Cocoa production in the "Oriente" region of Cuba (Baracoa) : Assessment, understanding and potential

Auteur : De Smet, Maxime
Promoteur(s) : Dogot, Thomas
Faculté : Gembloux Agro-Bio Tech (GxABT)
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MAXIME DE SMET

TRAVAIL DE FIN D'ÉTUDES PRÉSENTÉ EN VUE DE L'OBTENTION DU DIPLÔME DE MASTER BIOINGÉNIEUR EN SCIENCES AGRONOMIQUES

ANNÉE ACADÉMIQUE 2017-2018

PROMOTEUR: DR. THOMAS DOGOT

1 Dans ce cas, l'autorité académique est représentée par le(s) promoteur(s) membre(s) du personnel enseignant de GxABT.

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ABSTRACT

Cuba is a fringe actor in the world of cocoa. Due to the country's characteristics and history, cocoa farmers have turn to agroecology to maintain their plantations. This exploratory study aims to understand the production system to draw out its potential. A survey has been conducted during interviews on a sample of farms with differences in characteristics. This was also the opportunity to make direct observation and inquire with the people working around the farms. The different results have allowed to give an overview of the farms and to reveal some key factors in managing them. Demography and shade appeared to play important roles. A surprising truth was revealed when it was realised that a negatively impactful event like hurricane Matthew could beget beneficial results too.

Key words: cocoa - *Theobroma cacao* - Cuba - agroecology - cooperation

RÉSUMÉ

Cuba est un acteur marginal dans le monde du cacao. En raison des caractéristiques et de l'histoire du pays, les producteurs de cacao se sont tournés vers l'agro-écologie pour maintenir leurs plantations. Cette étude exploratoire vise à comprendre le système de production pour en extraire le potentiel. Une enquête a été menée lors d'entretiens sur un échantillon d'exploitations présentant des différences de caractéristiques. Ce fut aussi l'occasion d'observer directement et de se renseigner auprès des personnes travaillant autour des fermes. Les différents résultats ont permis de donner un aperçu des exploitations et de révéler certains facteurs clés de leur gestion. La démographie et l'ombre semblent jouer un rôle important. Une vérité surprenante a été révélée lors de la réalisation qu'un événement ayant un impact négatif, comme l'ouragan Matthew, pouvait aussi produire des résultats bénéfiques.

Mots-clefs : cacao - *Theobroma cacao* - Cuba - agro-écologie - coopération

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ABBREVIATIONS AND ACRONYMS

CUP: Cuban pesos

CUC: Cuban convertible pesos

USD: United States Dollar

GDP: Gross Domestic Product

USA: United States of America

WB: World Bank

HDI: Human Development Index

UNDP: United Nations Development Programme

GNP: Gross National Product

WTO: World Trade Organisation

GSTP: Global System of Trade Preferences among Developing Countries

LAIA: Latin America Integration association (Argentina, Bolivia, Brazil, Chile, Columbia, Ecuador, Mexico, Paraguay, Peru, Uruguay and Venezuela)

ILO: International Labour Organisation

FAO: Food and Agriculture Organisation

CCS: "*Cooperativas de Crédito y Servicios* " (Credit and Service Cooperatives)

CPA: "*Cooperativas de Producción Agropecuaria*" (Cooperatives of Agricultural Production)

UBPC: "*Unidades Básicas de Producción Cooperativa*" (Basic Units of Cooperative Production)

UBACC: "*Unidades básicas agro industriales del cacao/café*"

Introduction

Cocoa is one of the big commodity trades in the world. It can not be produced everywhere and non-producing countries tend to be the biggest consumers. This creates commercial ties between countries and continents.

This can lead to different countries from opposite ends of the value chain to work together. One such example is the academic cooperation put in place between Belgian and Cuban universities in the development project "Design and strengthening of an agro-ecological cacao production system in Cuba". The present thesis is strongly linked to this partnership.

Cuba's cocoa production is marginal when compared to global figures and mostly serves its internal market. In addition, the insularity of the country and its political system are bound to create particularities. The idea behind this exploratory study is to be able to assess the system and to understand how it works in order to see its underlying potential.

To reach that goal, the first objective is to describe the plantations and their variations. The second objective is to see how the organisation works between the farms and after production. The third objective is to identify the impact the environment can have on the plantations and conversely. The final objective is to see the potential of Cuban cocoa and what can impact its future.

In order to gather the data and get a sense of on-the-ground reality, questionnaires were applied in interviews with farmers. During these encounters, notes of direct observations and interactions with cocoa-savvy people were taken to complement the inquiries.

Before presenting and discussing the results leading to the conclusions, this work will set down some context and concepts linked to the subject.

1. Context and problematic

1.1 Cuban economy

1.1.1 General presentation of the country

Biggest island of Caribe's region (cfr. **fig.1**), Cuba has around 11,2 million inhabitants (estimate as of July 2017, CIA, 2018) which mostly speak Spanish. The estimated population growth in 2017 is in the order of -0,3% with a median age of 41,5 years. Approximatively 77% of Cuban population is living in cities (stable number) and quite well distributed in the territory. Total area of the country is 111.000 km² (Belgium : 30.528 km²). Natural resources of Cuba are cobalt, nickel, iron ore, chromium, copper, salt, lumber, petroleum and arable lands (CIA, 2018). Cuba's climate is subtropical.

Figure 1: Location of Cuba

Havana, its capital, is where numerous governmental institutions can be found. Raúl Castro, brother of Fidel, still was the leader of the socialist unique party in the beginning of 2018. There is a dual monetary system in which the CUP (Cuban pesos) and CUC (convertible pesos) coexist. A simple way of seeing it is the following: 1 CUC is worth 25 CUP or 1$ USD and is used by foreigners and the tourism sector. The CUP is the locals' currency.

The country has relied for a long time on sugar and tobacco to sustain its activity. Nowadays, the agricultural productions of the country only represent 10% of GDP (Gross Domestic Product) and around 20% of workforce. Changes occurred in favour of nickel mines, services and tourism.

Venezuela, mainly under Hugo Chavez' presidency, can be considered has "Cuba's best friend" especially for its support regarding fossil fuel.

It should be reminded that the island has been under embargo from the United States of America (USA) for nearly 60 years. Furthermore, the USA have also been maintaining a naval military base near Guantánamo since Cuba's independence from Spain in 1902. For these reasons, the presidential visit of Obama in 2016 (first since 1928) was an important event in the politico-economic landscape of the country.

1.1.2 Some macroeconomic factors

GDP

Cuba's GDP, according to the World Bank (WB), has known a positive evolution between 2007 and 2015 (cfr. **fig.2**). However, the year 2016 showed a contraction to 0,5% real growth rate. Per capita GDP was estimated at nearly 8000 USD in 2016. A multiplicative factor of 1,5x is required to obtain equivalent purchasing power. Though variable, for informative purpose, the growth rate of GDP was about 4% in 2015 (CIA, 2018).

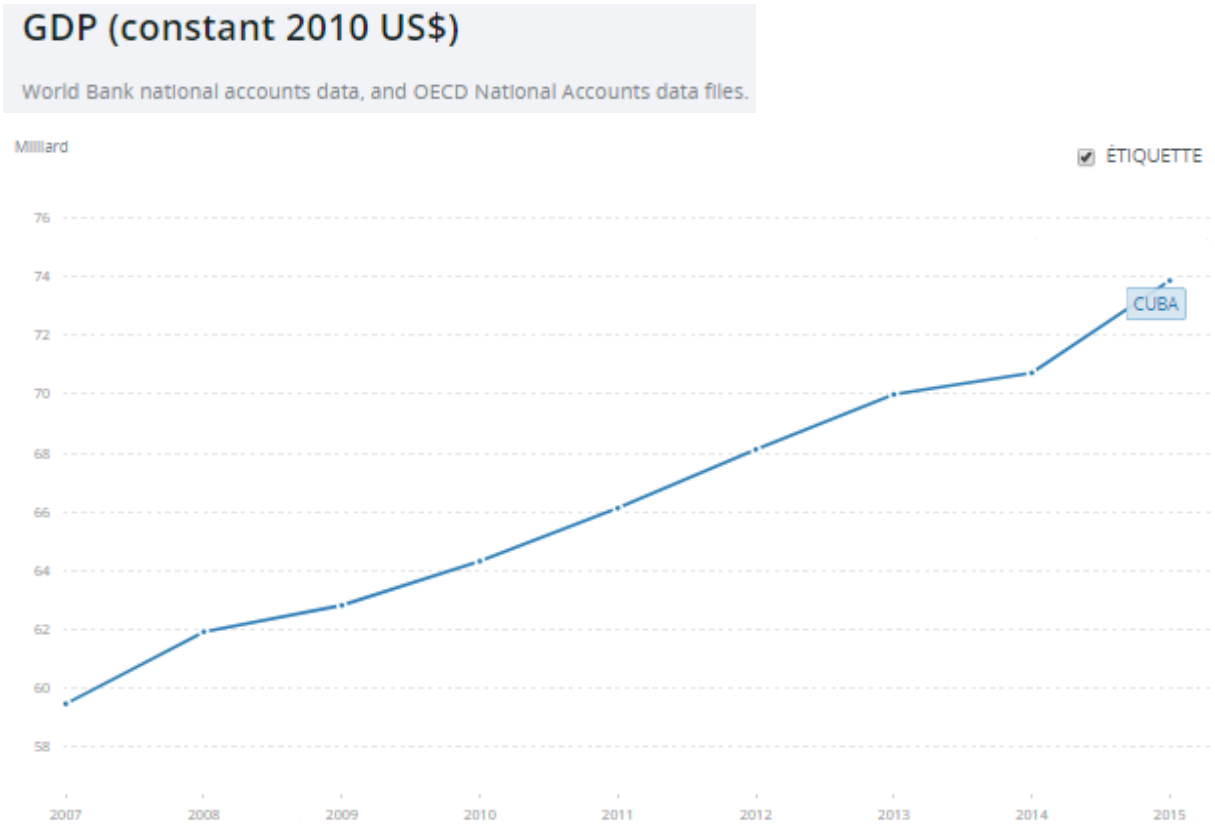

Figure 2: GDP of Cuba between 2007 and 2015 in constant 2010 USD (The World Bank, 2018)

Agriculture represents 18% of workforce (which is around 4,7 million workers) for 3,9% of GDP. The industries (mines, petroleum, pharmaceuticals, etc.) generate 22% of GDP employing 10% of the work force. Finally, services occupy a small 70% of workers for approximately the same proportion of GDP. It should be noted, however, that the public (state) and non-public sectors distribution is about 70% and 30% respectively (CIA, 2018).

The preponderant importance of services on Cuba's economic activity is plain to see. It is therefore easy to conceive that tourism is an important sector for the island.
To go further than the GDP, its Human Development Index (HDI) was 0,77 in 2014 (UNDP), 67th of 105 countries (Belgium : 0,89 -> 21st). This result was increasing during the decade 2000-2010 and is now relatively stable.

