Nevertheless, cocoa continues to be associated with low incomes, low productivity, and poverty (Bymolt et al., 2018, p. 132). Ivorian cocoa is produced by approximately 800,000 – 1,200,000 smallholder farmers (Ingram et al., 2017). The average yield per farm has remained low, amongst other things, due to the use of traditional and extensive cultivation methods, inadequate maintenance, inadequate pest and disease control, little use of fertilizer, poor shade management, and aged cocoa trees (Wessel and Quist-Wessel, 2015). Multiple external factors explain why little improvement has been made regarding these agricultural practices, such as low farmgate prices, high price volatility, high input prices, limited credit access, small farm sizes, high transportation costs, illiteracy, political instability and extreme weather events (Wessel and Quist-Wessel, 2015; Matissek et al., 2012; Waarts et al., 2019).

These external factors make that smallholder farmers often end up in a low-input low-output cycle. This has led to the expansion of farms by cutting down virgin forests since recently cleared forest has a high 'forest rent': fertile soil and low pressure from weeds, diseases, and pests (Schroth and Ruf, 2014). Virgin forests are also increasingly cleared after periods of high cocoa prices, which attracts waves of migration towards tropical forest areas to set up new farms (Ruf and Schroth, 2013 in Fourcade, 2018). The expansion of farms and settlements of new farms in virgin forests make that cocoa is one of the main drivers of deforestation in Ivory Coast (Wessel and Quist-Wessel, 2015). Cocoa continues to compete with crops that rely less on the forest rents of recently cleared forests (Schroth and Ruf, 2014). This can be other cash-crops such as coffee or palm, or subsistence crops such as maize and yam (Ingram et al., 2017). The competition with other crops could be exacerbated by the large population growth in Ivory Coast resulting in a greater demand for food and corresponding higher prices for these alternative crops. Low yield levels, competition with other crops, and high levels of deforestation can constrain future cocoa supply. Consequently, there is a call for growing more cocoa on less land (Wessel and Wessel-Quint, 2015; WCF, 2016).

To tackle the interrelated problems of low productivity, low incomes, and poverty in the cocoa sector, many sustainability initiatives have been developed since the mid-2000s (Ingram et al., 2018). Besides the focus on improving productivity, there is an increased focus on creating a living income for cocoa farmers. A living income has been defined as "*the net annual income* *required for a household in a particular place to afford a decent standard of living for all members of that household*" (LICoP, 2020). The initiatives come in many forms, such as voluntary sustainability standards (VSS), individual corporate initiatives, platforms, and campaigns. Different initiatives usually overlap and work in tandem (Ingram et al., 2018). Two of the most common sustainability initiatives are certification programs and corporate initiatives.

Interventions – certification programs

Some of the leading VSSs in the cocoa industry are the certification standards UTZ and Rainforest Alliance (RA), which merged in 2018 under the name of Rainforest Alliance. UTZ certification is one of the most adopted VSSs in the cocoa sector, and UTZ-certified cocoa grew sevenfold in West Africa during the period of 2010 to 2017. In the 2016/2017 production season, 329,978 farmers in Ivory coast were UTZ certified, together producing approximately 34% of the national cocoa exports (Ingram et al., 2018). At farm-level, UTZ certified cocoa farms must uphold certain standards related to environmental, social, and economic sustainability (RA, 2020). Part of the standard requires farmers to work towards adopting Good Agricultural Practices (GAPs) These are *"practices that address environmental, economic, and social sustainability for on-farm and postproduction processes, and result in safe and quality agricultural products''* (UTZ, 2015, p10). Other focus areas by UTZ in the cocoa sector are strengthening the relationships between farmers and buyers and providing the farmers with a variable premium on top of the market price (UTZ, 2019). Various studies on the effectiveness of these programs have shown modest and mixed effects regarding this environmental, social and economic sustainability (Fountain and Huetz-Adams, 2018; Waarts et al., 2019; Bennett et al., 2012). The effect of certification on yield and farmer income remains largely uncertain, although two extensive studies on the topic found both yield and incomes to be higher for UTZ or RA certified farms. However, both studies also show that this effect is fading over time and that non-certified farmers seem to catch up (Ingram et al., 2017; Bennett et al., 2012).

Interventions – corporate initiatives

Working in tandem with certification programs, companies have developed their own programs regarding cocoa sustainability (Lumina Intelligence, 2019). To create a living income for supplying farmers, their programs put most emphasis on increasing productivity levels, or as it is generally referred to: *"produce more cocoa on less land*" (WCF, 2016b, p2). However, concerns have been raised regarding this influence from the industry. In the Cocoa Barometer 2018 report, authored by a consortium of NGOs, it is stressed that without third-party verification the transparency and reliability of reporting is at risk, and that such initiatives could make farmers more dependent on the large cocoa companies, whereas they are already struggling with power asymmetry in relation to their buyers (Fountain and Huetz-Adams, 2018). Another concern is that whereas UTZ and RA certification premiums are published annually, there is little transparency on premiums paid by companies (Lumina Intelligence, 2019). However, companies often implement their interventions in addition to third-party certification, and not instead of.

Increasing the transparency of interventions by the cocoa industry is part of the CocoaAction program, launched in 2014 by the World Cocoa Foundation and nine of the world's largest cocoa and chocolate companies. CocoaAction is a voluntary, industry-wide strategy aimed at tackling the most pressing issues in cocoa sustainability. CocoaAction works with the governments of Ivory Coast and Ghana and other key stakeholders with the vision of creating *''a sustainable and thriving cocoa sector where farmers prosper, cocoa-growing communities are empowered, human rights are respected, and the environment is conserved''* (WCF, 2016b, p2). Within CocoaAction stakeholders align on priorities and necessary activities and share best practices and challenges, but the participating companies still make individual commitments and carry out their own interventions (WCF, 2016b). CocoaAction can thus not be seen as an intervention in itself but rather as a platform for aligning interventions. The participating companies are required to collect data according to a Monitoring & Evaluation (M&E) framework. Nevertheless, there remains large unclarity on the effects of these company interventions and the resulting impact on farmer income.

1.2 Research problem

Working in tandem with certification programs, cocoa traders, manufacturers, and retailers have started developing their own interventions. In these interventions, regarding farming practices, most attention goes to be on the adoption of Good Agricultural Practices. These private interventions show the continuous reliance on producing more on less land when it comes to creating a living income for smallholder cocoa farmers. However, it is not clear whether their interventions result in higher productivity levels. It also remains unclear whether increased productivity levels are sufficient to create a living income for smallholder cocoa farmers, when external factors such as low farmgate prices, high price volatility, high input prices, a lack of access to credit, small farm sizes, high transportation costs, illiteracy, and extreme weather events, are not addressed simultaneously.

1.3 Research questions

The aim of this research is to answer the following research question:

To what extent can the adoption of good agricultural practices contribute to creating a living income for smallholder cocoa farmers in Ivory Coast?

To answer the main research question, the following sub-questions are defined:

1. *What is the role of cocoa farmgate prices in the adoption of GAPs on smallholder cocoa farms in Ivory Coast?*
2. *To what extent can GAP adoption and weather events explain productivity levels of smallholder cocoa farmers in Ivory Coast?*
3. *What is the difference between current incomes and a living income in Ivory Coast, and can this difference mostly be attributed to productivity levels or to cocoa farmgate prices?*

1.4 Methodology

To answer the research questions, quantitative data is analyzed. The data analyzed in this research has been collected by Rainforest Alliance alongside the annual UTZ-audits. The data collection was commissioned by Nestlé, Cargill, Hershey, and Mars for CocoaAction reporting requirements. It is farm-level data collected between 2016 and 2019. This data is analyzed using relevant econometric models. These models are checked, among others, for robustness, validity (goodness of fit), and predictive power. The models are based on the existing data and relevant literature. Literature is also used to explain and discuss the outcomes of the analysis.

Chapter 2 The Ivorian cocoa sector

This chapter provides background information on the Ivorian cocoa sector and consists of four parts. The first part describes the current yield gaps on Ivorian cocoa farms. The second part of this chapter describes the climatic conditions under which cocoa is grown in Ivory Coast. The third section describes the cocoa value chain, including the supply chain, pricing mechanism, and market power. The fourth and last part of this chapter provides an overview of interventions by Nestle, Hershey, Cargill, and Mars that are central in this thesis.

2.1 Yield gaps in Ivorian cocoa production

Cocoa (*Theobroma cacao*) production in Ivory Coast is commonly not reaching its genetic yield potential (Adomako, 2007). To what extent farmers are not reaching the potential is usually expressed as the yield gap, which is the subtraction of the average yield from the yield potential. The potential yield is obtained when the cocoa is grown in good environmental circumstances, with the necessary amounts of water and nutrients, and not affected by pests and diseases. In West Africa, a yield potential of 1890 kg/ha has been found (Aneani and Ofori-Frimpong, 2013). Average cocoa yields in Ivory Coast are substantially below the potential yield, ranging from 300 to 800 kg/ha. In contrast, in Southeast Asia (Malaysia and Indonesia), average yields of 1000 up to 1800 kg/ha are found (Dormon et al., 2007; Nkamleu et al., 2007). Many factors have been described in what explains these low yields, but overall, yields have remained low due to the use of old and extensive cultivation methods (Wessel and Quist-Wessel, 2015). An extensive overview of factors influencing yield is given in the following chapter.

2.2 Climatic conditions

Ivory Coast is a West African country with a generally warm and humid climate (ADB, 2018). It is situated in the West African cocoa belt, and most cocoa is grown in the south of the country (Schroth et al., 2016). There are annually two rainy seasons, differing in length. The short season takes place from September to October and the long season takes place from April to June. The mean annual rainfall in the south is 1420 mm/year, and the least rain generally falls in December and January (ADB, 2018). The West African cocoa belt has a longer dry season compared to other cocoa-producing regions in the world (Schroth et al., 2016). In the south, there is a daily mean temperature of 27°C, but the temperatures show only small seasonal differences, with the highest temperatures at the start of the long rain season and another but lower peak in the second half of the short rain season (ADB, 2018).

2.3 Value chain description

This section describes the value chain of cocoa from Ivory Coast. It starts with a description of the supply chain, including the stakeholders and processes that are involved when turning the cocoa beans into chocolate for consumers. After that, the pricing mechanism and division of market power within the value chain are explained.

2.3.1 Supply chain

As described in the introduction, Ivorian cocoa is produced by approximately 800,000 – 1,200,000 smallholder farmers (Ingram et al., 2017). Smallholder farmers in cocoa are generally defined as having a farm size smaller than 5 hectares (Hütz-Adams et al. 2016). There are several marketing channels through which farmers sell their beans, including cooperatives, private traders, or directly to exporters (Mota et al., 2019). Described in this section is how UTZ cocoa generally flows through the supply chain. The harvesting of cocoa takes place in two crop seasons. The main crop season takes place between October and March, and the mid-crop season takes place from May until August (ICCO, 2014). After harvest, cocoa beans are fermented and dried on the cocoa farms (Harper, 2019). Due to the small scale of production, it is often too expensive for smallholder farmers to carry the beans to the exporters for sale. Consequently, they sell their beans to local intermediaries (Malan, 2014). The first intermediary is usually the "pisteur", a local trader who brings the cocoa from the farmers to cooperatives (Harper, 2019). It occurs that the farmer does not receive the full farmgate price from the pisteur, when the farmer does not have access to information on the farmgate price (Mota et al., 2019), or because the pisteur takes a share of the price as compensation for bad infrastructure (Harper, 2019). The cooperatives are then aggregated warehouses. It usually is not an entity run by farmers, but rather a private business, often funded by different parties (Harper, 2019). These cooperatives, in turn, sell the beans to contractors or straight to exporters (Malan, 2014). When the beans are first sold to contractors, which are often also called cooperatives, the beans are prepared for shipping by removing the dust and waste and packaging them (Harper, 2019). The beans are then sold to exporters, or traders. Every year the Conseil du Café-Cacao (CCC), a state-run marketing board, auctions around 100 export licenses. The traders may directly sell the beans to the processors, who in turn process the beans into cocoa liquor, cocoa butter, and cocoa powder. However, some of the larger traders process the beans themselves. The processed beans are sold to manufacturers, who turn the cocoa liquor, butter, and powder into chocolate products. The chocolate products are then sold to retailers, and eventually to consumers (Harper, 2019).

