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COFFEE FARMING, FOR ETHICAL AND HIGH-END COFFEE IN UGANDA

International Master 1 "Science and Technology of Agriculture, Food and Environment"

YEAR 2021 – 2022

FROM 01.05.2022 TO 31.07.2022

Tutor teacher: Isabelle Michel

Internship supervisor: Shakeel Padamsey

Summary:

As part of my first year of the international master "Science and technology of agriculture, food and environment" at the Agro Institute of Montpellier, I did one from 01.05.2022 to 31.07.2022 at The Coffee Gardens, Uganda. This company is based in the east of the country, at the foot of Mount Elgon. It works directly with farmers and offers its European customers ethical and premium coffee.

The missions of this course are the realization of a guide on the maintenance practices of the coffee tree and the participation in the implementation of a new water treatment plant. Thus, we will see in this report the agrarian diagnosis carried out to understand the practices of farmers and a step back on the development of the guide. The second mission will not be developed specifically here.

Thus, the study carried out showed that coffee cultivation is an interesting cash crop for farmers. In addition, the guide made it possible to popularize scientific and technical knowledge for the assistants.

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THANKS

First of all, I would like to thank THE COFFEE GARDENS for the trust it has placed in me and especially Mrs. Line COSMIDIS without whom my internship would not have been possible.

I also thank Mr. Shakeel PADAMSEY, director of the company and tutor of my internship who knew how to supervise and guide me during the realization of my missions by encouraging and advising me.

I would like to express my gratitude to all theteams that accepted me within the structure by facilitating my welcome and integration by showing me the team spirit that reigns there.

I also address my sincere thanks to my teacher tutor Mrs. Isabelle MICHEL for her follow-up during these 3 months of internship, her indications and advice that were beneficial to me for the writing of my report.

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I. INTRODUCTION

As part of my first year of the international master's degree "Science and technology of agriculture, food and environment" at the Institut Agro de Montpellier, I did a 13-week internship in a company. It took place from 01.05.2022 to 31.07.2022 at The Coffee Gardens, Uganda.

Uganda is an East African country, in the heart of the Great Lakes region. It has been chaired by Yoweri Kaguta Museveni since 1986 and its official language is English. Its area is 236,860 km² for 45.74 million inhabitants (France Diplomatie, 2022). Uganda has traditionally been a tea-consuming country and the few coffee shops currently open in Kampala are a relatively recent phenomenon. Local consumption accounts for only 9 tons, or 4% of national production (Department of Agricultural and Rural Development, 2003).

Thus, the coffee produced is mainly exported to European countries by large companies. As part of this dynamic, The Coffee Gardens also exports its coffee to this destination, while making it a point of honor to the traceability of its product and offers high quality coffee. : specialty and ethics. Located in the east of the country, this region combines all climatic and soil conditions (volcanic soils, high altitude, shade) to produce world-renowned Arabica coffee. Indeed, Arabica coffee from Mount Elgon is an appellation recognized for its quality.

Based for 6 years in the village of Chambongo, located on the Mount Elgon range, The Coffee Gardens' micro-treatment plant sorts, washes and driesthe coffee of its farmers. The company works directly with small family farms and offers a wide range of social and environmental programs.

My main mission of this internship is the development of a guide for assistants responsible for training and raising awareness among farmers. The objective here is to limit the number of sick berries or poor quality representing a loss for the company. The challenge here is to popularize the scientific and technical knowledge of good cultural practices to support the discourse of the assistants. Thus, the guide will be a tool to improve farmers' practices by supporting the speech of the assistants.

Then, an agrarian diagnosis on an agricultural explanation of the village of Chambongo made it possible to refine the understanding of a farming system in the region. It is based on the obtaining of data obtained in the field.

In this report, we will first see the context and the request for the internship followed by the study of the agricultural dynamics and types of farms of the region. In a third part, a zoom on a farm will be done and finally, we will return to the development of the guide.

II. BACKGROUND, INTERNSHIP APPLICATION AND DEVELOPED ACTIVITIES

A. Uganda's Mbale region: an ecological niche for high-end coffee

1. Coffee in the world

Of African origin, coffee finds its cradle in Ethiopia and will be diffused at the end of the fifteenth century in Arabia then, thanks to botanists and navigators, it landed in the seventeenth century in Indonesia and Reunion, before conquering Martinique, Cuba and South America (A. Conesa, 2006).