We can also see that GNP (Gross National Product) is higher than GDP since 2007 (ratio can be 1,3x and more) according to figures from the CIA World Factbook. This reflects significant cash inflows from the work of Cubans abroad. This phenomenon comes 3 years after the start of the Cuban decision to monetize its medical services (Jarry, 2017).

Inflation rate

An increase in inflation after 2008 crisis can be noted (cfr. **fig. 3**). This leads to believe that consumption prices increased due to difficulties in supply. Indeed, the economic crisis did not spare Cuba and made it more economically fragile. This crisis was also alimentary and Cubans imports can reach around 50% of their food.

Figure 3 : inflation rate in Cuba between 2006 and 2016 (in %) (Trading Economics, 2017)

Trade balance

Main partners for importations are China (22%), Spain (14%), Russia (5%), Brazil (5%), Mexico (4,9%), Italy (4,8%) and USA (4,5%) (numbers of 2017). The main countries towards which Cuba exports are, Venezuela (17,8%), Spain (12,2%), Russia (7,9%), Lebanon(6,1%), Indonesia (4,5%), and Germany (4,3%) (CIA, 2018). In **figure 4**, we can observe that 2008 was a particularly nocuous year for Cuban trade balance. Exports suffered from the crisis while imports' amount increased.

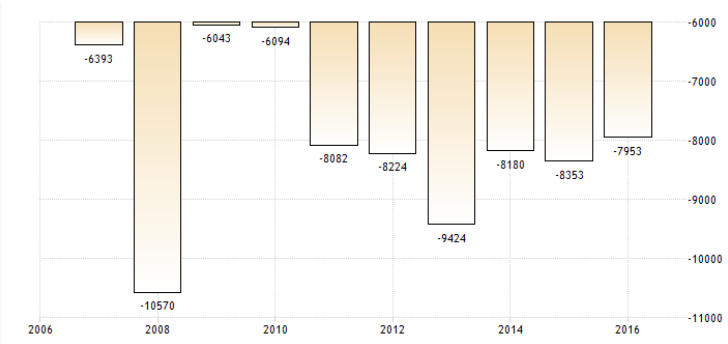

Figure 4: Cuba's trade balance between 2007 and 2016 in million USD (Trading Economics, 2017)

The World Trade Organisation (WTO) lists Cuba in two regional trade agreements: Global System of Trade Preferences among Developing Countries or GSTP and Latin America Integration association or LAIA (Argentina, Bolivia, Brazil, Chile, Columbia, Ecuador, Mexico, Paraguay, Peru, Uruguay and Venezuela).

Balance of payments

Balance of current accounts, unlike trade balance, is usually positive (see **fig. 5**). A notable exception can be spotted for the year 2008 when the economic crisis was felt once again. That year, Cuban payments from abroad will not have been enough to offset the country's trade imbalance.

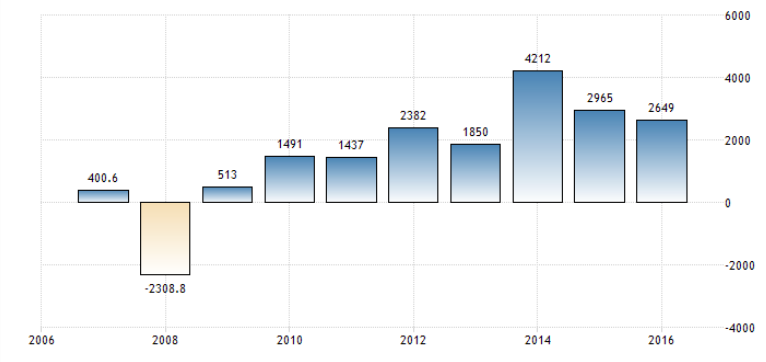

Figure 5: Balance of current accounts of Cuba between 2007 and 2016 (million USD) (Trading Economics, 2017)

External Debt

Figure 6 and **figure 7** allow to see that the external Cuban debt is reducing in percentage of GDP while it is increasing in absolute numbers. In 2016 a debt restructuring took place in accordance with « le club de Paris ». This consist in a capital repayment adjustment (2.6 billion USD) and the abandonment of interest (8.5 billion USD) (Bruxellles Economie et Emploi, 2017). This is reflected in the amount of debt going, in estimated data (CIA, 2018), from 29,54 billion USD in 2015 to 20,59 billion USD in 2016.

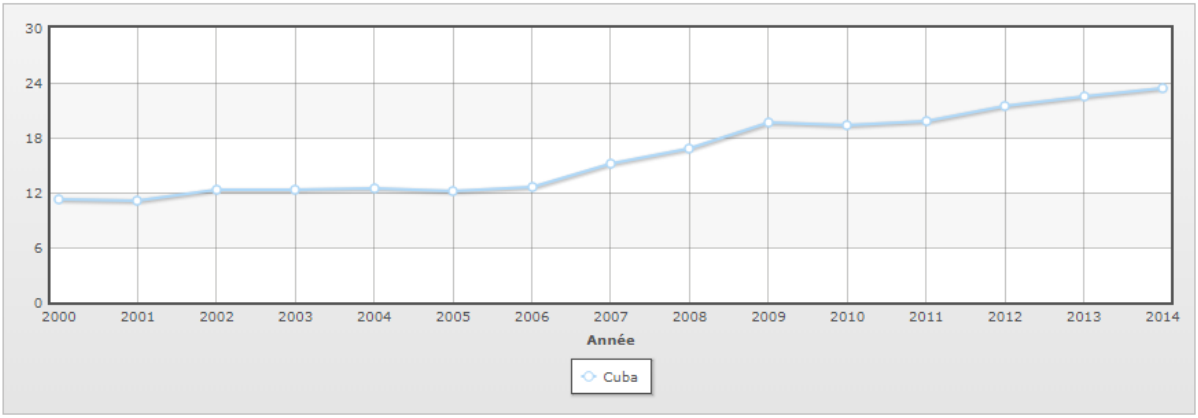

Figure 6: External debt in billions of USD every year (2000-2014) (CIA world factbook through indexmundi.com)

2011	41,35
2012	38,51
2013	36,50
2014	35,34
2015	33,19
2016	22,42
2017	21,03
2018	20,05

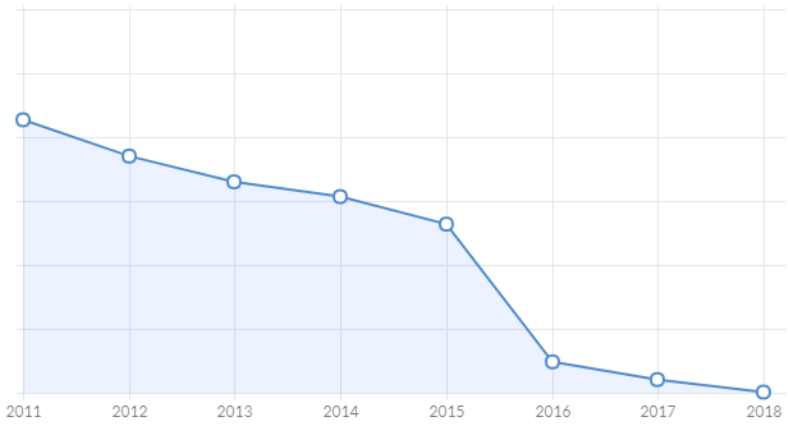

Figure 7: external debt of Cuba expressed in % of GDP (Agence wallonne à l'Exportation et aux Investissements étrangers, 2018)

Unemployment rate

There were 1,6% of unemployment in 2008 (ILO), a low number that can be considered as full employment takin into account the « friction unemployment ». Other years in **figure 8** also show a rather reduced unemployment rate. It is probably wise to take these figures carefully given the level of transparency of local authorities as well as the way the country operates (public employment, ...).The evolution of the unemployment rate in the years after 2008 comes after the financial crisis, a period that has seen the country suffer in terms of foreign currency income and economic activity.

Figure 8: unemployment rate in Cuba between 2007 and 2016 (Trading Economics, 2017)

1.1.3 Teachings from the indicators

Based on above indicators, it can be observed that Cuba suffers from a trade balance structurally in deficit. The country's debt increases accordingly, though diminishing in proportion of GDP. Moreover, public spending tends to overshoot budget. In 2016, budget deficit was estimated at 6,9% of GDP. Incomes for that year were around 51 billion USD (CIA, 2018). Fortunately for the country, relations with USA have eased (potential for tourism and investments) and the country's creditors agreed to restructure Cuba's debt.

The difficulties caused by the international economic crisis have not spared the island, proof that its isolation is only theoretical. In addition, Venezuela's woes have had a significant impact on Cuba. Indeed, up to 60% of the oil (about 100,000 barrels / day according to the CIA) arriving there came from Venezuela on preferential terms.
Cuban immigrants to the US would be a little more than a million and they participate in the finances of the island by sending money to their families ("*remesas*"). This phenomenon is not insignificant because it represents about 25% of current account revenue in the country (Credendo, 2017a).

Cuba has a competitive advantage in the training of its population. Almost all the population benefits from the school system and its medical and pharmaceutical training is at the forefront. The latter, initially developed to also be useful outside the borders, was monetarized by the government in the beginning of the years 2000 and now represents an important part of the incomes of the country (Jarry, 2017). According to the CIA, some 30,000 medical personnel would be in Venezuela in exchange for easier access to oil and investments in Cuban infrastructures. Brazil and South Africa would also host a certain number. The World Health Organization has recognized Cuban health action during the Ebola crisis in West Africa. The Cubans were the first to intervene on site (CIA, 2018).

Unemployment remains low but inflation tends to increase in recent years. Should we see an effect of the increase in tourist numbers? This financial windfall has indeed become one of the main resources of the country and the trend is unlikely to be reversed. However, the investment climate, although positive, is not the best (cfr. **figure 9**). The government wants to keep a strong hold on its socio-cultural model. That said, international development zones are imagined as in the port of Mariel at 40 km west of Havana (Cámara de Comercio de la República de Cuba, 2017).

Figure 9: Country risk, (Credendo, 2017b) 1 or A = best rating

1.1.4 Post-Fidel Cuba

Unfortunately, the liberalization of Cuban economy did not develop as expected after Obama's visit. In addition, there was the arrival of Donald Trump as President of the United States of America and the fiscal crisis. This crisis was caused by oil supply problems from Venezuela. This led to periodic closures and blackouts disabling the economy. As for the Trump administration, it seems colder towards Cuba at first glance. On the relationship with this new government will depend the opening of Cuba and the lifting of the embargo. Other dominant countries like China and Russia show interest for the island but it is not certain that these partners will be of help in the relationship with the USA. However, there is interest from American companies, such as Google, to access the Cuban market.

In April 2018, a new Cuban leader came to power, Miguel Díaz-Canel His arrival should be the start of a greater opening and, potentially, a single Cuban currency. The changes to come should not be too strong since Raoul Castro will stay head of the socialist party until 2021. This is done in order to insure support for and control over the new president of the country. Mister Díaz-Canel will most likely follow the guidelines put down by is mentor R. Castro.