2.3.2 Pricing mechanism and market power

After a period of liberalization starting in the mid-1980s, the Ivorian government reformed the cocoa sector in 2011 to regain control of the sector. The aim was to increase productivity levels and farmgate prices (Oomes et al., 2016). The government established a state-run marketing board: the Conseil du Café-Cacao (CCC) (Fountain and Huetz-Adams, 2018). The CCC is responsible for managing the development and quality of the cocoa sector, and for price stabilization (Oomes et al., 2016). The latter they aim to do by guaranteeing a yearly fixed minimum price, which they set at the start of the harvesting season in October (Oomes et al., 2016). The CCC bases this price on the world cocoa price (Harper, 2019). Figure 1 shows that this price has been systematically below the world market price.

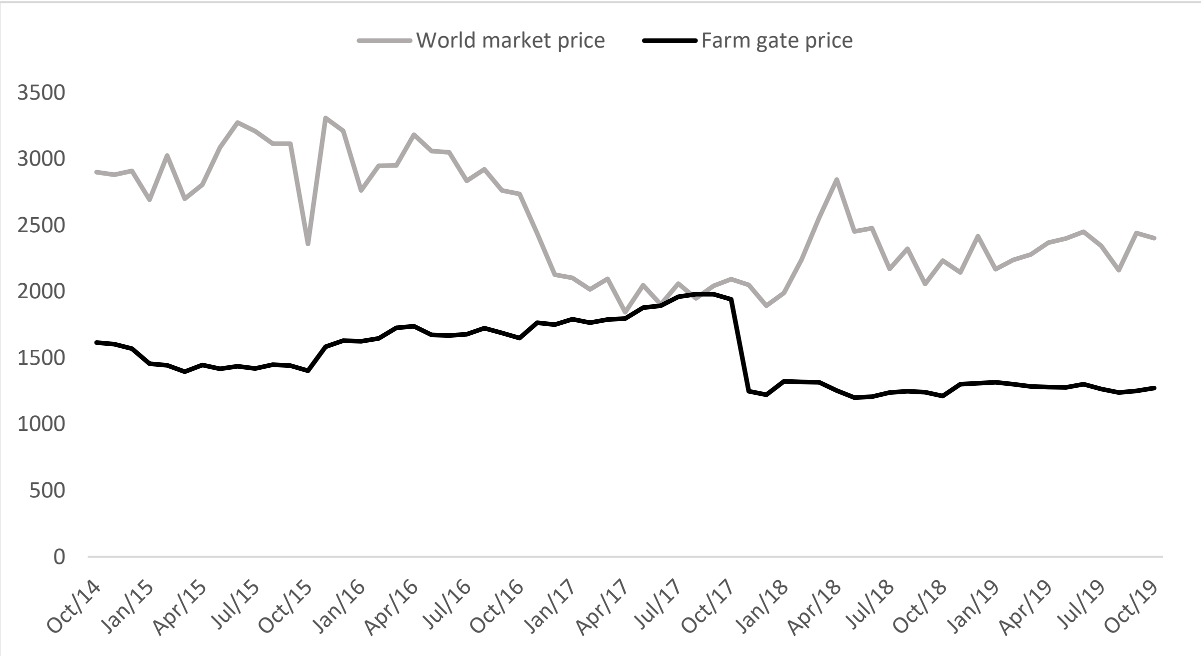

Figure 1 Worldprice and farmgate price in USD/t

Data: Bassompierre et al., 2019 ; Fountain and Huetz-Adams, 2018; Fusion Media Limited (2020);Trading Economics (2020).
Note: within year variation for cocoa farm gate prices result from USD-CFA exchange corrections.

The CCC forward sells 80% of the national expected cocoa production to local national traders. The other 20% is to be sold during the season (Fountain and Huetz-Adams, 2018). The farmgate price, the price received by farmers, is set at minimally 60% of the price at which the CCC forward-sells the cocoa (Oomes et al., 2016). Farmers do not always receive the full farmgate price, because they have limited possibilities in selling their cocoa. The pisteur often takes a share of the price, because it is costly to transport the beans when farmers are living in remote areas with poor infrastructure (Harper, 2019). When the CCC makes revenues due to increases in cocoa market prices, these are saved in funds, to compensate farmers when the prices decline again (Oomes et al., 2016). The goal of setting a minimum price is to stabilize and increase farmgate prices, and to protect farmers against power imbalances in the market. Nevertheless, the farmgate prices of Ivory Coast are around 25% lower than in cocoa-producing countries where cocoa prices are not regulated. This can partly be explained by the share that the CCC takes of the sold cocoa, whereas the reinvestment of these taxes has not resulted in larger productivity levels in Ivory Coast. A major pitfall of the system became clear in the season of 2016/2017. At the start of the season, the CCC had auctioned 80% of the cocoa to both national and international traders, at the set minimum price. Right after the auctions, early signs of a good harvest and a lower than expected demand from Asia, resulted in a large oversupply of 500.000 tonnes (Fountain and Huetz-Adams, 2018; Harper, 2019). The world market price plummeted from around 3000 USD/t to below 2000 USD/t. When national traders saw the world market price drop below the obligated farmgate price, they did not have an incentive to buy and sell the cocoa anymore. Unlike international traders, these national traders are not obligated to presell the cocoa, so they had the liberty to not buy the cocoa from the farmers anymore. In addition, the 20% share of production that had not been auctioned by the government was also not traded. As a result, half of all Ivorian cocoa of that season was not sold (Fountain and Huetz-Adams, 2018).

Concerns have been raised regarding the highly concentrated end of the cocoa value chain, which would be prone to abuse of market power and unequal distribution of the value added along the chain (Fountain and Huetz-Adams, 2015). A large study by Oomes et al. (2016) on market concentration in the cocoa value chain found that there is indeed a high concentration in the upper part of the value chain, especially in the trading/processing and manufacturing sectors. This is partly a result of horizontal integration, where due to mergers and acquisitions these sectors are in the hands of a small number of companies. This horizontal integration can be explained by the theory of economies of scale, since fixed costs in cocoa processing and manufacturing are very high (Oomes et al., 2016). Concentration in the upper part of the value chain is also a result of increasing vertical integration, where companies take up other segments of the value chain. An example of vertical concentration is that cocoa traders increasingly start processing the cocoa themselves. Vertical integration also occurs in the lower end of the value chain, where manufacturers and traders start establishing relations with local cooperatives (Oomes et al., 2016). The study did not find evidence that these levels of market concentration are excessive, or that market power is being abused. Rather, the world cocoa price is determined by demand and supply, and established on cocoa futures markets, of which the most important is the London International Financial Futures and Options Exchange (Oomes et al., 2016). That there is no market power abuse is confirmed by Ohemeng et al. (2016), who find that cocoa market prices operate efficiently. In addition, the world cocoa price is not more volatile than other world commodity prices (Oomes et al., 2016). However, even though Oomes et al. (2016) and Ohemeng et al. (2016) show no proof for abuse of market power in pricing, Bonjean and Brun (2014) show that the transmission of price fluctuations in cocoa has been asymmetric: when the world market price for cocoa goes up, retail prices rise quickly, but when the cocoa price falls, retail prices drop very slowly. As a result, a drop in the price of cocoa beans results in an increase in profit margins for some participants in the value chain, in particular retail, but not farmers (Bonjean and Brun, 2014).

2.4 Interventions in the Ivorian cocoa sector

The farm-level data used in this research has been collected on farms that supply to chocolate manufacturers Nestle, Hershey, and Mars, and cocoa trader Cargill. All four companies have conducted a range of interventions on Ivorian cocoa farms. This section provides a brief overview of interventions aimed at increasing productivity.

The four companies have all developed their own programs about cocoa sustainability: Nestlé launched their 'Nestlé Cocoa Plan' and opened a research and Development center in Abidjan in 2009 (Nestlé, 2020), Cargill launched their 'Cocoa Promise' in 2012 (Cargill, 2020), Mars launched their 'Cocoa for Generations Strategy' in 2018 (Mars, 2020), and Hershey launched their 'Cocoa for Good' in 2018 (Hershey, 2020) (figure 2). Hershey's also developed the agricultural training and empowerment program Hershey's Learn To Grow, in 2014 (Hershey, 2014).

Despite the separate development of these programs, they are also aligned through the World Cocoa Foundation (WCF), including the CocoaAction data collection and the Cocoa and Forests Initiative (CFI) which started more recently.

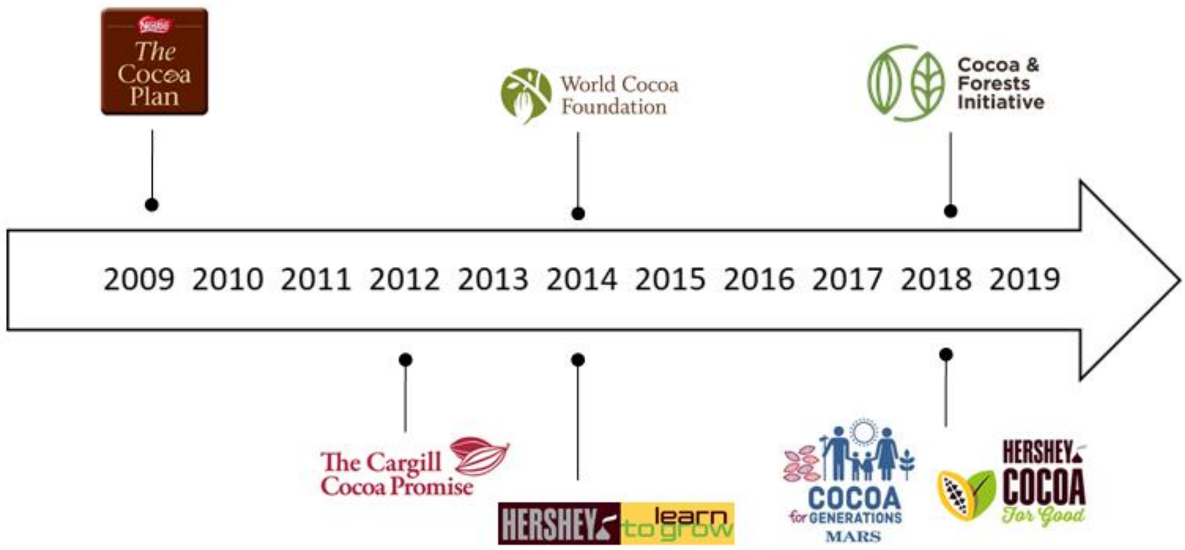

Figure 2 timeline of interventions in the Ivorian cocoa sector

Note: CocoaAction does not have a logo, the logo of the initiator, the World Cocoa Foundation, is depicted instead

CocoaAction and CFI include a wide range of interventions, ranging from child labour prevention, primary education and women's empowerment, to diversifying farmer incomes, GPS farm mapping, deforestation risk assessments, increasing traceability and provision of shade trees, cocoa trees and multi-purpose trees (WCF, 2016b; WCF, 2020). The scope of this research is on those interventions aimed at increasing productivity levels. This is an important pillar in the CocoaAction program. As described, CocoaAction is not an intervention in itself, but rather a platform to align on interventions. The CocoaAction program describes what practices and interventions should be conducted to increase yields and requires data collection to examine to what extent farmers are currently adopting these practices. These practices include, amongst others, training farmers on Good Agricultural Practices (GAPs), and making planting materials and fertilizer available to the farmers. The CocoaAction program defines five GAPs: cocoa tree pruning, cocoa pest and disease management, cocoa weed management, cocoa shade management, and cocoa harvest management. These GAPs are very much aligned with those required for UTZ certification (UTZ, 2015). CocoaAction's hypothesis is that the adoption of GAPs, combined with fertilizer application and improved planting materials will raise yields (WCF, 2016b). The numbers of farmers trained on GAPS shows the reach of their interventions. In 2019, Nestlé had already trained 68.965 farmers, Cargill 105.000, Mars 48.926, and Hershey 29.496 (Nestlé, 2020; Cargill, 2020; Mars, 2020; Hershey, 2019). However, these numbers are likely overlapping since Cargill trades cocoa for Nestlé, Mars and Hershey.

Chapter 3 Theoretical background

This chapter describes the theoretical background on Ivorian cocoa production, upon which the models described in the methodology section are based. It starts with an overview of relevant research about what determines whether farmers adopt new technologies and practices, and what farming practices and climatic factors have been found to affect yields. The conceptual framework summarizes important aspects of Ivorian cocoa production at country level. The aim of the framework is to create a better understanding of what factors influence cocoa production and hence income from cocoa for cocoa farmers.

3.1 Agricultural practice adoption amongst small-scale farmers

Extensive research has been conducted on what socio-economic factors make it more likely for farmers to adopt agricultural practices (Nmadu et al., 2015; Aidoo and Fromm, 2015; Obuobisa-Darko, 2015; Danso-Abbeam and Baiyegunhi, 2017; Baffoe-Asare et al., 2013; Djokoto et al., 2016; Nkamleu et al., 2007). A multitude of factors has been identified. Factors found to positively influence the chances of adoption of practices are the level of education (Nmadu et al., 2015; Aidoo and Fromm, 2015), whether a farmer is member of a farmers' organization (Aidoo and Fromm, 2015; Obuobisa-Darko, 2015; Nkamleu et al., 2007), whether the farmer has access to credit (Aidoo and Fromm, 2015; Obuobisa-Darko, 2015; Djokoto et al., 2016; Nkamleu et al., 2007), whether the farmer is male (Nmadu et al., 2015; Djokoto et al., 2016), the age of the head of the household (Danso-Abbeam and Baiyegunhi, 2017; Baffoe-Asare et al., 2013), and whether the farmer has received training on the practices (Baffoe-Asare et al., 2013). Extension contracts and visits also seem to have a positive effect on the adoption of practices (Obuobisa-Darko, 2015; Danso-Abbeam and Baiyegunhi, 2017; Djokoto et al., 2016). A factor found to negatively influence the chances of adoption of practices is the age of the farm, indicating that farmers with older farms are less likely to adopt new practices (Nkamleu et al., 2007; Baffoe-Asare et al., 2013). The effect of farm-size remains uncertain, where Aidoo and Fromm (2017) found a negative relationship between farm size and practice adoption, and Danso-Abbeam and Baiyegunhi (2017) and Nkamleu et al. (2007) found a positive relationship. These results come from studies using statistical analyses. However, there may also be contextual and personal factors that affect the decision to adopt a practice. For example, the adoption of a practice may conflict with social norms, other expenditures are prioritized such as school fees or food, or adopting a practice may require too much labor. Investments may also be considered too risky, and adoption of a practice depends largely on the expectation that the farmer has from this practice (Waarts et al. 2019).

3.2 Farming practices explaining yield levels in cocoa production

The CocoaAction framework contains the most commonly recommended practices by companies and other actors, which are called Good Agricultural Practices (GAPs). The five GAPs in the CocoaAction framework are pruning management, pest and disease management, weeding management, shade management and harvest management. In addition, the CocoaAction framework focusses on fertilizer application and tree density. This section provides a literature overview on the practices, fertilizer use, and tree density. An overview of all sources is provided in appendix A.

3.2.1 Pruning management

Pruning is said to bring many advantages including maintaining the coca trees' shape suitable for harvesting, maximizing the nutrient distribution towards the fruit pods, and the prevention and mitigation of pests and disease (Vos et al., 2003). Pruning has also been found to have a significant effect on yield, because it improves photosynthesis activity, facilitates pollination of flowers and strengthens the formation and growth of new leaves and pods (Uchoi et al., 2018; Zhang and Motilal, 2016).

3.2.2 Pest and disease management

In Ivory Coast, yield loss in cocoa due to pests and disease is estimated at 10 to 30% (Duguma et al., 2001). Some of the most common pests and diseases in cocoa production are swollen shoot virus disease, capsid bugs, black pod disease (phytophthora pod rot), and mirids (Wessel and Wessel-Quist; Dormon et al., 2007). There are many methods to mitigate their effects, including the reduction of humidity levels, regular weeding, regular pruning, regular harvesting, removal of diseased pods, growing cocoa in an agroforestry system, and the application of fungicides and pesticides (Opoku et al., 2000; Bisseleua et al., 2013; Guest, 2007). The application of pesticides and fungicides is widely promoted by organizations such as the WCF and CCC (WCF, 2016a; CCC, n.d.).

However, even though agrochemical pest and disease management is promoted as a GAP, there are concerns regarding its effect on human and environmental health, and its use has caveats. One caveat comes with the application of copper-based fungicides, which can be applied to tackle black pod disease. After four years of applying these fungicides, earthworm casting (feces) reduces significantly, which is important for nutrient cycling in the soil (Norgrove, 2007). Another caveat is that synthetic pesticides can cause resistance in pests and destroy natural enemies. This in turn can result in resurgence or secondary pest outbreaks (Dormon et al., 2007). To minimize the negative effects of pesticides and fungicides, there is an increased focus on the adoption of Integrated Pest Management (IPM). With IPM, pest control methods are combined such that it minimizes risks to human and environmental health (ICCO, 2015; RA, 2017). However, the application of IPM with non-synthetic pesticides can be labor-intensive and not readily available to farmers (Dormon et al., 2007).

3.2.3 Weeding management

As mentioned in the above section, weeding helps with the mitigation of pests and diseases (Opoku et al. 2000; Aneani and Ofori-Frimpong, 2013). Weeding also makes that the nutrients necessary for cocoa production remain available in the soil for the cocoa trees (Ofori-Frimpong et al., 2008). Lastly, weeding is said to reduce the competition for water, and to be especially important for younger trees that do not have crowns large enough to provide shade that prevents weeds from growing (WCF, 2016a).

3.2.4 Shade management

Cocoa is an understory plant and can be grown with shade trees, ranging from planted timber or fruit trees up to a highly diverse agroforestry system (Niether et al., 2018; Tscharntke et al., 2011). Growing cocoa with other trees comes as a trade-off. Some of the advantages of growing cocoa with shade trees are the buffering of climatic conditions, a higher soil organic matter content, improved filtration of water, and natural pest and disease control (Niether et al., 2018; Bisseleua et al., 2013; Tscharntke et al., 2011). Also, growing cocoa in a system of agroforestry is considered important for biodiversity conservation and the protection of pristine habitats (Tscharntke et al., 2011). However, even though young cocoa trees grow well in an understory, older trees will give lower yields due to competition for light and rainfall, and due to an increased humidity favoring pests and diseases (Gockowski et al., 2013; Koko et al., 2013; Niether et al., 2018; Tscharntke et al. 2011). A solution to this trade-off may be to increasingly prune shade trees as the cocoa trees become older, in order to allow for more light and rainfall to enter, and to reduce humidity (Tscharntke et al., 2011; Niether et al., 2018). To balance the interests of yield and biodiversity, for the shade management GAP, 12-18 shade trees per hectare are recommended (WCF, 2016a).

3.2.5 Harvest management

Harvest of cocoa pods should occur when the pods are mature. When they are harvested too early, the quality will be less as well as the weight and thus the income for the farmer (WCF, 2016a). When the pods are harvested too late, and become overripe, the pods have a higher chance of becoming diseased, and potentially spreading the disease in the tree (WCF, 2016a; Guest, 2007; Opoku et al. 2000). Good harvest of cocoa pods also includes a proper pod cutting practice that does not leave scars on the tree (WCF, 2016a).

3.2.6 Fertilizer application

Aging plots where cocoa is cultivated become depleted of vital nutrients, when no fertilizer is applied as a replacement (Aikpokpodion, 2010). Fertilizer is therefore often mentioned as an important input for increasing cocoa yield (Aikpokpodion, 2010; Edwin and Masters, 2005; Uribe et al., 2001). Fertilizer can be both organic, in the form of mulch, crop residue or compost, or inorganic (synthetic) (WCF, 2016a). In monoculture, organic fertilizer is usually not sufficient to compensate for the depletion of nutrients (Aikpokpodion, 2010). With (in)organic fertilizer application, it should be taken into account that its effects are delayed and that it takes several years to get significant increases in yield. Also the timing of fertilizer application is important, and it is best applied at the start of each rainy season (Uribe et al., 2001).

3.2.7 Tree density

Even though tree density strictly speaking is not a farming practice, it is still considered here because it has been found to affect yield. Little research has been conducted on the planting density of cocoa for Ivory Coast specifically. However, a study on planting density in Brazil showed that higher planting densities of 2500 cocoa trees per hectare can maximise yields, although this is expected to decline rapidly because it will also result in more witch’s broom (Souza et al., 2009). A study conducted in Malaysia found that the optimal tree density depends largely on the variety of cocoa tree planted (Lockwood and Yin, 1996). Tree densities also differ greatly throughout the world’s cocoa belt, with planting densities of 556 to 1848 trees/ha found in Ivory Coast, 272 to 2598 trees/ha in Indonesia, and 276 to 3626 trees/ha in Ghana (Daymond et al., 2018). The recommended tree density for West Africa is 800 – 1500 trees/ha (WCF, 2016a)

3.3 The effect of weather on cocoa yield

In research examining the relationship between the growth of cocoa trees and climatic conditions, several factors have been described to be of most influence on yield levels. The most important of these is drought or periodic water shortage (Schroth et al., 2016; Laderach et al., 2013; Zuidema et al., 2005). Drought can be expressed in the number of consecutive months with less than 100 mm of rainfall, indicating the length of the dry season (Schroth et al., 2016), or in the amount of rainfall during the driest months (Zuidema et al., 2005). These dry periods reduce the leaf area index (LAI), resulting in lower bean yields after the dry season (Zuidema et al., 2005). The soil type can play an important role in the effects of the dry season on yields, where clayey and sandy soils have lower water retention capacity than loamy soil, exacerbating the effect of drought (Zuidema et al., 2005). Besides drought, although less influential, the temperature is described as an influential factor for cocoa production (Lawal & Omonona, 2014; Laderach et al., 2013). Temperature can be expressed in the maximum temperature of that year (Schroth et al., 2016). The role of temperature is ambiguous. Regressions of yield against temperature have resulted in a positive correlation, indicating that higher temperatures could boost pod production (Lawal and Omonona, 2014). However, another study describes the indirect effect of temperature on cocoa, where temperature increases the potential evapotranspiration and thereby decreases the water availability to the trees (Laderach et al., 2013). This would thus indicate a negative correlation between yield and temperature. It seems that the effect of temperature mostly depends on whether it is compensated with sufficient rainfall. An increase in temperature may amplify the effects of drought and thus decrease yields, but in combination with sufficient rainfall it may increase yields. In summary, the most important climatic conditions affecting the growth of cocoa trees are drought and temperature. These can be captured in the amount of rainfall during the driest months, the number of consecutive months with less than 100 mm of rainfall, and the maximum yearly temperature.