1.2 Cocoa in the world

According to the FAO (FAO, 2018a), approximately 10 million hectares in the world are being cultivated for cocoa production (this area is almost that of Cuba) with a production of roughly 4 450 000 metric tonnes (t) of beans. The revised estimates for the 2016/2017 year of production give 4 744 000 tonnes of beans and 4 400 000 tonnes of grinded cocoa (International Cocoa Organization (ICCO), 2018). This means there was a surplus of cocoa during this period. Indeed, grindings represent the consumption of cocoa by the industry, which in turn is driven by demand from consumers. Revised forecasts, as of May 2018, anticipate that production and grinding will be almost identical around 4 536 000 t. This resulting from a decrease of the former very close in proportion to the increase in the later (more or less 3%). That said, for these two years of production, stocks represent just about 40% when compared to grindings (International Cocoa Organization (ICCO), 2018).

Theobroma cacao L. originated in tropical South America. Belonging to the Malvaceae plant family (previously Sterculiaceae) (Bayer & Kubitzki, 2003), it was already cultivated by the Mayas more than 1500 years ago (Barell, 2009 ; CIRAD-GRET, 2002). This culture was spread to Asia and Africa by the colonial empires from the XVI century onwards. Though it arrived on mainland Africa only in the late XIX century, it is now the main region of production (CIRAD-GRET, 2002).

After 4 to 6 years the cocoa tree reaches full potential for production. It starts to produce after two years for the most precocious varieties and can keep producing for more than 50 years. Flowers are produced all year long on the previous year's wood. The pollination of these very small white/pink flowers is exclusively entomophilous. Cocoa trees are often prone to self-incompatibility and even with other trees of the same genetic group. Despite a great number of flowers being produced, only a dozen fruits will fully develop. They are called pods and need five to seven months to get to its average weight of 400 g. It then contains 100 g of fresh beans covered by a sweet and tart white mucilaginous pulp. From these seeds, 35 to 40 g of sellable cocoa will be harvested. The beans is rich in fat with a content of 50 to 55 % of cocoa butter. The germination power quickly fades after pod is opened, it is a matter of hours (CIRAD-GRET, 2002).

The cocoa tree requires some specific conditions in order to grow well. Average annual temperature should be about 25°C and temperatures below 10°C are not tolerated. This tree can grow between the tropics depending on the height above sea level. On the equator cocoa can be grown up to a 1000 m of altitude. Annual rainfalls should amount to between 1500 and 2500 mm with a dry period of no more than 3 months. Cocoa is an understory tree, providing shade is necessary and depend on the regional level of incidental illuminance and cultural techniques. It is paramount for the first three years. As for the soil, it should be rich in organic matter, slightly acidic and providing good water retention without asphyxiating the plant (CIRAD-GRET, 2002).

It is advised to use a nursery to prepare new plantations rather than sowing in place. In poorer soils, plantation density is higher due to the lesser development of the trees. In that kind of situation, a 2,5 m x 2,5 m disposition will result in 1600 stems of cocoa per hectare. In better conditions, spacing can be increased, 3 m x 3 m plantations end up with 1111 stems/ha.

Maintenance mainly consist in replacing missing trees and clearing the undergrowth for the first two years. After that, the work load mainly consist in pruning and cutting. Firstly to ensure that the crown forms above 1,2 m, then to remove suckers and finally to manage diseases. Fertilisers and manure are more useful when applied to plantation of high yielding species and low shade ratio, their use is therefore quite limited.
Pests and diseases can wreak havoc in the plantations and, on a worldwide scale, take down the harvest to half its potential. Rodents (*i.e.* rats and squirrels) and monkeys can physically damage the pods and promote decay. The black pod disease can be found more or less anywhere cocoa is produced.

Cultural practices can reduce the impact of *Phytophthora sp.* but an additional chemical (copper) treatment is usually required to achieve effective control. Other fungal and viral diseases can also have a significant impact on production levels, such as *Crinipellis perniciosa* Aime & Phillips-Mora 2006 causing the witches' broom disease, the vascular streak disease - or swollen shoot - caused by *Rhizoctonia theobromae* (P.H.B. Talbot & Keane) Oberw., R. Bauer, Garnica, R. Kirschner 2013 and the frosty pod rot caused by *Moniliophthora roreri* Moniliophthora roreri (Cif.) H.C. Evans, Stalpers, Samson & Benny 1978. Among insects impacting cocoa production, the family of mirids (*Miridae*) and the cocoa pod borer (CPB) - *Conopomorpha cramerella* (Snellen, 1904) - can be mentioned (CIRAD-GRET, 2002).

Because of the need to harvest only the ripe pods and the sensitivity of the flowering area, harvest needs to be done by hand with care and coming back to the tree several times. Pods are then split open on field or in gathering areas. From there starts a crucial part of cocoa production, the fermentation stage. This starts almost immediately after seeds exposure to air. It allows to get rid of the pulp sticking on the seeds, trigger the development of aromas and eliminate the germinability. To ensure proper preservation, water content is brought down to 7%. This stops fermentation and takes out part of the acetic acid formed during that process. Drying can be achieved over a period of one to three weeks, mainly depending on meteorological conditions, and with a numerous work force. It is the most common mean of drying. The other option, for bigger quantities of seeds, is to artificially dry cocoa using hot blown air. This technique achieves the extraction of water under 48h but as the inconvenient to keep a major part of the acetic acid in the seeds. Equatorial climatic conditions are not favourable to storage of dried cocoa. Great care must be taken to avoid humidity and smells to be absorbed by the seeds and prevent rodents from getting to the stock (CIRAD-GRET, 2002).

Production in familial plantations can be expected to achieve between 300 and 700 kg/ha. In industrial production systems, with high inputs, average figures of 1 to 2,5 tonnes of merchant cocoa per hectare can be achieved.

Cocoa production mostly comes from small familial farms on which first steps of processing are conducted (up to drying). Merchant cocoa is taken in charge at the farm gate by a succession of collectors and wholesaler. These, with exporting agents, sort and take care of the dried beans before delivering them to the industry. Factories are located in consumer country but tend to develop in producer countries too. Two main types of production exist. The first kind consist in cocoa butter producers who transform beans into butter, powder and mass. The other kind is chocolate making (CIRAD-GRET, 2002).

The current global world of cocoa revolves around two main regions, Africa and Europe. Indeed, on the forecasted approximately 4 600 000 tonnes of cocoa beans production for 2018, more or less 75% will be produced in Africa. The Ivory Coast on its own represents a little less than 45% of the world production while its neighbour Ghana represents 20% of that production. But, as can be noticed in **figure 10**, zones of consumption do not match zones of production, making cocoa trade an important one. Europe is to cocoa consumption what Ivory Coast is to production. In fact, Europe consumes around the same amount as that African country produces. The hart of cocoa grinding and chocolate making revolves around Germany, the Netherlands and countries like Belgium, France or Switzerland (International Cocoa Organization (ICCO), 2018)

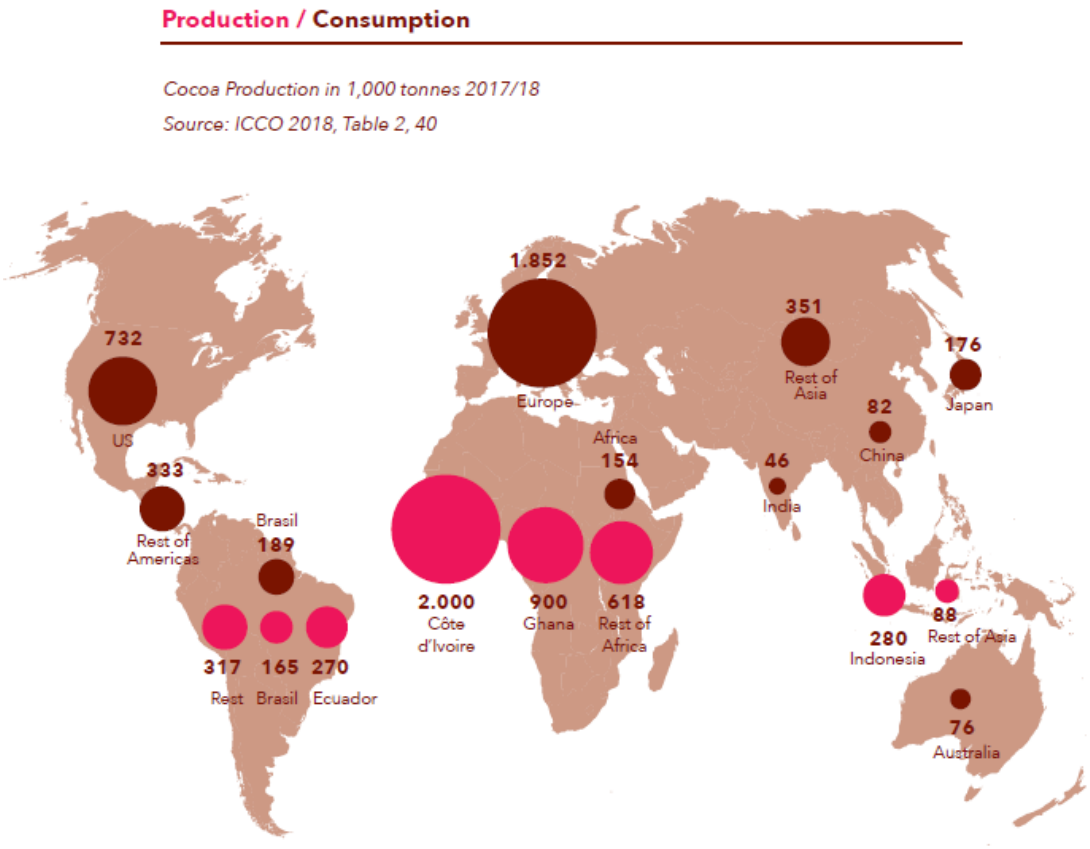

Figure 10: cocoa production/consumption in the world (International Cocoa Organization (ICCO), 2018)

Cocoa is a perennial culture system. When time comes to renew the plantations, it is often easier to expand on natural forest using a "slash-and-burn" technique. After many decades of exploitations, old fields tend to have lost fertility and accumulated diseases and pests. Or, the rainforest close by is mostly fertile and with low level of vermin. Thus for a long time, by its nature, cocoa production as often been a pioneering front type culture. This is now a concern even for the people acting along the value chain. Ivory Coast with its numerous plantations is highly concerned by that phenomenon. (Fountain & Huetz-Adams, 2018; World Cocoa Foundation, 2017) Another challenge for the cocoa industry is to reduce child labour in its sector. There could be around 2.000.000 children in West African alone working the fields (*McCoy, 2018*; Fountain & Huetz-Adams, 2018).