3.4 Conceptual framework

The conceptual framework (figure 3) summarizes important aspects of Ivorian cocoa production on the country-level scale. The aim of the framework is to create a better understanding of what factors influence cocoa production and hence income from cocoa for cocoa farmers. Central in the framework is the theory of change that shapes the interventions by companies and the CocoaAction platform. These interventions focus on increasing farmers' knowledge on GAP adoption and input use, and providing them with access to these inputs. This improved knowledge and access would then result in increased input use and GAP adoption, thereby increasing yields and eventually income from cocoa. Income from cocoa would result in a larger net household income, and hence better access to inputs, creating an overall more productive and financially sustainable farm. Inputs consist of all those necessary for GAP adoption and fertilizer application, such as access to labour in the form of hired gangs for spraying and/or pruning, seedlings for shade trees, fertilizer, pesticides and herbicides.

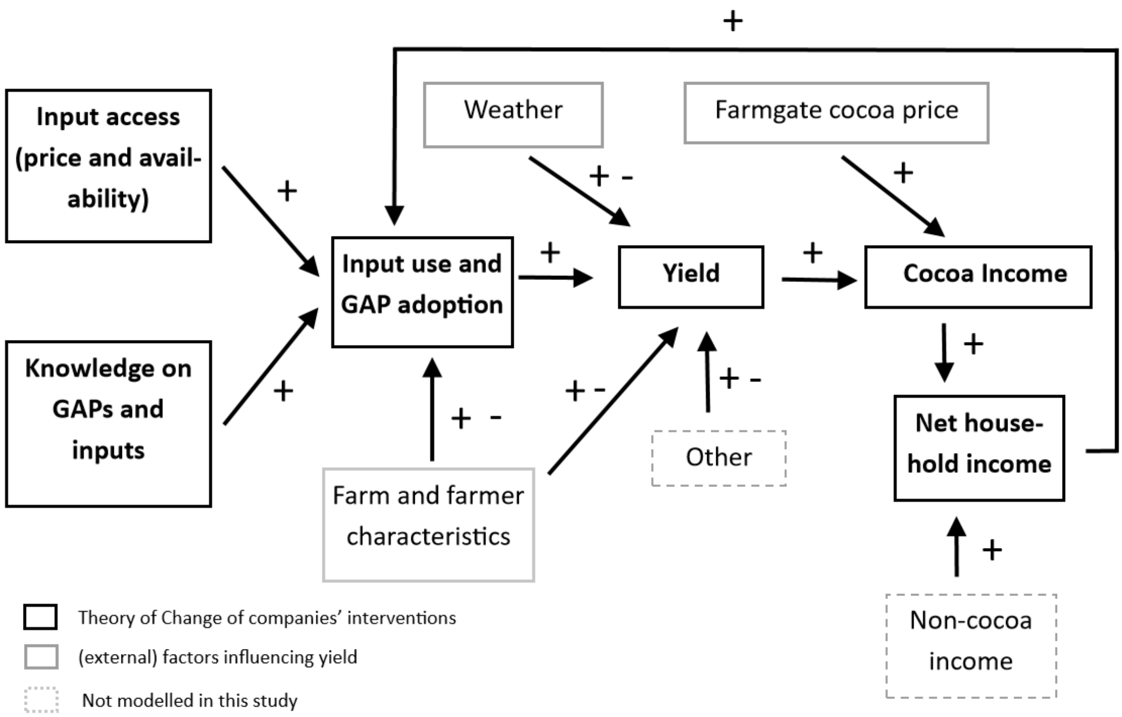

Figure 3 Conceptual framework: companies' interventions and external factors explaining cocoa production and household incomes for Ivorian cocoa farmers

However, there are external factors that play a role in the actual improvement of farmer incomes. Three of these factors are described in the conceptual framework and applied in this study, based on the availability of data and expected influence. First of all, the weather affects production levels. A severe drought can decrease yields, whereas the effect of temperature remains ambiguous. Secondly, there are both farm and farmer characteristics that may be related to the use of inputs and adoption of practices, as well as to yield. Farm and farmer characteristics included in this study that are expected to positively affect gap adoption, input use and yield are the age of the household head, whether the farmer received training, whether the farmer is male, and the number of years the cooperative that the farmer is a member of has been certified. More uncertain are the effects of farm size, the differences between districts, and the tree density. Expected to negatively affect yield is the age of the farm, whereas its effect on GAP adoption and input use remains ambiguous. The effect of farm size also remains uncertain. There are also farmer and farm characteristics expected to influence GAP adoption, input use and yield, that are not included in this study. These are depicted in the conceptual framework as 'other'. These are, amongst others, whether the farmer is in a cooperative which cannot be examined because all farmers in this study are in a cooperative, and the number of extension visits to the farm. The fourth external factor in the model is the cocoa farmgate price. The cocoa farmgate price determines the income from cocoa given a certain amount of cocoa produced. Even though it is expected that Ivorian cocoa production may influence the world market price, this market price also depends on the expected production from other cocoa-producing countries and global demand. The world market price, in turn, largely determines the farmgate cocoa price set by the CCC. Therefore, the cocoa farmgate price is here considered to be external, especially from a farmer's perspective. The last external factor included in the conceptual framework is the aspect that the household income of the farmer does not solely depend on cocoa. Households also have other sources of income, both on-farm and off-farm.

Chapter 4 Data and Methodology

4.1 Data

There are three types of data used in this research: farm-level data, data on weather conditions, and farm-gate cocoa prices. This section describes in more detail the data that is used in this research.

The main dataset is farm-level data that has been collected alongside annual UTZ audits from 2016 up to and including 2019. Sample sizes were correspondingly 283, 1274, 1156 and 1503 farmers. The data-collection is commissioned by cocoa-trader Cargill and chocolate manufacturers Nestlé, Hershey, and Mars. A questionnaire was used, as well as on-farm observations. When a farmer is managing multiple plots, both the questionnaire and on-farm observations were taken on the largest plot the farmer owns. The framework for the data collection has been developed according to the CocoaAction data-collection criteria, developed by the World Cocoa Foundation (WCF, 2016a). Each year a different set of farmers were interviewed, which were randomly selected from cooperatives that were selected by the companies. The dataset includes information on farmer characteristics such as age, sex and whether the farmer received training on agricultural practices. The dataset also includes information on farm characteristics including how long the cooperative the farmer is member of has been certified, how long cocoa has been grown on the plot, the yields, the district the farm is situated in and the tree density. Yield smaller than 100 kg/ha or larger than 1800 kg/ha have been removed from the dataset because of agronomic unfeasibility based on Aneani and Ofori-Frimpong (2013). Tree densities larger than 1850 trees/ha have also been removed because of unfeasibility (Daymond et al., 2018)

The dataset describes which agricultural practices have been adopted, including the five GAPs, i.e. pruning management, pests and disease management, weeding management, shade management and harvest management. GAP adoption is binary, determined by CocoaAction criteria and thresholds, and based on enumerator evaluation at three observation points on the farm (WCF, 2016a). Some GAPs are expected to influence the yield in the year of data collection. These are pruning, pest and disease management, and weeding. Pruning is expected to affect yield due to its mitigating effects on pests and disease control, and because proper pruning is found to increase the number of pods within the same season (Uchoi et al. 2018). Pest and disease management is also expected to immediately affect yields, because for this practice to be classified as adopted, there must be proof of good pest and disease control (WCF, 2016a). Weeding is expected to directly affect yield because on a properly weeded farm the cocoa trees will have less competition for nutrients and water (Ofori-Frimpong et al., 2008; WCF, 2016b). However, the other two practices are not expected to affect yield in the year of data collection. For the practice of shade management, this is because shade management will also be classified as adopted when the farmer has recently planted shade trees which will not yet provide any shade. For the practice of harvest management this is because it is largely related to whether the harvest left scars on the tree and whether there are overripe pods on the trees, which are not expected to affect the yield of the past 12 months. Besides the GAPs, fertilizer use is reported by the farmer. Fertilizer use in the past year is not expected to explain yield at the time of data collection because it effects on yield require several years of application. Also cocoa production and farm size are reported by the farmer, and used to calculate yield.

Data on temperature and rainfall is retrieved from World Weather Online, who provide open-access historical weather data from all over the world (WWW, 2020). Weather data on regional level is being used, which is more local than the district the farmer is situated in. Lastly, data on the yearly set farm-gate cocoa prices are collected from De Bassompierre et al. (2019) and Fountain and Huetz-Adams (2015). The descriptive statistics can be found in table 1. The descriptive statistics per year can be found in appendix B.

Table 1 Descriptive statistics

Variable		Description	Mean	S.D.
Farmers characteristics				
Age	*Farmerage*	Age of the farmer in years	45.42	12.32
Sex	*Sex*	1 = if farmer is male	0.89	0.31
Training	*Training*	1 = if farmer received training on practices in the past 12 months	0.89	0.32
Farm characteristics				
Plot size	*Plotsize*	The size of the plot in hectares	3.31	3.04
Plot age	*Plotage*	The age of the plot in years	22.77	11.64
District	-	1 = if the farmer is in a specific district	-	-
Years coop certified	*Yearscoopcertified*	Number of years how long the coop has been UTZ certified	4.93	1.65
Tree density	*Treedensity*	The density of trees in 1000 trees/ha	1.16	0.36
Farming practices				
Tree pruning	*GAP1Pruning*	1 = if the farmer has pruned sufficiently	0.41	0.49
Pests and disease management	*GAP2Pests*	1 = if the farmer has made sufficient effort to address pests and diseases	0.83	0.37
Weed management	*GAP3Weeds*	1 = if farmer has weeded sufficiently	0.56	0.50
Shade management	*GAP4Shade*	1 = if farmer has sufficient shade trees and/or shows proof of newly planted shade trees	0.40	0.49
Harvest management	*GAP5Harvest*	1 = if the farmer harvests correctly	0.70	0.46
Fertilizer	*Fertilizer*	1 = if the farmer uses fertilizer	0.40	0.50
Weather				
Rainfall	*Rainfall*	The amount of rainfall during the driest months in mm. per region	45.73	55.81
Temperature	*Temperature*	The highest temperature reached that year in Celsius degrees per region	35.37	2.38
Cocoa price				
Price	*Price*	The yearly fixed farmgate cocoa price in 1000 CFA/kg, during the year of data collection	0.86	0.17
Lagged price	*Laggedprice*	The yearly fixed farmgate cocoa price in 1000 CFA/kg, in the year prior to data collection	0.91	0.17
Yield				
Yield	*Yield*	Production of cocoa in t/ha[1]	0.59	0.26

4.2 Methodology

4.2.1 Determining the role of cocoa farmgate prices in the adoption of Good Agricultural Practices

Based on the conceptual framework discussed in chapter 3, for each Good Agricultural Practice (GAP) *i* (i=1 for tree pruning, =2 for pests and disease management, =3 for weed management, =4 for shade management, =5 for harvest management, =6 for fertilizer usage), a model is specified to explain adoption by farmer *k* in year *t*:

$$GAP_{i,kt} = \beta_0 + \beta_1 X_{kt} + \beta_2 V_{kt} + \beta_3 PRICE_{t-1} + \varepsilon_{i,kt} \qquad (1)$$

Although not by definition a GAP, fertilizer is included because it is an agricultural practice that is expected to increase yields. In the model X_{kt} is a vector of farmer characteristics, including the farmer's age, sex and whether he or she has received training on practices. V_{kt} is a vector of farm characteristics, including the plot size, plot age, the district where the farm is located, the number of years the cooperative that the farmer is a member of has been certified, and the tree density. $PRICE_{t-1}$ is the farmgate cocoa price that the farmer received in the previous year. $\varepsilon_{i,kt}$ is the error term.