1.3 Cocoa in Cuba

Cocoa has been part of the Cuban landscape for centuries and as a certain tradition and popular culture ensued around it. Numerous beverage have arisen, marked by the various immigration waves. It is a way, as for chocolate bars, to celebrate special events as well as to start or finish another day's work (Hartman Matos & Larramendi , 2011). Baracoa is the main selling feature for tourists going to Guantánamo province, it is a place to admire nature but also to discover the Cuban culture of cocoa.

Between 2011 and to 2016, cocoa production in Cuba as oscillated between 1500 and 2000 tones. That last number barely represents 0.05% of world-wide production (International Cocoa Organization (ICCO), 2018 ; ONEI 2017).

In Cuba, there is around 6 227 000 hectares of agricultural area. Of these, 5 600 hectares were dedicated to cocoa production in 2016. Roughly 91% of that area belongs to the non-state sector. Slightly less than 4 200 hectares have been harvested that same year. The areas aforementioned have decreased before 2016, mainly when transiting from 2011 to 2012. The Irene hurricane of august 2011 having touched the province of Guantánamo most probably explains this situation where mostly tree type cultures have regressed. During this period, an average of 416 kg/hectare was noticed with a minimum of 293 kg/ha and a maximum of 527 kg/ha (ONEI, 2017).

Baracoa represents some 75% of the country's cocoa production with around 2 500 people working for it on more or less 4 000 hectares. The cultivated area (permanent (90%) and temporary) of the region is a little under 20 000 hectares and the population slightly over 80 000 inhabitants (ONEI, 2016).

There are four kind of cocoa in Cuba, depending on reproduction model and origin. These types are the clonal cultivars, the traditional, the hybrids and the "children of TSH" (Trinidad Selected Hybrid) (Márquez & Aguirre, 2008 ; Márquez & Aguirre, 2010). The low genetic variations and the high variability of morphology encountered in traditional Cuban cocoa is the consequence of the evolution from plants introduced in Cuba, with a bottle neck resulting from a narrow genetic base. The traditional Cuban cocoa classified in the Trinitario, according to its genetic and morphological variability, shows potential to genetically improve commercial cocoa in Cuba (Bidot Martínez, 2015).

The black pod disease caused world-wide by *Phytophtora sp*. is no stranger to the island of Cuba. The prevalence of the species *P. palmivora* was observed as it was found in all the explored sites. Decaying organic material seems to be a fertile ground for the development and transmission of yeasts. These attract drosophilids that can become vectors to the healthy cocoa pods. The large diversity of endophytic fungi in the cocoa agro-ecosystem of Cuba could be the source of biocontrol measures (Yurelkys, 2015).

1.4 Problematic and objectives

This thesis is meant as an exploratory study. It is linked to a project taking place in Cuba. This project, "Design and strengthening of an agro-ecological cacao production system in Cuba", is a partnership between Belgium and Cuba. The universities of Havana and Guantánamo are teamed up with universities of Louvain-la-Neuve (UCL) and Gembloux (Gembloux Agro-Bio Tech, Uliège). Several Ph. D. thesis or post-doctoral works are linked to this project, mostly for Cuban personnel. Most of the Cuban cocoa is produced around the town of Baracoa, it is why the study focuses on this area. As seen previously, the quantities harvested in the island are negligible compared to global production and the Cuban context is a particular one. One could be wandering if there is a future to be found in the cocoa market of Cuba. The problematic of this sector is to know how sustainable it is and how the model can face or adapt to the challenges ahead.

To address that subject, some objectives were defined. In **table 1** hereafter, more details about what kind of data is wanted to achieve these objectives are presented.

Table 1: objectives of this work and wanted data to achieve it

Objectives	Data
Production system (farms) characterisation	- Type of management (Farmer strategy, crop system, passive/active …) - Socio-economic characterisation - Other linked productions - Types of trees - Yields - Diseases - Etc.
Defining the organisation at higher levels	- Inter-farm organisms types - What it brings - How it differs - What happens after production (harvest) - Prices - Etc.
Identification of impact from/to the environment	How is the natural environment managed? What are the risks linked to it? What are the consequences to take it into consideration or not? Are they important? The same questions can be asked about rules, traditions and other socio-economic aspects of the environment (population)
Drawing out the potential	All the previous points plus complementary information and comparison to other models

The main idea is to be able to assess the system and to understand how it works in order to see its underlying potential. To get there, the first objective is to characterise the production system and its variants within farms. The second objective is to see what systems exist for a higher level of organisation and what it means for farmers. The third objective is to identify the impact of the environment (natural and socio-economic) on the plantations and vice versa. The final objective is to extract, from the results of the previous objectives, what can affect (positively or negatively) the sustainability of the Cuban cocoa production. From that, the potential of this sector shall be drawn out.

Knowing the context and problematic of this thesis, the next part will address the conceptual and theoretical framework of the study. The path taken will go through the concepts of agroforestry, agro-ecology and eco-systemic services whilst keeping in touch with cocoa production systems.

2. Conceptual and theoretical framework

2.1 Agroforestry, agro-ecology and cocoa

In a working paper of 2016, Meine van Noordwijk et al. write that agroforestry brings the opportunity of multiple scales of analysis. They add that existing ways to define it are referring to a single scale. They also claim that, hypothesis-based research has made less progress on the socio-economic and policy dimensions than on the biophysical-ecological aspects. Often agroforestry is simply define by decomposing the word and saying it is a mix of agriculture and forestry, implying to bring trees in the system or preserve existing once. In the paper mentioned above, the new definition proposed is "*Agroforestry, a contraction of the terms agriculture and forestry, is land use that combines aspects of both, including the agricultural use of trees".* They pursue saying it encompasses farming inside forests and at their margins, the trees present on farms and in agricultural sceneries, as well as tree-crop systems, including rubber, oil palm, coffee and cocoa.

Agroecology can be seen as the ecology of food systems (Francis *et al.*, 2003). Among the ways to define agroecology, some shared principles can be determined. The more obvious one being to fully take advantage of the ecosystem functions. Others are to reconcile environmental, economic and social challenges sustainably by making biological regulation in agro-ecosystems stronger and making the most of functional biodiversity (Schaller, 2013). Finally, a very interesting and simple way of defining agroecology is to say that : it is the integrated use of natural resources and mechanisms with the goal of agricultural production in mind. This ties together the social, ecological and economical aspects in order to take profit of the interactions between animals, plants, humans and the environment (Ministère de l'agriculture et de l'alimentation, 2015). Hence, agroecology is a complex science field also concerned with environmental and social preoccupations. Agroforestry can be considered, at least in part, as belonging to the agro ecological systems.

Cocoa production, is agro ecological by nature especially in its traditional form. The main reason being the impact of shade on this culture. The Cuban context makes a quasi-obligation for this systems since procuring oneself with inputs (pesticide, fertilisers …) is somewhat of an issue on the island. After the fall of the USSR, Cuba had to reorganise its relations with the outside world in order to survive to the "special period". A change of cultural system was needed as energy and imports became more expensive, the embargo from the USA aggravating the situation (Rosset & Medea, 1994; Funes, 2002; Machín-Sosa *et al.*, 2010).

As a legacy of the infield experience of technicians, researchers, farmers and rural communities, a deep and consequential understanding of agroecology science and practice thus emerged in Cuba. This allowed to draw principles of an agricultural strategy that made Cuba able to attain, with limited energy supply and external inputs, high levels of productivity and resilience. Given the potentially devastating meteorological events and the embargo, agro-ecological ways and techniques can be a sound alternative to industrial farming in order to reach some level of food independence, and thus political autonomy (Altieri & Funes-Monzote, 2012).

2.2 Agroforestal cocoa plantations

It is a multi-layered system consisting of an association between *Theobroma cacao (L.)* and herbaceous (multi-) annual plants and/or perennial woody plants (forest trees, fruit trees, cash crop, timber …) voluntarily located on the parcel studied and having a certain value at the commercial level or from the point of view of the services rendered. It is possible to plant cocoa trees in an existing forest (partially clearing it), on a savannah type environment, or on an open forest system with slash and burn techniques. There are some advantages to this system. A first advantage is to maintain the yield of cocoa / ha, or even increase it in a cocoa farm of more than 20 years (age at which the fertility and resistance to bio-aggressors of "industrial cocoa farms" begin to decline and where it is necessary start to bring in inputs to sustain some production). It also makes the recovery of a cocoa farm maintained to the minimum possible by cuttings (cfr. **figure 11**), the elimination of declining individuals, and the replacement of new dead plants by new ones.

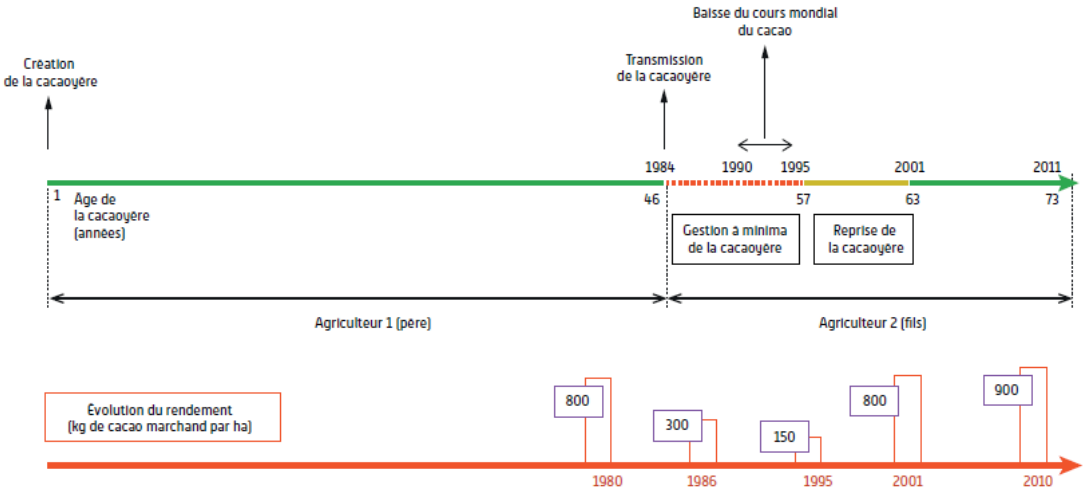

Figure 11: Resilience of an agroforestry cocoa farm in Cameroon: the cocoa farm returns to its level of yield after a "à minima" (minimalist) management of 11 years and a recovery phase of 6 years (Jagoret, 2011).

Other advantages can be : maintaining the fertility of cocoa trees by recycling organic matter (high turnover of biomass) in forest areas and limiting soil erosion and nutrient leakages in the soil profile; Obtaining a lifespan of 50 years against 20-30 years for a culture of *Theobroma cacao* (L.) alone in non-intensive production system (no inputs, "mining agriculture"). A similar agro-forestry system is considered sustainable even beyond age 50, if it is properly renewed (Duguma, *et al.*, 2001); Maintaining a plant cover and therefore shading. This limits the development of some weeds and slows the development of insect pests (such as Miridae). The shade is also favourable to a certain extent to the development of cocoa. When planting a cocoa tree in a secondary forest or a long fallow, certain trees are maintained (i.e. fruit trees, trees with medicinal properties, or used for the production of timber or precious wood) for their commercial value and the shade provided to cocoa saplings. This selective clearing has little impact on soil structure. Trees such as mango, avocado, guava, orange ... can be added to the agroecosystem afterwards (Duguma, *et al.*, 2001); The reduction of costs related to chemical inputs (phytosanitary products, fertilisers ...) (Penot & Feintrenie, 2014). It also provides greater resilience to farmers by diversifying their sources of income (selling fruit, wood for cabinet making, etc.). One last example of interests this system is the provision of eco-systemic services (refuge for biodiversity, soil quality, etc.). The specific richness of some places in central Cameroon is 23 species per plot (Jagoret, *et al.*, 2014). What is more, the forest species used can have several functions.

There are also some constraints to this system. Farmers often need to be shown that exploiting an agroforestry system can be profitable, whether it is through the sale of cocoa or the use of "annex" trees as fruit growers, sources of medicinal substances, timber or lumber (Penot & Feintrenie, 2014). A change in mentalities might be necessary to promote the adoption of new agroforestry methods and the transition from one agro-forestry model to another, with a different composition in terms of additional cash crop trees (Penot & Feintrenie, 2014). It also requires a large workforce for the first years of the implementation of a cocoa, depending on the area. Forest species supplementing *Theobroma cacao* (L.) in agroforestry systems have not necessarily been genetically selected or improved. The development of agroforestry programs and the selection of other varieties of trees of interest should be done in a participatory manner with cocoa producers. This system requires technical knowledge on interactions between the cocoa tree and its environment on one hand and Cultivation associations with each other and with *Theobroma cacao* (L.) (competition effects, Etc.) on the other. Agroforestry systems should not be over-simplified in the species that composes it (i.e. it is not desirable to limit them to 2-3 high-yielding tree varieties in addition to cocoa) but instead keep some complexity of interesting species to meet the needs of cocoa farmers and their families. Lastly, the management of shade and light incidence in the cocoa plantations can be complex: the need for light varies according to the site, the age of the cocoa, the variety of cocoa used ... All producers do not necessarily optimally put it in place.

2.3 Eco-systemic services

As seen in the previous part (2.2 Agroforestal cocoa plantations), a cocoa plantation can provide eco-systemic services. What does this consist in?

In 2014, these services were valued at 125 thousand billion USD, though not necessarily entering national accountings (FAO, 2018b). The quick definition is that those services are the one produced by nature (ecosystems) that benefit to mankind, by making there life possible or more enjoyable (FAO, 2018b ; Poletto A., 2013). That notion of eco-systemic services has been developed to answer the need of a better understanding of the dependencies between society and ecosystems. Other definitions will highlight the fact that the services can benefit humans without it being obvious at first site due to indirect contributions (Costanza. *et al.*, 1997 ; Kumar, 2010).

The eco-systemic services are classified in four categories which are: provisioning, supporting, regulating and cultural (Millennium Ecosystem Assessment, 2005 ; Union Européenne, 2010).

- Provisioning: they provide the goods such as food, water, wood and fibre;
- Supporting services: they include soil formation, photosynthesis and recycling of fertilisers, without which there would be no growth or production;
- Regulating: they regulate climate and precipitation, water (e.g. floods), waste, and the spread of diseases;
- Cultural services: they relate to beauty, inspiration and recreation that contribute to our spiritual well-being.

These categories can have conceptual overlaying making it harder to clearly classify the services observed or at least to only see it as part of one. This explains, in part why some people will use less classes and reduce them to 2 or 3. It may also be because it makes it more practical and sensible in order to evaluate the services (Mäler *et al.*, 2008; UICN France, 2012). In three classes it can be services of production, regulation and culture. Some have merged provisioning and cultural services into a final services category, and supporting and regulating services into the intermediary services category. The reasoning behind this being is that cultural and provisioning services are directly affecting human well-being, where the others do it indirectly (Mäler *et al.*, 2008).

In order to evaluate or quantify the value of the services, it is generally converted in an approximated economic value (much like for accounting externalities). It mostly consists in finding out the value people associate to the studied elements. That part can be done directly by asking them, for example how much they would pay to keep something. It can also be done indirectly by using data that gives a measure by proxy, for example, the amounts and time people are ready to spend (transport, etc.) to enjoy something (e.g. a natural reserve). One major problem for the inclusion of ecosystem services in national accounts is valuing the services, but progress are being made. An accounting system has to be created. Thus, when dealing with ecosystem services, it is necessary to work out the accounting prices from knowledge of the way each ecosystem functions. This makes it complicated to design a standardized model (Dupras *et al.*, 2013 ; Mäler *et al.*, 2008).

Even though valuating the eco-systemic services is not the aim of this work, the concept of such services still gives an interesting angle of approach. It brings valuable information for the assessment and understanding of cocoa production in Cuba. As seen previously, agro-ecological practices are intrinsically linked to the Cuban farming model or at least a major part of it, particularly when talking about *Theobroma cacao* (L.). This notion with the one of agroforestry give a good basis to reach a better appreciation of the world of Cuban cocoa production.

3. Methodology

The conceptual frame is set and the problematic is stated. It is now time to define the chosen approach. The aim is to get to understand an agricultural production system by enquiring about its fundamentals and its context. This study intends to use socio-economic data of the structure and the implications of the agro-ecological concept to see the potential of the system. The choice of an analytical level also had to be made as briefly specified in the "farm survey" part below. In order to assess the way the cocoa production works in Cuba, several methods were employed. They can be listed as follows:

- Documentary research
- Farm surveys
- Verbal interactions with field protagonists
- Direct observations

Documentary research

The research of subject linked documents serves two main goals, preparing the other approaches and complementing the results. The latter is also meant to bring comparison and reliance to the results. These documents mainly consist in governmental publications and thesis or works carried out by Cuban scientists with more or less outsourced support from other countries (Agencies, Universities …).

Farm surveys

There is a group of Cuban scientists working on different aspects of the cocoa plantations in the region of Baracoa. They do this in the context of a partnership project between Belgium and Cuba. Given the logistical circumstances of the infield study, an extensive questionnaire was made. The aim of this inquiry form is to gather information on many aspects for the team. The questions concerning this thesis were mainly of socio-economical nature. Though, they were completed by open questions that were more suited for an understanding of the production system. In section 2.1, it was stated that agroforestry brings the opportunity of multiple scales of analysis. The cooperation project involves different level of analysis (ecotopes, region …), for this thesis the focus is on the farm level with a certain emphasis on socio-economic dimensions. In the following table (**table 2**) the various parts of the form are presented in parallel with the interest they represent for this thesis. For more details, a blank example of the questionnaire is in **annex 1**.

Table 2: parts of the survey and their interests regarding this stud.

Part of the form	Interest
A. General data	Identification of the farm
B. Socio-demographic data	Description of people living on the farm (age, school …) and living conditions
C. Farm data	Description of superficies, what is produced and an idea of what the morphology of the farm is
D. Economic and productive data	Description of cocoa production, description of the cocoa plants, obtain an estimate of production including a comparison before/after hurricane Matthew, some costs and earnings
E. Organisational and commercial aspects	Identify the parkour followed by the cocoa and the organisation around it
F. Inputs	Identify if, what, when and how much fertilisers and pesticides are used.
G. Environment	Assessing the natural risks and what is done to manage them
Open questions	Bring a better understanding on various points that were raised prior the beginning of the inquiries

On the twelve that where visited, ten ended in the final pool for the two others had no one on site at least twice in a row. It should already be noted that this limited sample will not allow to give representative numerical results (*I.e.* area of production, age of farmers, etc.). Hence, it represents a limitation in this work. Therefore, results will have to be considered as indicators of a tendency. This work being an exploratory study, the focus was instead turned towards obtaining a greater diversity. The farms were chosen by the Cubans beforehand. To do so, criteria of diversity of site and management were chosen. These elements are detailed some more in **table 3**. Other farms should be added in the near future for the project.

Table 3: Criteria and details of the choice making of the sampled farms

Criterion	Details
Site	- Type of soil - Exposition - Landforms - Natural impactful elements (rivers …) - And other such criteria allowing to increase the diversity of ecological conditions (ecotopes) encountered
Management	- Type of structure on the farm - Management supposed sanitary care - Diversity of production - Type of organisation between the farms The aim being to have an enlarge vision of how the system of production can be organised.

The following table (**table 4**) gives a brief overview of the site and management variability than can be expected by counting the number of farms corresponding to the intersection of criteria. These criteria are the one assumed to bring the most variability in site conditions and/or management. UBPC and CCS are intra farms organisation types and will be explained in results section.

Table 4: overview of the site and management variability of the sample. Slopes : A=mostly flat; B=half the area flat; C=mostly sloping. UBPC and CCS are intra farms organisation types (see results section.) Numbers represent the number of farms corresponding to

Town	El Jamal			San Luis			Paso de Cuba		
Slope	A	B	C	A	B	C	A	B	C
UBPC	1	.	3	.	.	.	1	1	.
CCS	.	.	.	2	.	1	1	.	.

Meeting people infield

When going to the production areas to meet the farmers, there was more to it than just filling in questionnaires. Talking with the producers also brings useful information, including on how things are perceived. The open questions were also there for that purpose. Usually before going to the farms, a head of local group was met. On such occasions it was possible to discuss of the cocoa value chain and what is done at the cooperative level. This also allowed to know more about other products linked to cocoa production, such as coco or banana. Other sources of information of this type exist. Some researchers of different levels work on this type of production. Some are students and other have a Ph. D and give classes. Cubans of Guantánamo province also have a thing or two to say regarding cocoa and chocolate production.

Direct observations

Finally, going to the field allowed to take notes of unspoken elements as well as to be able to relate to concrete aspects. Notes were taken while inquiring on the farms or moving to or between them. Pictures were taken so as to remember specific observations and to be able to illustrate this work. This was also the opportunity to test the results of the chocolate value chain.

Some constraints to the farm visits

A four hours trip in bus is necessary to join Baracoa from Guantánamo. Once there the means of transportation are by foot, by "*coche*" (horse driven carriage) or some form of collective transportation vehicle. This limited freedom of movement made it hard to go back to one particular location in the given time of the "expeditions". The farms where visited according to their proximity. The questionnaire was elaborated by grouping the questions of every member of the team, if there was any. Making sure every question made sense and could be easily understood, or at least easily explained by the investigators, was adamant to allow the group to split in smaller contingents once in Baracoa. This also allowed to send only part of the team as investigators and to optimise the time in the location. Farmers are not always on hand and the choice was made to see them once for a longer encounter rather than several shorter once. In addition to those aspects, the immigration office requires that foreigners get authorised to go in the farms. This implies that a request had to be made before hand. Then periods of visits in Baracoa had to be declared. Finally before going to the farms, local authorities had to be told about the team's presence and timetable.