Each of the GAPs takes a value of 1 if a practice is adopted, and a value of 0 if it is not. Due to this binary nature of the dependent variables, a probit model can be applied to estimate the relationship between adoption and a set of independent variables. However, the adoption of agricultural practices has been found in previous studies to be simultaneous decisions, where farmers consider (technological) practices as a bundle. The farmers then choose the bundle that maximizes their expected utility. It is thus commonly argued that the adoption of practices should be treated as simultaneous interdependent decisions (Kassie et al., 2013). A model that allows for this interdependency is the multivariate probit (MVP) regression. This technique allows for simultaneous modelling of the adoption decisions, and for the error terms to be freely correlated (Kassie et al., 2013). When simultaneity in adoption is indeed the case, a MVP will produce more efficient coefficient estimates then when a set of separate estimated probits is used (Mittal and Mehar, 2016).

To decide whether to use separate probit regressions or a MVP regression, the models are being compared for their suitability in this study. Both the separate probits and a MVP regression have been run. The first step is to look at the likelihood ratio test on the error terms after the MVP, to determine if running an MVP provides any added value. The test result, (chi2(15) = 211.276, Prob > chi2 = 0.000), rejects the null hypothesis of independence of the error terms of the GAPs. This shows that the adoption of the different practices have unobserved and/or unmeasured variables in common, and that using this method would result in more efficient coefficient estimates. Another way to compare the models is by looking at the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) to determine the goodness of fit, where lower AIC and BIC values are preferred. The separate probits combined have AIC and BIC values of correspondingly 24475 and 25027, and the multivariate probit model has AIC and BIC values of correspondingly 24573 and 25216. The AIC and BIC values are thus slightly lower for the separate probits, although this difference is very small. The likelihood-ratio test points towards using an MVP, whereas the AIC and BIC values point towards using separate probits. However, there are several reasons why separate probits are believed to be more appropriate to use in this study. First, when running a MVP it is difficult to obtain the marginal effects, which is crucial for a better understanding of what explains the adoption of practices. Second, the separate models are better at predicting whether a farmer adopted a practice than the multivariate probit. This is examined by subtracting the percentage of farmers who adopted a practice (baseline) from the percentage of correct predictions (Count R-squared). The result is the percentage of correct predictions compared to a model without any explanatory variables but only a constant term (table 2). The results show that for all practices, separate probits are better at predicting adoption than the MVP model. For some practices in the multivariate model, the model even performs worse than a model with only a constant. Thirdly, tree density has a proportion of 18.41% missing values and has been found to be solely significant for the practice of weeding. Adding tree density in the MVP reduces the number of observations for all practices. Estimating separate probits allows for only adding tree density to the probit for weeding, resulting in a smaller loss of observations. In summary, even though the adoption of different practices have some unobserved and/or unmeasured variables in common, it is believed that the advantages of using separate probits outweigh the disadvantages. Therefore, this study continues with a set of separate probit regressions to estimate the relationship between GAP adoption and a set of independent variables.

Table 2 Count R-squared compared to baseline for multivariate probit and separate probits

Practice	Multivariate probit	Separate probits
Pruning	+18.1%	+24.2%
Pest and disease management	-13.3%	0%
Weed management	-9.7%	+4.5%
Shade management	+19.2%	+21.2%
Harvest management	-9.3%	+0.4%
Fertilizer application	+19.77%	+19.65

Results from probit regressions are intuitively difficult to grasp: the coefficients give the change in z-score for a one-unit change in the independent variable. Therefore, by looking at merely the coefficients, one can only interpret the direction and significance of the independent variable. To understand the quantitative effects on practice adoption, it is necessary to derive the marginal effects. Derived in this study are the average marginal effects (AME). AMEs are obtained by calculating the marginal effects at the average values of the explanatory variables.

4.2.2 Effects of GAP adoption and weather on productivity levels of Ivorian cocoa farmers

To understand the influence of GAP adoption and weather events on yields, the following model is specified to explain yields by farmer *k* in year *t*:

$$Yield_{kt} = \beta_0 + \beta_1 X_{kt} + \beta_2 V_{kt} + \beta_3 Rain_t + \beta_4 Temp_t + \sum_{i=1}^{I-1} \gamma_i GAP_{i,kt} + \sum_{t=1}^{T-1} \delta_t Year_t + \varepsilon_{kt} \quad (2)$$

As in the previous model explaining GAP adoption, X_{kt} is a vector of farmer characteristics, including the farmer's age, sex and whether he or she has received training on practices. V_{kt} is a vector for farm characteristics, including the plot size, plot age, the district the farm is situated and the tree density. $Rain_t$ is a variable for the rainfall during the driest months and $Temp_t$ is the highest temperature reached in the past year. $GAP_{i,kt}$ is a bundle of dummy variables for the three Good Agricultural Practices (GAP) i (i=1 Tree pruning, =2 for Pests and disease management, =3 for Weed management) that are expected to affect yield in the shorter term. $YEAR_t$ is a bundle of dummy variables for the year the data is collected, where 2018 is the reference year, and ε_{kt} is the error term.

A problem regularly faced in literature on adoption of practices and its effects on productivity, is that the adoption decision is commonly correlated with other factors affecting productivity that are not captured in the data (Doss et al., 2016). As a result, practice adoption has been found to be endogenous in previous studies (Arslan et al., 2017; Doss et al., 2016). Therefore, before running a regression for yield, it is important to check if the adoption of a practice is not endogenous. When endogeneity is the case, ordinary least squares (OLS) estimates will be inconsistent and it is better to estimate the parameters using an instrumental variable technique. To check for endogeneity, the Durbin-Wu-Hausman (DWH) specification test is used for the three practices in this regression: pruning, pest and disease management, and weed management. The null hypothesis is that of exogeneity, where an OLS estimator of the same equation would create consistent estimates. This DWH specification test requires instruments that are both valid and strong. An instrument is valid when it is uncorrelated with the equation's error term and thus exogenous. This means that the instrument should meet the 'exclusion restriction', indicating that it only affects yield through practice adoption and not directly or through an unobserved variable. A valid instrument should also not be influenced by the dependent variable itself (Verbeek, 2017, p.153). An instrument is strong, or relevant, when it has a nonzero correlation with the endogenous variable, conditional upon the other variables in the equation. A simple way to test whether the instrument is strong is by running the first-stage regression, and following the rule of thumb by Stock and Watson (2017, chapter 12) that the F-statistic of the first-stage regression is ideally larger than 10. The results from the DWH-test are presented in the results section.

4.2.3 Determining the difference between current incomes and a living income for Ivorian cocoa farmers

To understand whether the difference between current incomes and a living income can mostly be attributed to yields or to cocoa farmgate prices, the following model is specified to explain the difference between the net income and the living income benchmark for farmer *k* in year *t*:

$$\Delta Income_{kt} = \beta_0 + \beta_1 Yield_{kt} + \beta_2 Price_t + \beta_3 X_{kt} + \varepsilon_{kt} \tag{3}$$

In the model, $Yield_{kt}$ is the yield of the farmer, $Price_t$ is the farmgate cocoa price, X_{kt} is a vector of farmer characteristics including the farmer's age and sex, and $\varepsilon_{i,kt}$ is the error term. This model is estimated using the Ordinary Least Squares (OLS) regression. Below follows a description of how the farmer's net income and living benchmark are determined.

Several studies have been conducted by NGOs to determine the income of cocoa farmers. Estimates are very diverse, ranging from 0.50 USD per person per day (Fountain and Huetz-Adams, 2015) up to 1.17 USD per person per day (Balineau et al., 2016). This depends greatly on the methodology used. For example, it depends on whether in-kind value of household production consumed at home is included in the calculations or not. It also depends on how exact non-cocoa incomes are determined and included. The method to determine the net income used in this study is based on a study by Tyszler et al. (2019). To determine the household income, this method requires:

- The total cocoa production in kg/year per household;
- the total value of production by multiplying it with the received price in CFA/kg;
- the annual input expenses in CFA/year on fertilizer, herbicides, pesticides and fungicides;
- the annual hired labor expenses in CFA/year for many activities including fertilizer application, weeding, pruning and harvesting;
- the total non-cocoa income from the household.

The net household income is calculated by subtracting annual input costs and hired labor costs from the total value of production. The total household income is then determined by correcting this for non-cocoa incomes. Unfortunately, in the CocoaAction dataset there is no information on the annual input expenses, annual labour expenses and non-cocoa income. Therefore, these data will be approximated based on numbers found in the study by Tyszler et al. (2019). This study found the total input costs, including physical inputs and labor costs, to be 89 USD per farm on average, with an average farm size of 3.5 hectares. This comes down to 25.43 USD, or 14,668 CFA per hectare. Tyszler et al. (2019) further found that on average, the income from cocoa forms 66% of total household income. They do not include in-kind value of crop production in their main calculations, but have found this to be worth 650 USD or 374,927 CFA per year.

The benchmark used in this study is based on the only current living income benchmark available for cocoa farmers in Ivory Coast, developed in 2018 (CIRES, 2018). The living income found in this study is CFA 3,144,672 CFA/year for a family of two adults and four children. This covers costs for decent food, decent housing, non-food and non-housing costs and an additional 5 percent for sustainability and emergencies. It does not include in-kind values of production (CIRES, 2018). The study by Tyszler et al. (2019) found a slightly higher average household size of 3.5 adults and 3.5 children. They have therefore adapted the living income benchmark to 3,759,281 CFA/year or 6503.56 USD/year. Since the analysis in is thesis uses data on input expenses, annual labour expenses and non-cocoa income by Tyszler et al (2019), it will also use the adapted living income benchmark. To compare this living income benchmark to the net household incomes found in this study, it is necessary to convert the incomes found with the Consumer Price Index (CPI) (Tyszler et al., 2019). The CPI measures changes in levels of prices over time compared to a baseline, within a country (Investopedia, 2020). The indexes for the time that the CocoaAction data has been collected are presented in appendix C. Since data was collected between August and December, the average of the third and fourth quartile is being used. This average is then compared to the index for the time in which the benchmark data collection took place, which was in the second quarter of 2018.

Chapter 5 Results and discussion

5.1 The role of cocoa farmgate prices in the adoption of Good Agricultural Practices

The first objective of this study is to understand the role of cocoa farmgate prices in the adoption of Good Agricultural Practices (GAP). This has been analyzed with a set of probit regressions to estimate the relationship between GAP adoption and a set of independent variables including the farmgate price from the previous year, as described in section 4.2.1. The marginal effects and corresponding standard errors of the independent variables can be found in table 3. The marginal effects for the *Laggedprice* are significant for all practices except shade management. On average, a price increase of 100 CFA/kg decreases the probability of adopting pruning by 6.1%, for pest and disease management it will decrease with 0.87%, for weed management it will increase with 2.8%, for harvest management it will decrease with 4.3%, and for fertilizer application increase with 1.4%. A price increase thus seems to have a positive effect on the adoption of some practices but on others it is rather the opposite. These effects are not very strong since the probabilities only change with a few percentage points. The results thus indicate that the chance of adopting an agricultural practice in the next year does not simply increase when a farmer receives a higher price. There are several possible explanations for this finding. First of all, at least a share of the farmers are likely to be present-biased when making decisions on investments into the farm. Farmers may overestimate their patience and discount future utility costs for purchasing necessary inputs for practice adoption. In the last period in which purchasing inputs is possible, they may not have the required resources anymore (Duflo et al., 2011). Secondly, a share of the farmers may be so-called ‘harvesters’, which give little attention to their farm and do not actively invest in their farm but solely harvest from it. This can be because the farmer focusses more on other income generating activities, or is a retiree (Tyszler et al., 2019). Thirdly, it may also simply be that the farmer prioritizes other expenses such as school fees or food. Fourthly, it may be that farmers consider the investments too risky, and that they do not expect the adoption to be worth the investment (Waarts et al., 2019). However, these four potential reasons for the small effect of a price increase on adoption rates do not explain a significant decrease in some of the adoption rates. An explanation could be that farmers see less of a need to change their production technique when they received a good price in the previous year and vice versa that they are more inclined to adopt when they received a low price the year before.