4. Results

4.1 Farms

In **table 5** some human characteristics are presented with mean, minimum and maximum values as well as the number of farms where an answer was received for that information. On average 4,2 people live on the farm while 2,8 work on it. The owners and the first workers are around 60 years of age, other workers are mostly younger. First worker is typically a spouse but can be sibling too. Others are the children or sometimes the parents or nephews of the owners. They study on average at least 9 years (15 years old) especially the younger ones. The health of the people in the farms was describe mostly as good. The farmer who has the smallest farm is thinking to migrate in order to find another job. The other farmers did not. On average, head of farms have been working on their land for 35 years. While have been doing it for at least 14 years and some for more than 50 years, the most experimented have been working in the plantations for almost 60 years. One farm is owned by a female but all have a men as "head of family".

Table 5: human characteristics of the farms with the number of farms with answers. The worker 1 and 2 are the typical second and third workers of the farm. Level of education is the number of year of study, those with 12 finish at 18 years old

	Mean value	Min value	Max value	Number of answers
Number of people on the farm	**4,2**	2	7	6
Number of people working on the farm	**2,8**	2	5	10
Owner's age	**61,0**	38	83	10
School level	**9,6**	0	12	10
Worker 1 age	**57,3**	35	78	9
School level	**9,7**	6	12	9
Worker 2 age	**37,8**	26	78	4
School level	**10,3**	6	12	4

The usual breakfast will contain bread, coffee and milk. For meals taken for lunch or supper, the recurrent ingredients are rice, beans, some sort of root-crop called "*vianda*" and eggs, chicken or pork. Three meals are taken per day. Hot chocolate is also part of the diet. No farmer does all the steps of fermenting, drying and toasting in his farm but they keep some beans to make their own beverages. These beans mostly consist in lower quality parts of the harvest.

The rice, sugar, beans, bread, salt and some of the vegetables need to be bought outside for the huge majority of the farms. When a producer would like to produce another crop but do not do it, it is ether by lack of space or time.
Access to water is rarely assured by a public network but rather by wells or else. On the contrary, all farmer benefit from a constant supply of electricity through the grid. Only a couple have a phone (landline), this is to be expected in Cuba where a minority of homes possess such an apparatus.

Giving estimated numbers about their expenses (clothes, electricity, transport, health, alimentation …) was a hard task for farmers. Talking with one family an estimate was made for a household of four (cfr. **annex 2**) based on typical meals and expenditures. This resulted in the amount of 30.000 CUP/year.

Regarding the farms, a first description is found in **table 4**, previously shown in part 3. This table gives an overview of the site and management variability of the sample of farms. There are 4 farms in El Jamal, 3 in San Luis and 3 in Paso de Cuba. Four belong to a CCS and 3 out of 4 of them can be found in San Luis. El Jamal is the location with the most farms with important slops while Paso the Cuba is flatter. The slope classification is based on answers of farmers and observation. If most of the farm area is flat it is in category A, if it contains a clear majority of strong slopes (visual perception) it is in category C. When it is in between category B is used.

Farms area can vary as well as their composition. **Table 6** shows that the mean area of the farms visited is 8 ha but can vary from 2 to 16 ha. At least half of the area is dedicated to cocoa production and it can go up to 100%. On average 83% are devoted to cocoa. The smallest area cultivated for cocoa by a farmer is 1 ha whilst 16 ha is the biggest area with cocoa production. Areas with cocoa trees that do not produce yet (saplings) are called in development ("*fomento*"). More or less 10% is usually in such a state but farmers have reported values from 0% up to 40%. The mean area in for this is of less than 1 ha (0,7) and can reach 4 ha.

Table 6: farm area and areas linked to cocoa. In development means with cocoa trees not yet in production

	Mean value	Min value	Max value
Farm area (ha)	8,0	2	16
Cocoa area (ha)	6,6	1	16
Cocoa area (%)	83	50	100
Area in development (ha)	0,7	0	4
Area in development (%)	11	0	40

Practical classification of the varieties of cocoa in the farms is done between the denominations traditional, hybrid and grafted ("*tradicional, híbrido y injerto*"). In the sampled farms, on average about 1 tree out of 5 is a traditional, almost 1/3 is a hybrid and half the trees are grafted (see **table 7**). These proportions do not represent the overall proportions of the ten farms tree population. They represent the mean percentage on an average farm. Grafted type is found on all farms in proportions varying from five to a hundred percent. Hybrid type was found in 8 farms and represents 9 to 90 % of these farms populations. Finally, the traditional type was in half the farms and represented between 1 to 70% of the population.

The same approach is taken for the age of trees. Traditional variety is the oldest in the field with a mean age value of over 50 years. The youngest were 35 years old and the oldest were at least 60 (3 farms out of 5). The other types averaged a little under 25 years of age. The range of age of the grafted (5 to 40) is more important than that of the hybrid (10 to 35).

Farmers were asked to give their perception of the varieties by ranking them for several aspects. These aspects were the total production capacity, the resilience (ability to face adverse conditions), the level of resistance to phytophtora (lower occurrence and loss of harvest) and the qualitative perception (taste). The number of times farmers would give the first place to a tree variety has been summed for each aspect. The totals do not reach ten because the tree type had to be clearly chosen as number one. The grafted trees are declared more productive in one year. Traditional type has a more stable production with limited differences between periods of the year. It produces all year long with not much variation while other have peaks in the production and periods with nothing. Traditional was characterised as the more resilient and able to cope with black pod disease (under aggression by phytophtora). Hybrid type is also better perceived than grafted type on that last point. Finally, traditional trees also seems to have the favour of farmers on the quality side of things. None of the aspects gathered more than 50% of the farmers' clear preference for one type of tree.

Table 7: proportions, age and perception of cocoa varieties. Perception (last four lines of table) is the number of farmers that put the variety in first place

Variety type	Traditional	Hybrid	Grafted
Mean % of total trees	19	31	50
Mean age	53	23	24
Total production	3	1	5
Resilience	5	1	1
Resistance to phytophtora	4	3	1
Quality	4	0	1

In addition to vegetal productions, farmers often possess some kind of livestock. It is destined to be consumed by the household and mostly consist in poultry (chicken) and pigs (see **table 8**). Three farmers have sheep or goats and one has a horse for transport purposes. The pigs are kept near the house and off the cocoa trees because they could eat the lower fruits or cause damage. Chickens are free to roam around the farm with their chicks.

Table 8: number of farms (out of the 10) that possess these animals

	Poultry	Pigs	Sheep/goat	Horse/mule
Number of farms out of 10	8	7	3	1

4.2 Cooperatives and downstream systems

The cooperative part between the farms is a key feature in the Cuban production system. It will be explained in this last part of the results. As its understanding is considered as an objective and describing it as a result, it appears here and not in the introductive part of the thesis. **Table 9** is a brief overview of the cooperatives "dichotomy", more details are presented in the following paragraphs.

Table 9: brief overview of the Cuban agricultural cooperatives "dichotomy"

	Plot collective management	Plot independent management
Private land	CPA	CCS
State land	UBPC	-

It is in 1961 that the first cooperatives got organised. The CCS or "*Cooperativas de Crédito y Servicios* " (Credit and Service Cooperatives) came into existence. They are private owners or farmers who have usufruct on a piece of land who come together to commercialise products, manage and use equipment and receive credits. They work their fields separately and keep ownership of their land. This union of private owners allows them to access technical assistance, financing and material that the state provides to increase the production of small farmers and facilitate commercialisation. This organisation has a legal identity and patrimony may be called upon to answer for that entity.

Since 1975, CPA or "*Cooperativas de Producción Agropecuaria*" (Cooperatives of Agricultural Production) developed. The land that is possessed by members are joined together as one entity. Social responsibility is shared and the land is managed collectively.

The UBPC or "*Unidades Básicas de Producción Cooperativa*" (Basic Units of Cooperative Production) were created in 1993, during the "special period", on the lands previously managed by large agricultural state companies. Land is managed collectively and workers receive free usufruct on it. Other means of production have to be obtained through credit. Members of an UBPC work under the common labour legislation (Ministry of Labour and Social Security). They are syndicated as they are assimilated to other agricultural workers. An UBPC is listed in a state category register, unlike the CCS and CPA (non-state register). The members perceive money every month. This salary is an advance for what will be earned during a year. At the end of the year they received a complement according to the UBPC real revenues.

Vianda is a Spanish term to designate a starchy tropical tuber or root such as malanga, sweet potatoes, cassava, taro, or plantain bananas (*plátano burro*). It is often found in Cuban plates in addition to rice. In cocoa plantations it is essentially the production of banana that constitute their output of *vianda*. Once harvested they are brought to a "*punto de acopio*" (collecting point) which regroups several farms productions and is easier to access. The products are then acquired by selling points and social entities such as schools.

Another important production on the farms visited is coco nuts. They are used as food for their flesh and water content but have other purposes. The biggest is oil extraction which can in turn be utilised for cosmetics (soap, cream, etc.). They can also be preserved in cans or employed in the confection of sweets. Before hurricane Matthew, exportation took place to send coco in other provinces or even out of the country for those meeting standards of quality. Since that meteorological event, the production is mainly destined to intra-provincial consumption due to lower production.

The "*punto de acopio*" system is also used for coco, coffee and cocoa. The "*Empresa agroforestal y coco*" (agroforestry and coco company) collects all of these products. There are structures centralising the collects to ensure their treatment. Collecting points are close to the farms (max. 5 km). This is why all the cocoa is not fermented and dried in the farms but in so called UBACC (*Unidades básicas agro industriales del cacao/café*). After that process, the dried cocoa is processed in factory. This factory and the coco oil extraction one are located less than 4 km westward of the centre of Baracoa.

Some fruits may be produced on the farms, for these as for the other products there is officially no free market. This means they have to go through grouping in order to sell. The most common production after other than cocoa, banana and coco is citrus fruits (sweet orange, bitter orange and mandarin). The production was between 360 and 460 kg/ha. The biggest farm produced 3,7 tons before hurricane Matthew. There is a wider diversity of productive plants. These are: "*guayaba, ñame, yucca, Malanga, zapote, platano fruta, cedro, marañon, mango, guanabana, palmiche and aguacate".* All the names of plant species gathered during the survey can be found in **annex 3**.
The "*Empresa agroforestal y coco*", to which all production goes, gives assistance to the farmers through a cocoa research station (in Paso de Cuba). Specialists ("*extensionistas*") go to the farms to give advices.

Given loan rates could widely vary as answers went from 3,7% to 33%. Grouped loans get the better rates. All the Farms had contracted a loan, all farmers stated it was to recover from hurricane Matthew.

4.3 Environment, risks and management

The most common plants used to provide shade on the plantations are the banana tree (*Musa sp*), the gliricidia (*Gliricidia sepium*) and the "*algarrobo del païs*" (*Samanea saman*). Coco nut production is also linked to the cocoa production but does not always stand amongst cocoa trees.