Table 3 Marginal effects of covariates on agricultural practice adoption (standard errors in parentheses)

Variable	Tree pruning	Pests and disease manage-ment	Weed management	Shade management	Harvest management	Fertilizer application
Cocoa price						
Lagged price	-0.606*** (0.047)	-0.087** (0.040)	0.280*** (0.056)	-0.020 (0.051)	-0.434*** (0.047)	0.141*** (0.052)
Farmers characteristics						
Age	-0.001 (0.001)	-0.002*** (0.001)	-0.001 (0.001)	0.001 (0.001)	-0.002*** (0.001)	-0.001* (0.001)
Sex	0.007 (0.027)	0.007 (0.021)	0.025 (0.031)	0.034 (0.028)	0.004 (0.025)	0.002 (0.028)
Training	0.058** (0.027)	0.056*** (0.019)	0.103*** (0.030)	0.134*** (0.028)	0.080*** (0.024)	0.066** (0.027)
Farm characteristics						
Plot size	-0.002 (0.003)	0.000 (0.002)	-0.006** (0.003)	0.005* (0.003)	0.000 (0.003)	0.003 (0.003)
Plot age	-0.003*** (0.001)	-0.002*** (0.001)	-0.004*** (0.001)	0.000 (0.001)	-0.002** (0.001)	-0.001 (0.000)
Years coop certified	0.015*** (0.005)	0.006 (0.004)	0.013** (0.006)	-0.005 (0.005)	0.004 (0.005)	0.004 (0.005)
Tree density	-	-	-0.060** (0.026)	-	-	-
District						
Bas-Sassandra	0.114*** (0.033)	-0.03 (0.027)	-0.082** (0.037)	0.096*** (0.034)	-0.022 (0.030)	0.178*** (0.033)
Comoe	0.036 (0.034)	-0.104*** (0.027)	-0.200*** (0.038)	0.105*** (0.035)	0.017 (0.032)	0.033 (0.035)
Goh-Djiboua	0.086*** (0.032)	-0.068*** (0.025)	-0.089** (0.036)	0.182*** (0.033)	0.004 (0.029)	0.132*** (0.032)
Lacs	0.129*** (0.046)	-0.048 (0.037)	-0.046 (0.053)	0.276*** (0.046)	0.190*** (0.048)	0.038 (0.047)
Montagnes	0.082** (0.032)	-0.042 (0.026)	-0.092** (0.036)	0.123*** (0.033)	-0.043 (0.030)	0.088*** (0.033)
Sassandra-Marahoue	0.082** (0.041)	0.015 (0.035)	-0.054 (0.047)	0.270*** (0.042)	0.081** (0.040)	0.050 (0.043)
Other	0.003 (0.063)	-0.185*** 0.044)	-0.364*** (0.075)	-0.139 (0.072)	-0.213*** (0.056)	-0.083 (0.068)
Lagunes (baseline)	-	-	-	-	-	-

Note: *** = significant at 1%, ** = significant at 5%, * = significant at 10%

For the farmer's characteristics, the results show that the *farmerage* has a significant negative relationship with the probability of adopting pest and disease management, harvest management and fertilizer application. It appears that younger farmers are more likely to adopt these practices than older farmers. This finding is not in line with the findings by Danso-Abbeam and Baiyegunhi (2017) and Baffoe-Asare et al. (2013) who find the opposite effect. Baffoe-Asare et al. (2013) ascribe this to the experience of older farmers, making them more likely to adopt. However, they also describe how older farmers may also be more conservative and risk adverse. This could potentially explain the negative relationship found in this study. *Training* has a significant positive relationship with all practices, which is in line with the finding by Baffoe-Asare et al. (2013). It should be noted that this result does not say anything about the longterm-effect of training on practice. For the farm characteristics, *plotsize* is negatively related to weed management and positively related to shade management. This indicates that farmers with larger farms are less likely to weed (the majority of) their farm but more likely to have sufficient shade trees (planted). This ambiguous effect is also found in the literature where Danso-Abbeam and Baiyegunhi (2017) and Nkamleu et al. (2007) found a positive relationship, and Aidoo and Fromm (2015) found a negative relationship between farm size and practice adoption. *Plotage* has a negative significant relationship with all practices except shade management and fertilizer application. This is in line with the findings by Nkamleu et al. (2007) and Baffoe-Asare et al. (2013), who also find a negative relationship between farm age and practice adoption. This could be explained by the effect that the 'forest rent' decreases with the age of the plot, and thereby it loses the advantages of a fertile soil and low pressure from weeds, diseases and pests (Schroth and Ruf, 2014). In that sense, for a farmer with a younger plot, it is easier to meet the criteria for having 'adopted' a farming practice. *Yearscoopcertified* is positively significant related to pruning and weeding. This indicates that farmers that are member of a coop that has been certified for a longer period have a higher chance of adopting these practices. The last farm characteristic, *treedensity,* is only significantly related to weeding, where a higher tree density corresponds to a lower probability of sufficient weeding. Lastly, there are a multitude of significant regional effects at district level.

5.2 Effects of GAP adoption and weather on productivity levels of Ivorian cocoa farmers

The second objective of this study is to understand to what extent GAP adoption and the weather explain productivity levels of Ivorian cocoa farmers. In this section it will first be explained whether practice adoption is found to be endogenous. Then the results from the final regression are presented.

For this research objective, *GAP1Pruning GAP2Pests* and *GAP3Weeds* are included and investigated for endogeneity, since only these practices are expected to have a short-term effect on yield. As described in the methodology, the DWH-test to test for endogeneity requires strong and valid instruments. The instruments being checked are the predicted values after the probit regression for the practices from the previous research objective, named *GAP1hat, GAP2hat* and *GAP3hat*. The results for practice adoption showed that *GAP1Pruning GAP2Pests* and *GAP3Weeds* are all significantly related to *training* and *laggedprice,* and *GAP3Weeds* also to *treedensity*. Therefore, *pruning, laggedprice and treedensity* will be left out for this research question, as they explain the predicted values. For the predicted values to be valid instruments they should only affect yield through practice adoption. *Laggedprice* and *training* are expected to meet this requirement. *Treedensity* however, has been found to be related to yield (Souza et al. 2009). *Treedensity* thus lowers the validity of the instrument *GAP3hat* slightly. To test whether the instruments are strong, the first-stage regressions are run for each of the three practices and their corresponding instrument. *GAP1hat* seems to be a strong instrument (it is significantly related to *GAP1Pruning* with a t-statistic of 2.67, P-value = 0.008 < 0.05, and an F-statistic of 13.81 which is >10). *GAP2hat* does not meet the criteria of F being larger than 10, but is still at the higher end (t-statistic = 3.37, P = 0.001 < 0.05, F = 8.94). *GAP3hat* also does not meet the criteria of F being larger than 10 but is also at the higher end (t-statistic = 4.30, P = 0.000 < 0.05, F = 7.51). Overall, *GAP1hat* and *GAP2hat* seem to be valid and sufficiently strong instruments, and *GAP3hat* seems to be sufficiently strong with a slight decrease in validity. Finally, the Durbin-Wu-Hausman test is run to test for each agricultural practice the null hypothesis that the practice is exogenous. For *GAP1Pruning*, the null hypothesis is not rejected (P = 0.089 > 0.05). It can thus be concluded that the practice of pruning is not endogenous. For *GAP2Pests*, the null hypothesis is rejected (P = 0.041 < 0.05). Also for *GAP3Weeds* the null hypothesis is rejected (P = 0.023 < 0.05). It can thus be concluded that both *GAP2Pests* and *GAP3Weeds* are endogenous, and should be instrumented. Therefore, the final regression for this research question is an instrumental two-stage least squares (2SLS) regression, where *GAP2Pests* and *GAP3Weeds* are instrumented with their predicted values *GAP2hat* and *GAP3hat* from the probit regressions. The results of this regression can be found in table 4.

Table 4 IV regression estimates of variables explaining yields (standard errors in parentheses)

Variable	Coefficient (SE), IV regression	Coefficient (SE), OLS regression
Agricultural practices		
Tree pruning	-0.028 (0.020)	0.001 (0.011)
Pest and disease management	-0.013 (0.293)	-0.004 (0.014)
Weed management	0.300 (0.155)*	0.030 (0.011)***
Farm characteristics		
Plot size	-0.005 (0.002)***	-0.007 (0.002)***
Plot age	-0.001 (0.001)	-0.002 (0.000)***
Tree density	-0.015 (0.030)	0.004 (0.015)
Farmer's characteristics		
Age	-0.001 (0.001)**	-0.001 (0.000)***
Sex	0.037 (0.020)*	0.035 (0.018)**
Weather		
Rainfall	0.000 (0.002)	-0.000 (0.004)
Temperature	0.006 (0.008)	-0.002 (0.004)
District		
Bas-Sassandra	0.140 (0.029)***	0.105 (0.021)***
Comoe	0.075 (0.032)**	0.025 (0.022)
Goh-Djiboua	0.011 (0.029)	-0.002 (0.022)
Lacs	0.018 (0.035)	0.011 (0.031)
Montagnes	0.112 (0.035)***	0.069 (0.023)***
Sassandra-Marahoue	0.029 (0.037)	0.007 (0.028)
Other	0.327 (0.069)***	0.238 (0.045)***
Lagunes (baseline)	-	-
Intercept	0.262	0.245

Note: *** = significant at 1%, ** = significant at 5%, * = significant at 10%

GAP3Weeds is significantly related to *yield* at a 10% level of significant in the IV-regression, although it has a very large coefficient, which could indicate that it is biased. This may be the result of the quality of the instrument *GAP3hat*. *GAP3Weeds* is also related to *yield* in the OLS regression at a 1% level of significance, where it has a more realistically sized coefficient. This coefficient for *GAP3Weeds* from the OLS regression is also expected to be biased because *GAP3Weeds* has been found to be endogenous. However, that both the IV and OLS coefficients are significant, indicate that there is evidence for a significant effect of *GAP3Weeds* on *yield*. For the other two practices, no significant effect on *yield* is found. That these latter two are not found to be significant is not in line with extensive research on these matters (Aneani and Ofori-Frimpong, 2013; Uchoi et al., 2018; Zhang and Motilal, 2016). There may be several explanations for this finding. First of all, the practices may only increase yield when they are adopted in combination with other practices. For example, pruning has the potential to increase yield by maximizing the nutrient distribution to the cocoa pods (Vos et al., 2003), but when there is insufficient or incorrect use of fertilizer, there may not be sufficient nutrients to achieve this positive effect of pruning. Secondly, the effects may be limited due to insufficient or incorrect application of practices in terms of quantity, quality and frequency of application

(Tyszler et al., 2019). For example, the farmer may have used pesticides, but did not use this at the correct time and in the minimum quantity required to be effective. Thus, that there has not been a significant effect found for *GAP1Pruning* and *GAP2Pests* does not necessarily mean that these practices do not have the potential to contribute to higher yields. There is an extensive body of research on the role of practices explaining cocoa yields that do show the effectiveness of these practices. Rather, the results show that the effect of the practices on yield is not straightforward and may depend on other factors.