The inputs on the farms mostly consist in organic matter but fertilisers (bags of 50 kg) were frequently mentioned too. The organic matter is mainly the result of composting on site. Three farmers declared using herbicides, one of them in greater quantities (1,5-2 l/ha). One farmer declared using green fertilisers (nitrogen fixing plants) and bio fertilisers (mycorrhizae). None declared using (bio-)insecticides or (bio-)fungicides. Inputs are mainly used for seedlings (5-10 kg organic matter/compost when planting) and then compost is utilised to distribute the organic matter back to the plantation. Outsourced fertilizers are employed in a limited extend (200g/plant) to compensate for exports of fertility.

To manage the organic matter that pods represent, there is two main ways. The heap or the pit. Some farmers will put in a more or less scattered form the pods near the place they processed them, others will make a distinct heap. These locations move from harvest to harvest, their dispersal can be helped by chickens. The other way to go is to dig a pit which can be equipped with wooden (or bamboo) raisers. Infected pods are globally not distinguished in the process.

Inundation risks are a reality for four of the ten farmers, either linked to a river or the landforms. Draining can help in part. Strong winds are reported as natural risks by half the sample of farmers. The most frequent natural risk is erosion (7 farms), to manage that the most common practice is to create dams on contour. They can be planted or equipped with dead materials barriers. Living barrier are also employed in addition or in stand-alone methods. Spacing seems to be chosen according to slope. Dead organic material cover can be used to create soil cover too.

The black pod disease is perceived as a risk by almost all farmers (9/10). They state that yield loss is usually less than 5% but when the "climate" (weather or micro-climate) is rainy it can get over 25%. The rodent risk is equally present according to farmers. Insects digging into pods and woodpeckers are not in rest damage wise. Most of the managing actions consist in regulating the shade. Some taking down and composting of infected pods is done. For rodents, chemical products may be used but are not always available. After a cyclone, fallen pods are collected quickly in order to avoid an invasion of mice. Leafcutter type ants (locally known as *bibijagua*) are sometimes spoken of as a limited risk. They can weaken trees and bring pests and diseases by helping them spread.

The majority of the farms have a ground cover describe as reaching 100% or fairly close. This means that there is no place unoccupied by plants. It is to put in perspective with the type of culture studied here. Cocoa trees are usually placed on the basis of 3m x 3m structure (~ 1100 tree/ha) or on the basis of 3m x 4m (considered better by some farmers).

Figure 12 shows the variation of the mean production that occurred due to hurricane Matthew hitting Baracoa. The focus is on the main products of the farms. Declared numbers for cocoa, banana and coco nuts were, respectively, of approximately 12, 10 and 2,2 tons before Matthew. After that event the production was 6,5 times lower for cocoa, a third less important for banana and the coco production went to zero kilogram.

The loss in coco output was the same for all farmers, no more nuts to harvest after Matthew. For bananas, the losses of harvest went from 0 to 75% while for cocoa one farm retained 2/3 of production and the others retained less than 1/3. Mean production of cocoa is of 1,9 tons/ha and ranges from 1 to 2,8 tons/ha. Tonnage for cocoa is expressed for cocoa with pulp.

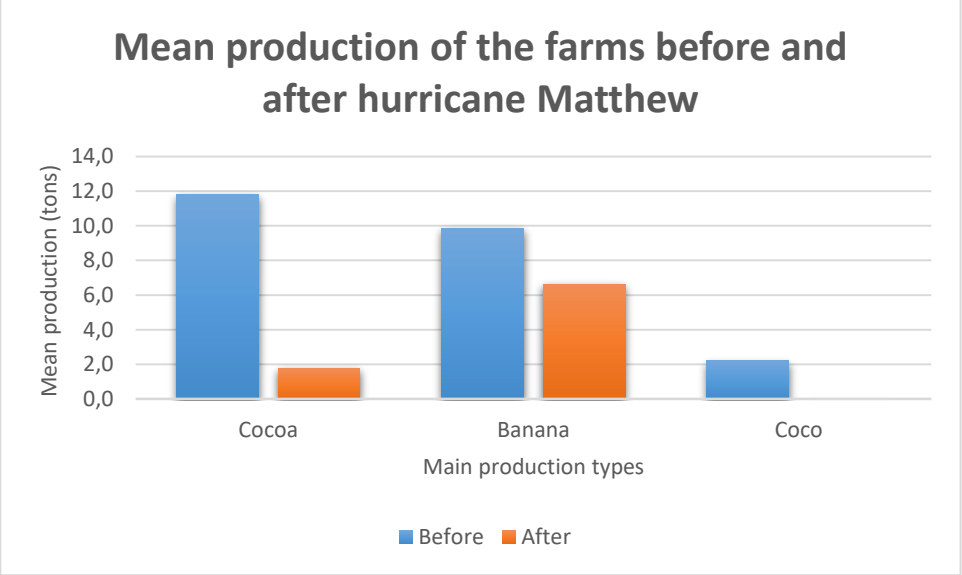

Figure 12: mean production of the farms before and after hurricane Matthew. The three main types of production are represented (cocoa, banana and coco). Tonnage of cocoa is expressed for cocoa with pulp

When comparing the 5 more productive farms (tons of cocoa/ha) to the others, only one factor seemed to make a difference, the slope. When creating a comparison between 3 groups (head, medium, and tail groups) to try to see a gradient, the results in **table 10** appeared. It shows that a land with more slopes produces less than one with medium slope which in turn produces less than relatively flat ground. The area cultivated per worker also seems to explain the difference, at least in part. The total area and cocoa area also form a gradient going in that sense. The limited size of the panel requires to consider the results accordingly.

Table 10: group analysis according to most obvious explaining factors

	Group 1 1-1,3 t/ha	Group 2 ~1,8 t/ha	Group 3 2,5-2,8 t/ha
UBPC or CCS (number of farms)	3 in UBPC	2 in UBPC	1 in UBPC and 3 in CCS
Number of farms from El Jamal, San Luis or Paso de Cuba	3 in Jamal	2 in Paso de Cuba	1 in Jamal 1 in Paso de Cuba 2 in San Luis
Percentage of Traditional, Hybrid or Grafted trees and average age of the plantation	T: 20 H: 26,7 G: 53,3 35 years	T: 2,5 H: 72,5 G: 25 19 years	T: 17,5 H: 11 G: 71,5 32 years
Size of the farm (mean value)	**9,4** ha of farm **8,7** ha of cocoa	**7,8** ha of farm **7,2** ha of cocoa	**6** ha of farm **4,8** ha of cocoa
Area/worker	**3,1** ha of farm **2,8** ha of cocoa	**2,6** ha of farm **2,4** ha of cocoa	**2,7** ha of farm **2,2** ha of cocoa
Owners age (mean value in years)	61	49	71
Slope categories (number of farms in categories A, B or C)	3 C	1 B and 1 A	4 A

4.4 Potential and constraints

As the value chain is regulated by the Cuban authorities, prices are not decided by the markets and buyers. Rather, they are set according to quality by officials and representatives of the tenants of the value chain. The notion of quality is not linked to the flavour directly but more to the sanitary state (diseases, decay …). All in all, the farmers are mostly satisfied with the prices. They have been increased and this was a source of encouragement to the producers. Still they would appreciate further augmentations and say that a decrease of the price would be problematic. Prices for 100 kg are in the order of 850 CUP for cocoa, 65-110 CUP for banana, 65 CUP for coco and 250 CUP for critics (sweet orange).

When asked what potential they see for cocoa production in Cuba and Baracoa, producers are confident that production can be increased. They add that it could be done by increasing cultivated areas and also by increasing yields. Selling prices increase and land planning/developing (e.g. drainage) are things that they mentioned would help achieve that.

The first constraint expressed by the interviewees, to achieve the potential development of the cocoa production, is the lack of plant material. Another important difficulty is to find the necessary workforce. The younger manpower is lacking and there is a phenomenon of depopulation in places. In line with this, farmers also think there is a need to give assistance to producers for better land use, better revenues and improved working conditions. Access to supplies (e.g. fertilisers) also are of concerns. One other worry is the frequency and impact of climatic manifestations to come.

5. Discussion

5.1 Farms

It appears that 2 to 3 people work on a cocoa farm. This is done in family with occasional outside help (1 or 2 persons), the third worker mostly being a son and sometimes a father. It seems that the farmers are educated and in good health. Access to education and health care are strong points of Cuba, which might explain this. Work seems to keep them going too, as the oldest members of the panel are in their early 80's. Consequently, some of them can boast about nearly 60 years of experience with cocoa. The number of people living on the farm can reach 7, they are member of the family such as siblings of the owners, nephews and their parents etc. All in all it looks like it comes from familial/intergenerational solidarity and that not everyone works on the farm.

Part of the diet is produced on the property and farmers can enjoy 3 meals a day. They also raise small livestock in order to get animal proteins (eggs, chicken, pork …). The poultry participate to the farm ecosystem by roaming freely in it. Cocoa drinks are part of the diet and it is made from the farm's second and third quality production. The cocoa produced on the farms is taken out the pods and put into bags but the rest of the transformation happens elsewhere. Though, in order to make their hot chocolate drinks, the farmers have to have notions of the fermenting and drying steps.
They do not have a lavish lifestyle but have access to permanent grid electricity. Water is available on every farm, often by operating a well. Means of transportation can be scarce in Cuba. None of the farmers seemed to have a car. This makes proximity and collective means important things.

With 4 farms in El Jamal, 3 in San Luis and 3 in Paso de Cuba, the two types of collectives and variations in landforms, there is some variation in the sample of farms. Additionally, every plantation has its own proportions of species and cocoa plant varieties. The differences in scales are important too, with the biggest farm spreading on 8 times the area of the smallest, 16 times if cocoa area alone is concerned.

It appears that different perceptions are granted to the main categories of cocoa trees. The traditional allows farmers to have a relatively constant supply of cocoa while the others will produce most of their mature pods in two harvests periods during the year. High production levels seems associated with grafted types whilst traditional types are recognised for their resilience. A major part of them have been around for more 60 years and are still producing. When it comes down to the ability to cope with phytophtora, it is suspected that there might have a location effect. It is hard to separate the apparent copping from the micro-climate these plants are in. It is thought that the added resilience allows the traditional cocoa to grow in more adverse conditions were humidity is reduced. Hence, it would reduce the risks of disease. As for the taste, where traditional is deemed of better quality, there might be a cognitive bias in favour of this type due to reputation and historical presence.

5.2 Cooperatives and downstream systems

With one chocolate production plant in the whole of Cuba, the fact that it is situated in Baracoa makes this city the heart of Cuban cocoa. This monopolistic situation is served by a particular value chain. Every producers will give is production to the same collecting system. Collecting points are situated in places close from farms to compensate for the hardship of transport and at the same time, in easily accessible access to facilitate larger volume collection.

This system of collecting point is used for all products “commercialised” by the farmers. These are mainly cocoa, banana, coco and citrus. The associations of farmer keep track of who produced what quantities. The *viandas* (includes and is mostly banana) follow their own path and so do the fruits. They will end in directly in selling points or in collective structures such as schools. The collecting company (*Empresa agroforestal y coco*) collects all the product in this monopolistic value chain. Productions needing transformation are brought to factories directly or through another organism. For cocoa (and coffee) the UBACC does the fermentation and drying processes for all farmers before the chocolate factory takes the resulting produce in charge.