For the temperature and rainfall, no significant relationship with yield has been found. For the temperature this might be explained by the fact that there was little variance over the years. The temperature is also described in literature as less influential than rainfall (Lawal & Omonona, 2014; Läderach et al., 2013). The finding for rainfall is surprising since the data contains larger variance and sufficient rainfall has been described in literature to be the most important climatic condition for yield (Schroth et al., 2016; Läderach et al., 2013; Zuidema et al., 2005). A possible explanation is that the data in this study does not contain information on the soil, which plays an important role in the effects of drought on cocoa yield, since clayey and sandy soils have lower water retention capacity than loamy soils (Zuidema et al., 2005). It is possible that this effect of the soil is captured by the regions, which may have different soil composition and conditions. The significant regional differences found may also capture other conditions of the farms and its context.

From the farm characteristics, only *plotsize* is significantly negatively related to yield, indicating that a larger plot size corresponds to lower yields. This is in line with the finding by Aneani and Ofori-Frimpong (2013). However, this decrease is rather minor with an extra hectare corresponding to a decrease in yield of 5 kg/ha. Interestingly, *plotage* is not significantly related to yield in the IV-regression, but it is in the OLS regression. A t-test for *plotage* where the farmers are grouped into having yields higher or lower than the average yield, shows that farmers with higher than average yields indeed have a lower mean *plotage* (df=3841, t=4.09, P= 0.000). This can be explained by a decrease in forest rent which decreases with age, thereby losing the advantages of a fertile soil and low pressure from weeds, diseases and pests (Schroth and Ruf, 2014).

From the farmer's characteristics, *Farmerage* is negatively related to yield, where an age increase of one year corresponds to a small decrease of 1 kg/ha. *Sex* is positively related to yield, indicating that men tend to achieve higher yields and on average produce 37 kg/ha more. However, this is only significant at a 10% significance level and should thus be interpreted with caution.

5.3 The difference between current incomes and a living income for Ivorian cocoa farmers

The third objective of this study is to determine the difference between current household incomes and a living income benchmark, and to understand whether this difference can mostly be attributed to yields or to cocoa farmgate prices. The average income, the living income benchmark, the difference between these (the gap to a living income) and the percentage of farmers making a living income are presented in table 5.

Table 5 Living income calculations

Year	Cocoa farmgate price (CFA/kg)	Average yield	Average income (USD)	Living income benchmark (USD)	Average gap to a living income (USD)	% farmers making a living income
2016	1000	581	4669	6391	1722	20.7
2017	1100	615	5697	6452	755	28.7
2018	700	585	3222	6509	3287	7.8
2019	750	580	3582	6430	2848	10.8
Average	*887.5*	*590*	*4293*	*6446*	*2153*	*16.3*

To understand more thoroughly whether the gap to a living income can mostly be attributed to yields or to cocoa farmgate prices, the variables *yield, price, farmerage* and *sex* are regressed on the gap to a living income. The regression results are presented in table 6.

Table 6 OLS regression estimates of variables explaining the gap to meeting the living income benchmark (standard errors in parentheses)

Variable	**Coefficient (SE), USD**
Yield	-5371 (325)***
Price	-5645 (484)***
Farmer age	-24 (7)***
Sex	-1004 (284)***
Intercept	12275 (626)***

Note: *** = significant at 1%, ** = significant at 5%, * = significant at 10%

The results in table 5 show that the percentage of farm households making a living income changed mostly with changing prices, as yield remained relatively stable. It further shows that over the years, on average 16.3% of the farmers make a living income, and the average income gap is 2153 USD. To my knowledge, the only studies extensively comparing Ivorian cocoa-farmer incomes to a living benchmark are that by Tyszler et al. (2019), and with a smaller sample size, Waarts et al. (2018). They found, respectively, 13% and around 25% of the households to earn a living income (Tyszler et al. 2019; Waarts et al. 2019). The average percentage found in this study thus lays between their findings. However, for the same period as the study by Tyszler et al. (2019), the 2016-2017 season, the percentage is 28.7%, which is more than double the 13% found by Tyszler et al. (2019). Since average values for costs per hectare, percentage of income from cocoa and household size used in this study are derived from Tyszler et al. (2019) this difference can be mostly attributed to differences in yield, where Tyszler et al. (2019) found an average yield of 349 kg/ha versus an average of 590 kg/ha in this study. Overall, comparing the results shows the importance of both farmgate cocoa prices and yield levels in determining whether a farmer meets the living income benchmark. This is confirmed by the regression results in table 6, which show that increasing yield with 100 kg/ha would decrease the difference between current incomes and a living income with 537.1 USD, whereas an increase in price of 100 CFA/kg would decrease this difference with 564.5 USD. Considering the average living income gap estimated is 2153 USD, yields would have to increase with around 400 kg/ha, price would have to increase with around 400 CFA/kg, or a combination of the both. The regression results further show that the gender and age of the farmer play a significant role in the size of the gap to a living income, where female and young farmers are less likely to meet the living income benchmark.

It is important to note that Tyszler et al. (2019) found plot size to be an important factor in making a living income, where 6.9% of households with a plot smaller than 4 ha meet the benchmark, versus 32.5% of households with a plot larger than 4 ha (Tyszler et al. 2019). A t-test for the living income gap and the farmers grouped into having a plot size smaller or larger than 4 ha, confirms that farmer with plots larger than 4 ha indeed have a smaller mean income gap (df=3575, t=28.15, P= 0.000). On average, they are even earning more than the living income benchmark. This finding is not surprising, as net household income is calculated using the plot size. More informative may be to look at average yield. A t-test for yield and the farmers again grouped into having a plot size smaller or larger than 4 ha, shows that farmers with larger plots have a lower mean yield (df=3575, t=2.94, P= 0.000). Also Tyszler et al. (2019) found lower yields for farms larger than 4 ha, which highlights the importance of the farm size in the ability for a household to make a living income. This might explain the expansion of farms by cutting down virgin forests (Schroth and Ruf, 2014). However, it should be noted that the living income benchmarks in this study are not tailored to the number of members in the household, whereas in the sample form Tyszler et al. (2019) farms with a plot size larger than 4 ha have a slightly higher number of members in the household. Overall it can thus be concluded that the cocoa farmgate price, yield, plot size, but also the gender and age of the farmer are important in explaining whether a cocoa-farming household is making a living income.

Chapter 6 Conclusion

6.1 Conclusions

Working in tandem with certification programs, cocoa traders, manufacturers, and retailers have started developing their own interventions to address the interrelated problems of low productivity, low incomes, and poverty in the cocoa sector. In these interventions, large attention is paid to the adoption of Good Agricultural Practices (GAPs), illustrating a continuous reliance on '*producing more on less land'* when it comes to creating a living income for smallholder cocoa farmers. In order to understand such interventions' potential in contributing to a living income for Ivorian cocoa farmers, this study investigated what determines whether a farmer adopts a practice and whether this practice will then result in more yield. It is also investigated to what extent yield and price increases may lower the gap to a living income.

It is found that a higher farmgate cocoa price does not simply lead to higher adoption rates of GAPs. Several potential explanations for this effect have been addressed. For example, a farmer may be present-biased, the farmer may considers investments too risky, may prioritize other expenditures such as school fees and food, or may simply not be interested in investing into the farm. For a deeper understanding of what drives decision making by Ivorian cocoa farmers, in-depth interviews or focus groups are recommended. The continuation of training on agricultural practices is also recommended as it found to improve adoption rates. When investigating the effect of adopting GAPs on yield, a significant effect was found solely for the practice of weeding. Again, potential explanations have been given. The other practices may only work in certain combinations, or may be limited to insufficient or incorrect application of practices. That no strong effects of GAPs on yield was found in this study, does thus not necessarily mean they are not effective. In fact, a large body of research has shown their effectiveness. Rather, it shows that increasing yield requires more precise farm management. Therefore it is recommended to continually investigate what combinations and more specific application of the GAPs will result in higher yields, considering the resource constraints that farmers face.

The results further showed that the majority of the Ivorian cocoa farming households in this study are not meeting the living income benchmark. The cocoa farmgate price, yield, plot size, but also the gender and age of the farmer were found to be important in explaining whether the living income benchmark is met. Focusing on yield for increasing farmer income is easily motivated by the fact that current yields are way below the yield potential (Adomako, 2007). However, considering the complexity of farmer decision making regarding GAPs, the uncertain role of these GAPs on yield, and the stability of yield over the years, increasing yield cannot solely be relied on for increasing incomes. Furthermore, even when yield would successfully increase, this might result in an oversupply driving down prices, especially if this occurs simultaneously with a drop in demand as was the case in the 2016/2017 season. One can also argue for increasing the farmgate cocoa price. The world cocoa price is currently determined by demand and supply, although the Ivorian government does set yearly minimum farmgate prices. The Ivorian government can only increase the minimum farm gate price to a certain extent, because a price too high might drive traders away from buying Ivorian cocoa. Some have argued for creating a 'cocoa OPEC' where governments of cocoa producing countries manage international supply and minimum cocoa prices (Koning and Jongeneel, 2006). It is the question however, whether the industry should and is willing to contribute and support such radical change. To add to the complexity of yields and prices, farm size limits the potential of interventions to create a living income. On a small farm, it may be nearly impossible to reach a living income, even when yield and cocoa prices would increase substantially (Waarts et al., 2019). Therefore, some argue for a large scale land reform (Waarts et al., 2019) or dual transmission (Oomes et al., 2016), where a share of cocoa farmers move out of cocoa farming, and the remaining farmers have larger farm sizes. Once again, it is a question of whether this is and should be coming from the industry. Therefore, it is likely that future interventions will remain focused on increasing yield through practice adoption. This research has demonstrated this to be complicated. In future interventions and research it is necessary to try out novel approaches and to increase knowledge on pathways to increase yield. During this process it is important to simultaneously improve knowledge on what drives farmer's decision making and to tailor interventions to their needs and aspirations, as well as the resource constraints they face.

6.2 Critical reflection

The data used in the study has a few limitations. First of all, a different sample was taken each year. This limits the extent to which adoption rates can be explained from price. It also limits the extent to which yield can be explained from practice adoption, as several practices are only expected to affect yield over multiple years. Secondly, the CocoaAction data collection framework, as developed by the World Cocoa Foundation, has slightly changed the definition for GAPs over the years. This is likely to affect results on practice adoption, as the variable for the lagged price may represent these changes. Thirdly, the farmers in this study were all member of a cooperative and the cooperatives were selected by the traders and manufacturers. As a result, the sample in this study might not be representative for the population of Ivorian cocoa farmers, limiting the extent to which the results found in this study can be extrapolated.

The methodologies used in this study also have limitations. Examining what drives practice adoption using separate probit estimations for each practice, ignores the fact that one adoption decision may affect others and vice versa. Secondly, two practices were found to be endogenous in explaining yield. Even though instrumental variables were used with proper strength and validity, a biased result was found for one practice. This shows the difficulty in finding or developing good instrumental variables. Thirdly, in regressing the (instrumented) practices on yield, no interaction affects were addressed. Lastly, the methodology for calculating the farmer income is rough and based on findings in other studies. The costs per hectare, share of cocoa income to total income and living income benchmark were assumed the same for all farmers. Also, even though comparing a farmers income to a living income benchmark is crucial for setting policy, it can be argued to be a suboptimal way of determining whether farmers live in poverty. In agricultural populations, income is commonly understated for several reasons: a lack of clear wages and salaries, poor-record keeping, a high diversity of income sources by household members, reluctance to report illegally earned income, the exclusion of how belongings have risen in value and the exclusion of in-kind value of food produced and consumed by the household. Other methods to measure poverty are to look at the expenditures by the household and its wealth and assets (Bymolt et al., 2018).