Collecting of cocoa is scheduled two or three times a week. Fermentation usually takes 3 to 4 days. A phenomenon that occurs is that some cocoa can arrive 2 or 3 days after harvest (pods opening) to the UBACC. The bags are then all considered as being at day 1 of fermentation. This is problematic as there might be a difference between the bags and in that fermentation is spontaneous. Therefor causing to double fermentation time and giving non-homogenous batches.

Quality selection is not based on taste but rather on visual and sanitary state of the cocoa beans. Farmer usually make sure what they send will be number one quality type and keep the lesser beans for their own consumption.

This centralised systems as advantages too. Prices of cocoa is decided rather than submitted to the market. This gives a vision of the prices for some time and is done with producers revenues in mind. Also, a research centre and specialists from the "*Empresa agroforestal y coco*" can help to transmit the knowledge acquired by scientists and provide advices.

The farmers themselves are grouped in cooperatives. It allows them to be benefit from that support, put in common the material and get credit and commercialise more easily. In the sample there are CCS and UBPC types of collectives. The main aspects of dichotomy between them (see **figure 9**) probably makes for a difference in spirit. Though the real dissimilarity perceived *in situ* was that UBPC seemed more equipped. It looked like CCS consisted in a meeting place (little building) whilst the UBPC could propose propagation structures for cocoa and coco plants. Also, not only was there an oxen cart, there was also a tractor. These can serve to bring material to the plantations and collect cocoa as it is not too far (for oxen use).

5.3 Environment, risks and management

Cocoa is an understory tree, to bring it shade other plant species are brought in or kept in place. This diversity makes for a system with multiple crops and services.

The farmers' management system can be described as one that preserve their revenue. They know that preserving the soil and fertility is good for that, so they do it even without direct financial incentives. As it is not easy to get access to chemical products, other ways have been researched, developed and employed. This has produced an agro ecological ecosystem that could quite easily get Bio labels. In return, the cocoa plantations bring eco-systemic services such as soil preservation, cultural identity (strong in Baracoa), visual interest and a wide range of productions.

Keeping all the organic matter they can on site, use of compost is widely adopted. The use of nitrogenous plants is well spread as well, they bring nitrogen and procure some shade.

It appears that managing inundation risks still causes problems as manual drainage is often insufficient. Managing water and humidity especially is key to limit the spread of diseases. Shade management is an important feature in tuning the system. By itself it can reduces losses due to insects and diseases and increase yield (optimal sun gains and low pressure by pests).

Figure 11 showed the dramatic effect a meteorological event like hurricane Matthew can have. Plantation are more resilient than one may think and come back from huge canopy loss and even being laid down and only partly connected to the ground. That said, the plants will not go back to their previous levels of production in just one season. It takes time. Time during which farmers have to work extra in order to bring the plantation back to its former glory. Frequency and strength of these natural events may be factors affecting the viability of a productive system.

5.4 Potential and constraints

For the Cuban cocoa producers there is clearly potential for an increase in both surface of cocoa plantations and intensification (yield increase). While good prices are an incentive to go in that direction, there are some constraints.

The lack of plant material and/or rodenticides have been evoked. There is a constraints that seems greater though, the succession. Not only farmers talked about depopulation but also that younger generations are less interested by this job. Consequently, cocoa trees are not the only one growing older in the plantations. They have accumulated a great deal of experience and it would be a true loss if it was not transmitted. Evolution of a plantation can be slow but its complexity is great given the variety of plants that can be found in them, practical knowledge can help in dealing with that.

Only one small wood workshop was seen, though there are trees on every plot that can become timber or lumber. When collected, beans lose a juice that is called "*miel de cacao"* (cocoa honey). It is not much used but some people ferment it to produce an alcoholic beverage. These two previous examples show that some potential may be left aside.

An estimation of annual spending was previously made for a family of four, it amounted to 30.000 CUP. Solely based on cocoa production and given the average yield obtained (2 tons more or less) and the price of cocoa, a bit less than 2 ha would be required to finance that. Firstly, when looking at statistical figures (ONEI, 2017) for cocoa production (country-wise between 2011 and 2016) for Cuba, the production appears half (with approximations) of what was said by the farmers. Secondly cocoa is not the only production and running the plantation also has costs involved. Therefor only half the given quantities will be taken into consideration and banana and coco will be added to see the result. More or less 6900 CUP/ha for an average farm (6 tons cocoa, 5 tons banana (at65 CUP/100kg) and 1 ton coco) would be earned. This means 4,4 hectares of farm would be needed to sustain a family of 4.

All but one farm achieve this figure. It is a very wild guess based on the data at hand and using big error margins. Yield may also vary greatly from year to year. These farms also provide their owners with part of their diet and also other conveniences like medicinal plants. The diversity they offer brings resilience to the system and also to the farmers as not all crops will behave the same way.

The little exercise in the previous paragraph shows that possessing more robust data on a wider scale could allow to better characterise the cocoa plantation and envision their future. Knowing what surfaces are available to new plantations could help see the potential of development. The other approach is to increase yield. Doing so in keeping with agro-ecological concepts implies to reach for ecological intensification. The agroecosystem regulation services and biodiversity can be pushed to increase this kind of intensification. The fact that supply of plant material and workforce is scarce could be a major constraint to the development of the sector, both for expansion and intensification. Finding out what could attract younger generations to this production seems important as without them there is no future but only lost potential.

When looking at the differences in yield between the farms, neither the village, nor the type of cooperatives seemed to make a difference. The same goes for the proportion of cocoa tree varieties or the age of owners or plants. The only thing that seems to make a difference is slopes, flatter plots are the one which produce the most cocoa per hectare. One farm in group 3 (see **table 10**) has 2 people working 10 ha (one of the biggest) but 6 persons are living on the farm. The four other (among which 2 adults) are not considered as working on the farm. Though, they could help and this would bring numbers down for area/worker factor. The area per worker, both for the whole farm and for cocoa plots, could thus be another factor. The total area and the cocoa area of farms seems to go in that direction too. It is even possible that the ratio of cocoa plays a role.

All this could be linked to two main themes, fertility and ease of work. A flat area has more chance to keep its soil and fertility than one with important slopes. It might also influence the quantity of water available to the plant. A flatter surface is also easier to take care of. The ease of work is increased with the reduction of land per worker. This way, more time and care can be given to the cultivated area. The factors are taken mostly as mean values, the values composing them may go against the established gradient based on these averages. Only when talking about slopes is it clear for all the farms. From what is written above, a family of four with 2 working adults could take care of 4 to 5 hectares (given some punctual help through cooperatives or relatives and friends) with a good yield. From what was estimated previously, this amount of land is also what it would take to sustain such a household.

Looking at how varieties of cocoa trees can be used to match the micro conditions in the landscape has the potential to lead to a yield improvement. In the same order of idea, shade management is key to a good production. Before Matthew, a lot of cover was too important. Because of the lack of material and the risk cutting it represented, it was left in this situation.

Many farmers said that this hurricane also brought better conditions and yield as it felt down excessive canopy cover, shade is now more closely managed. Lastly, as Cuba is a little player in the world of chocolate, its interest (apart from serving domestic needs) is to produce high quality products. Research on different categories of quality and work on the collecting system could help improve that. The idea of decentralised (but collective) fermentation and drying systems could help increase quality. What is more, Baracoa is city with an interesting appeal, it is the place to see in the province. With its chocolate culture, its natural environment and key features in the landscape, it could be the image of Cuban chocolate abroad. Another part of the cocoa landscape is the *algarrobo* tree. With its wide-span branches covered in epiphytes, it has the potential to host an interesting ecosystem with possible use for cocoa. Visually it is a significant piece of the plantation, giving it a certain mysticism.

Conclusion and perspectives

In order to assess, understand and judge the potential of the production of cocoa in the *oriente* region of Cuba (Baracoa), several objectives were set. They allowed to address several topics.

The first objective permitted to picture what a cocoa plantation in Cuba might look like. The average farm seems to consist in 2 or 3 people working on a mean value of 2 to 3 hectares per person. On this land, a great diversity of plant exists and some small livestock is reared for proteins. Some crops are only for the household whilst main commercial productions are cocoa, banana (plantain), coco and citruses. The diversity in the farms is variable in land relief, land size, proportions of cocoa varieties, etc. Three categories of cocoa are referred to: traditional (oldest), hybrid and grafted. A larger sample should be investigated to reach a better precision and sufficient mass for statistical purposes, mostly on landforms (or ecotopes), flora composition, yields and the people working in the farms. This would also allow to look further for groups of farms along the gradients of chosen factors.

Regarding the second objective, though the type of cooperative system does not appear to influence yield, there seems to be a real difference between the two types encountered (more services proposed by UBPC). Understanding the cooperative system is important as it concerns all producers. Collective and monopolistic, the value chain of cocoa is alike Cuba. Farmers are regrouped in collectives where land is either privately owned and independently managed (CCS) or the opposite (UBPC). Collecting points are close to the farms and used for all main productions. Fermentation and drying and later processing of cocoa are done away from the farms in centralising factories. The choice to go for the farm scale to do the inquiries appears to be sound in retrospective as it is the epicentre of the cocoa production environment. This did not forbid to pay interest to smaller (ecotopes) and bigger scales (cooperatives). As suggested by the theoretical framework, this multiscale approach was useful as cooperation is an important part of the system. These structures could be evaluated for fermentation and drying at village scale, in order to seek better quality.

Farmers are down to earth people and manage their land with the aim of making a living. Given the Cuban context of "isolation", they go after that goal with agro-ecological concepts. In return, the cocoa plantations bring eco-systemic services such as soil preservation, cultural identity (strong in Baracoa), visual interest and a wide range of productions. The main natural risks they face are the black pod disease, some insects and rodents, as well as excess of water and strong winds. They try to act early on to limit damages. Though it caused many damages, hurricane Matthew helped to retake the hand on shade management, which is important for good yields, by taking excessive cover down. Through the third objective it was possible to identify the possible impact from and to the environment and it showed the use of eco-systemic services. It also gave food for thoughts regarding the potential of cocoa production.

When looking at this potential, farmers say that new plantations and (ecological) intensification are possible ways to increase production. The main limitations they see is the lack of material (plant and products) but more importantly the lack of a younger generation to take over. The diversity an agroforestry system like the one of cocoa under agro-ecological principles brings a whole range of opportunities. Other plants in the system can be sources of revenue, medicinal and timber making plants for example. Other possibilities are the exploitation of secondary products such as the transformation of *miel de cacao* into an alcoholic beverage.

In conclusion: given its market size, Cuban cocoa has an interest to play the quality card and Baracoa could give it the image to represent it. Further investigation should be done on improving yields, quality and quality management as well as how to awake the attractiveness of Baracoa's chocolate to the world and younger Cuban generations.

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