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Appendices

Appendix A. Literature overview

Table A1. Literature overview farming practices and yield

Author(s)	**Country**	**Type of study**	**Factors influencing yield**
Guest (2007)	-	Literature review	Pathogens causing black pod disease and stem cankers result in yield losses. They can be mitigated through pruning, shade management, leaf mulching, regular and complete harvesting, sanitation and pod case disposal, fertilizer application and fungicide use.
Koko et al. (2013)	Ivory Coast	On-farm trial + statistical analyses	Intercropping with fruit trees can lower cocoa yields due to competition for light and cocoa and fruit trees should thus not be planted too close to each other.
Uribe et al. (2001)	Colombia	On-farm trial + statistical analyses	Proper fertilizer management improves soil fertility and cocoa yields. Especially sunlight-exposed cocoa plantations need sufficient fertilizer. Rainfall distribution patterns should be a determinant of fertilizer application timing.
Norgrove (2017)	Cameroon	On-farm trials + statistical analyses	The use of copper based fungicides to tackle Black pod disease increases yields, but after four years it's use reduces surface casting by earthworms. This casting is important for nutrient cycling.
Bisseleua et al (2013)	Cameroon	On-farm data collection + statistical analyses	A high proportion of exotic shade-tree species results in low maintenance of forest-based beneficial fauna for mitigating pest damages. A greater diversity of indigenous shade trees leads to higher numbers of natural enemies to pests.
Gockowski et al. (2013)	Ghana	Secondary data from cocoa research station + primary data on input prices, labour estimates and expert interviews.	Planting cocoa under shade trees brings economic and environmental benefits but decreases yields.
Dormon et al. (2007)	Ghana	On-farm trial + statistical analyses	Synthetic pesticides may affect human and environmental health. The environmentally friendly alternative of Integrated Pest Management improves cocoa yields compared to little or no use of synthetic pesticides.

Opoku et al. (2000)	Ghana	Literature review.	For effective management of black pod disease, there is a need for: reducing humidity and increasing aeration through regular weeding, decreasing shade, removal of chupons, planting at recommended spacing, and draining stagnant waters. Other measures are regular harvesting, removal of diseased pods, and fungicide application.
Aikpokpodion (2010)	Nigeria	On-farm soil, foliage and bean sampling + laboratory research	Old cocoa soils often lack vital nutrients due to continuous nutrient mining without replacement. Leaf litter is not sufficient to replace lost nutrients. There is a need to adopt the use of inorganic fertilizer.
Aneani and Ofori-Frimpong (2013)	Ghana	Farmer surveys + statistical analyses	Factors influencing yield are frequent spraying of fungicides and pesticides, frequent weeding, the type of cocoa variety, the area of the farm and intercropping to control diseases.
Edwin and Masters (2005)	Ghana	Farmer surveys and literature review + statistical analyses	Newer varieties of cocoa trees have higher yields. Fertilizer results in higher yields. Older trees have lower yields.
Uchoi et al. (2018)	India	On-farm trial	Pruning increases the number of pods per tree, most likely due to more leaf area and production of new laterals.
Tscharntke et al. (2011)	-	Literature review	Shade trees enhance functional biodiversity, soil fertility, drought resistance and weed and pest-control. But shade trees also reduce cocoa yields, especially on the short term. Shade trees should by optimally pruned and spaced to reduce humidity, and the pruning should increase as cocoa trees mature, to improve yields.
Niether et al. (2018)	Bolivia	On-farm trial and statistical analyses	Shade trees in agroforestry systems buffer extreme climatic conditions, but also reduce throughfall and radiation which leads to unfavorable conditions for cocoa production. Pruning shade trees might be a solution.
Ofori-Frimpong et al. (2008)	Ghana	On-farm trial	Frequent weeding of three to four times per year and the use of herbicides could improve the availability of N and P for cocoa uptake.
Zhang and Motilal (2016)	-	Literature review.	The on-farm genetic diversity of cocoa trees is low, resulting in low resistance against pests and diseases. New breeding strategies are needed. Factors increasing yield are pruning, fertilizer usage, and phytosanitation.

Table A2. Literature overview GAP adoption

Author(s)	**Country**	**Type of study**	**Factors influencing adoption of interventions**
Nmadu et al. (2015)	Nigeria	Farmer surveys + statistical analyses	Sex and level of education are positively related to technology adoption. Constraints are high costs of inputs, lack of funds and lack of supporting and complementary inputs.
Aidoo and Fromm (2015)	Ghana	Farmer surveys + statistical analyses	The adoption of certification and sustainable cocoa production is driven by membership in farmer's organizations, awareness of certification, smaller farm sizes, access to credit, and a higher educational level.
Obuobisa-Darko (2015)	Ghana	Farmer surveys + statistical analyses	The adoption of technology is positively influenced by access to credit, primary education, membership of an organization, hired labour, own labour and the frequency of extension visits
Danso-Abbeam and Baiyegunhi (2017)	Ghana	Farmers surveys + statistical analyses	Positively related to fertilizer adoption: farm size, previous farm output, visit to demonstration farm, extension contracts, perceived fertility of the soil, and high incidence of diseases. Positively related to fungicide adoption: age of household head, previous farm output, farm size, off-farm income, extension contracts, and regional effects. Positively related to insecticide adoption: education, visit to cocoa demonstration farm and high incidence of pests.
Baffoe-Asare et al. (2013)	Ghana	Farmers surveys + statistical analyses	Experience, training, age of household head, household size and social capital are the most important variables positively influencing adoption of technologies to tackle black pod disease and capsids. The age of the farm negatively effects the adoption of the technologies.
Djokoto et al. (2016)	Ghana	Farmers surveys + statistical analyses	Farmers are more likely to switch to organic cocoa producing when they are male, have a smaller household, have less cocoa farming experience, have access to extension services, and have access to credit.
Nkamleu et al. (2007)	Ivory Coast	Farmers surveys + statistical analyses	Farmers are more likely to invest in agrochemicals when they are international migrants, are in a farmers' organization, have access to credit, have a larger farm, and have a larger household size. They are less likely to invest when they have a larger amount of plots and when the farm is older.

Appendix B. Yearly descriptive statistics

Table B1. Descriptive statistics 2016 (N=283)

Variable	Min	Max	Mean	S.D.	N
Farmers characteristics					
Farmerage	21	86	46.77	10.80	264
Sex	0	1	0.94	0.24	283
Training	0	1	0.91	0.28	279
Farm characteristics					
Plotsize	0.395	22	3.24	2.73	283
Plotage	4	116	22.87	15.05	246
District	-	-	-	-	-
Yearscoopcertified	2	6	3.61	0.93	283
Treedensity	0.63	1.84	1.45	0.28	175
Farming practices					
GAP1Pruning	0	1	0.40	0.49	253
GAP2Pests	0	1	0.95	0.22	283
GAP3Weeds	0	1	0.54	0.50	282
GAP4Shade	0	1	0.59	0.49	280
GAP5Harvest	0	1	0.90	0.31	280
Fertilizer	0	1	0.29	0.45	283
Weather					
Rainfall	6.32	21.94	14.59	6.00	283
Temperature	35	38	36.55	1.09	283
Price	-	-	1000	-	-
Laggedprice	-	-	850	-	-
Yield					
Yield	0.11	1.75	0.58	0.02	222

Table B2. Descriptive statistics 2017 (N=1274)

Variable	Min	Max	Mean	S.D.	N
Farmers characteristics					
Farmerage	14	90	45.15	12.57	1207
Sex	0	1	0.90	0.30	1274
Training	0	1	0.87	0.33	1271
Farm characteristics					
Plotsize	0.45	93.4	3.37	3.66	1260
Plotage	0	80	21.63	11.32	1125
District	-	-	-	-	-
Yearscoopcertified	0	7	4.12	1.64	1274
Treedensity	0.14	1.85	1.30	0.34	1007
Farming practices					
GAP1Pruning	0	1	0.28	0.45	1271
GAP2Pests	0	1	0.76	0.43	1273
GAP3Weeds	0	1	0.61	0.49	1270
GAP4Shade	0	1	0.41	0.49	1218
GAP5Harvest	0	1	0.60	0.49	1271
Fertilizer	0	1	0.42	0.49	1268
Weather					
Rainfall	0.05	135.53	38.50	41.17	1274
Temperature	31	38	34.78	2.07	1274
Price	-	-	1100	-	-
Laggedprice	-	-	1000	-	-
Yield					
Yield	0.1	1.8	0.65	0.30	1132

Table B3. Descriptive statistics 2018 (N=1156)

Variable	Min	Max	Mean	S.D.	N
Farmers characteristics					
Farmerage	20	95	45.13	12.14	1077
Sex	0	1	0.87	0.33	1156
Training	0	1	0.87	0.34	1154
Farm characteristics					
Plotsize	0.2	41	3.31	2.98	1150
Plotage	0	122	22.98	11.30	1044
District	-	-	-	-	-
Yearscoopcertified	1	8	5.12	1.29	1156
Treedensity	0.17	1.85	1.14	0.36	966
Farming practices					
GAP1Pruning	0	1	0.33	0.47	1156
GAP2Pests	0	1	0.85	0.35	1156
GAP3Weeds	0	1	0.60	0.49	1152
GAP4Shade	0	1	0.37	0.48	1152
GAP5Harvest	0	1	0.65	0.48	1156
Fertilizer	0	1	0.42	0.49	1150
Weather					
Rainfall	2.75	102.32	32.92	33.55	1156
Temperature	31	37	34.77	2.09	1156
Price	-	-	700	-	-
Laggedprice	-	-	1100		
Yield					
Yield	0.1	1.76	0.59	0.27	902

Table B4. Descriptive statistics 2019 (N=1503)

Variable	Min	Max	Mean	S.D.	N
Farmers characteristics					
Farmerage	13	99	45.65	12.51	1251
Sex	0	1	0.89	0.31	1503
Training	0	0	0.91	0.28	1503
Farm characteristics					
Plotsize	0.35	28	3.28	2.51	1475
Plotage	3	74	23.50	11.38	1428
District	-	-	-	-	-
Yearscoopcertified	1	9	5.73	1.53	1503
Treedensity	0.25	1.85	1.06	0.35	1292
Farming practices					
GAP1Pruning	0	1	0.59	0.49	1503
GAP2Pests	0	1	0.85	0.35	1503
GAP3Weeds	0	1	0.49	0.50	1503
GAP4Shade	0	1	0.39	0.49	1503
GAP5Harvest	0	1	0.80	0.40	1503
Fertilizer	0	1	0.39	0.49	1503
Weather					
Rainfall	11.5	279.9	67.56	74.86	1503
Temperature	31	39	36.11	2.70	1503
Price	-	-	750	-	-
Laggedprice	-	-	700	-	-
Yield					
Yield	0.1	1.76	0.58	0.20	1321

Appendix C. Consumer Price Indices

Table C. Consumer price indices

Consumer Price Index	Difference in cost of living
2016 Q3 = 111.19, Q4 = 110.96, average: 111,08	-1,73%
2017 Q3 = 112.39, Q4 = 111.87, average: 112,13	-0,79%
2018, Q3 = 113.05, Q4 = 112,97, average: 113,01	+0,09%
2019, Q3 = 111.46, Q4 = 112,11, average: 111,79	-1,13%

Reference is 112.92, CPI in 2018 Q2 when the benchmark was determined
Source: International Monetary Fund, 2020