Today, the Coffee is the most consumed beverage and is the first agricultural resource Exported to the world. The production Coffee is estimated at around 170 million bags of 60 kg in 2020/2021 (Commodafrica, 2021). It is Dominated by Brazil which provides one one-third of world production Followed by Vietnam and Colombia (Atlasocio, 2022). The market of coffee is booming as emerging countries have increased their consumption and are showing a strong Interest in specialty coffees. Despite the expansion of the sector, recurrent market imbalances andUnequal Distribution of income among market participants Threaten some million small-scale producers (FAO, 2022). Indeed in producer countries, Coffee is a source of income and employment for small family farms (CIRAD, 2022). The figure 1, opposite shows well of Wide variations over the last 4 years and has reached its lowest prices, especially on the 2018 period/2010, correspondent To the Covid-19 health crisis:

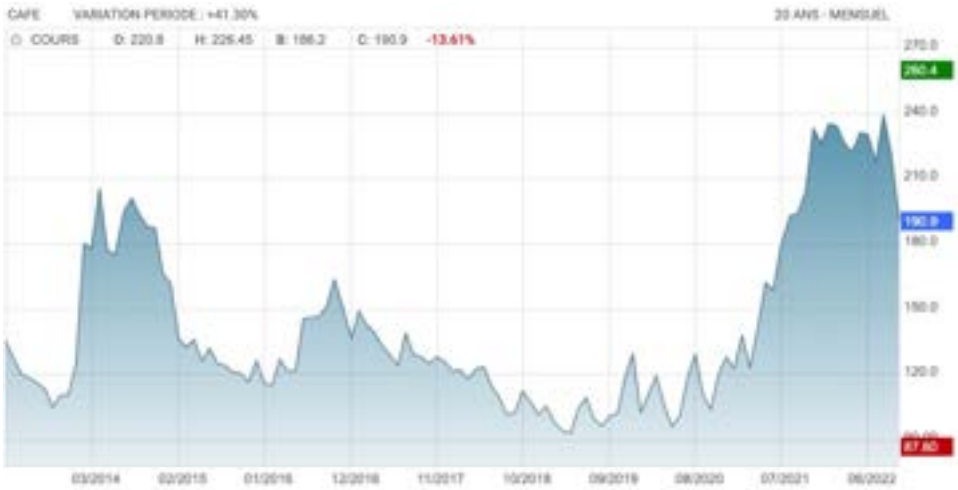

Figure 1/ Changes in coffee prices between 2014 and 2022. Spring: ABCBOURSE

2. The place of coffee in Africa and Uganda

On the African continent, producing countries are on the coffee belt, between the tropics of Cancer and Capricorn. Coffee is generally little consumed by local people and is mainly used as a cash crop.

In Uganda, the coffee industry is a key pillar of the economy. After Ethiopia, it is the^{2nd} largest exporter of African coffee and recorded 2.7% of world productionin 2022. Coffee is grown by more than 98% of small family farms and an average farmer produces one to two tonnes of coffee (R. Asselin et al. 2022).

There are two types of coffees marketed: robusta and arabica. Uganda exports almost all of its production; 20% Arabica and 80% Robusta (France Diplomatie, 2022). Annex 1 describes the ideal agronomic conditions for thesetwo varieties and their ranges in the country. Thus, the vast majority of

robusta coffee is grown throughout the territory, in the countryside and on the sides of Lake Victoria, while the arabica variety is grown on the mountains close tothe eastern and western borders, offering more favourable agronomic conditions.

3. The region of Mbale, a favorable area for the trade of coffee to high standards

The course took place in the east of the country, at the foot of Mount Elgon in Mbale. This city borders Kenya with which it shares themountain. This mountain offers the ideal agricultural conditions for the cultivation of Arabica coffee: altitude and fertile soils because volcanic. The introduction of this variety into the region is presented in Appendix 2.

Climate tropical present is also a Advantage for its culture since it is characterized by abundant rains all at Throughout the year and Two dry seasons: December to February and June to August where precipitation is less (Larousse, 2022). The Mbale umbrothermic diagram in the figure 2 Opposite highlights its different characteristics:

Thus, we see that in Mbale, the average annual temperature of the city is 20.3 ° C where the month of February is the hottest with 21.7 ° C and the coldest is in June with 19.5 ° C. Regarding precipitation, there is 7,139 mm annually where April records the highest rate with 962 mm and July is the driest month with 254 mm on average (Climate Data, 2022).

Figure 2/ Mbale umbrothermic diagram. Source: Climate Data, 2022

All farmers working with The Coffee Gardens (TCG) locate on the mountain of Mont Elgon. Thus, thehe main station of collection and micro-processing of The company Is à Chambongo, located in the middle of the ideal altitude for Arabica coffee. Le Office of Operations east in Mbale, located at 230 km of the capital Kampala. The figure 3 opposite represents the topographic profile ranging fromu Lake Victoria at Mont Elgon:

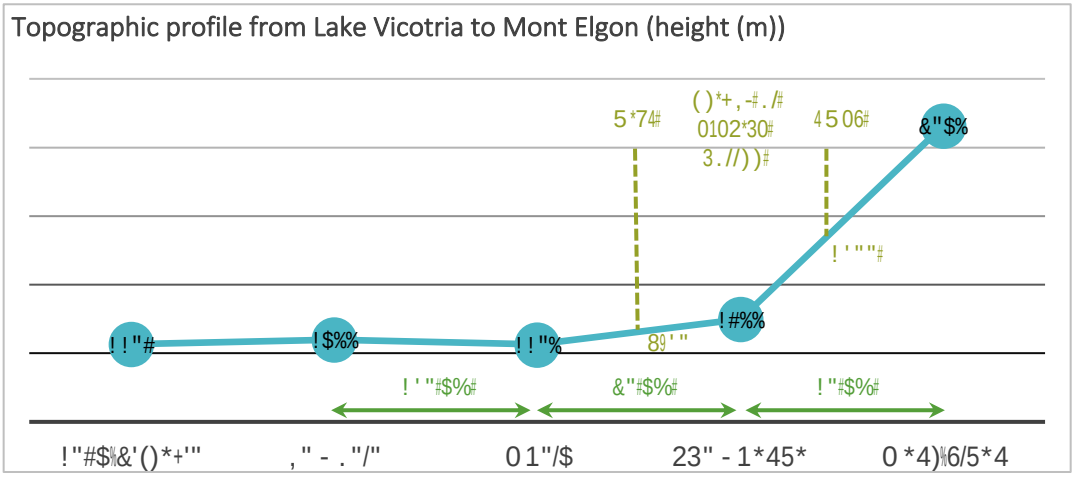

Figure 3/ Topographic profile from Lake Victoria to Mount Elgon. Source: Author

B. The sponsor and the internship location: an English company for an ethical and high-end coffee

1. Organization of the coffee sector in Uganda

At the national and international levels, these are the private sector entities IACO (Inter-African Coffee Organisation) who mainly control the marketing of coffee. In Uganda, since the liberalization of the sector in 1991, 22 private sector exporters have been responsible for its international marketing. and who also control theDomestic channels of trade : processors, roasters, collection centres. The figure 3 Following schematize internal organization marketing of the coffee in Uganda, details can be found in Appendix 3:

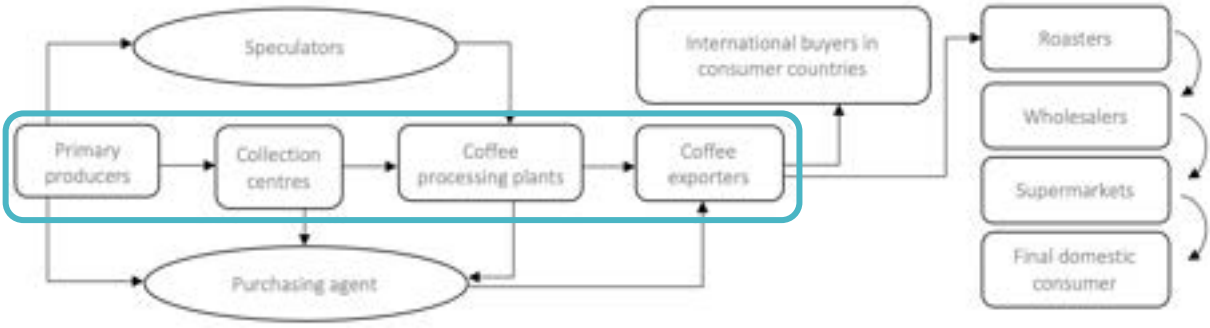

Figure 4/ Domestic marketing circuit for Ugandan coffee. Source: Department of Agricultural and Rural Development, 2003.

Thus, on this diagram, the place of The Coffee Gardens (TCG) in the internal circuit of coffee marketing is circled in blue. Indeed, the company manages from the collection from farmers to the export of coffee. It is also in contact with international buyers in consumer countries which are mainly European countries. Details of the organization of coffee collection and quality controls can be found in Appendix 3.

2. Presentation of the structure

TCG was created in 2016 by Shakeel Padamsey and Dana Siedem, already established in the Masaba region of Mbale, and wishing to offer a product combining high standards of quality (speciality coffee) and ethical sector. From the beginning of its activities, the farm has taken care to participate in the local development of its region of establishment. In addition to creating more than 200 jobs for people in the region, their presence has enabled the local government to bring electricity to the village of Chambongo, where the coffee collection and micro-processing station is located. Indeed, TCG buys the coffee berries of about 500 farmers based on the world price of coffee, thus supporting self-entrepreneurship.

In addition, the company is concerned about the environmental impact of their activity and that of their farmers. Indeed, it is vigilant on the effects of their activity on the environment or on the use of chemicals by farmers for example. It then offers training on their proper handling. This shows farmers that TCG is also concerned about their health, which reinforces their desire to want to work with the company.

Finally, to support their social commitment to farmers, TCG makes its products completely traceable for its customers. Thus, data such as transport costs, the origin of coffee and the price received by farmers per kg of coffee are made available.

In order to understand the hierarchical organization within TCG, here is Figure 5 presenting the organization chart of the company:

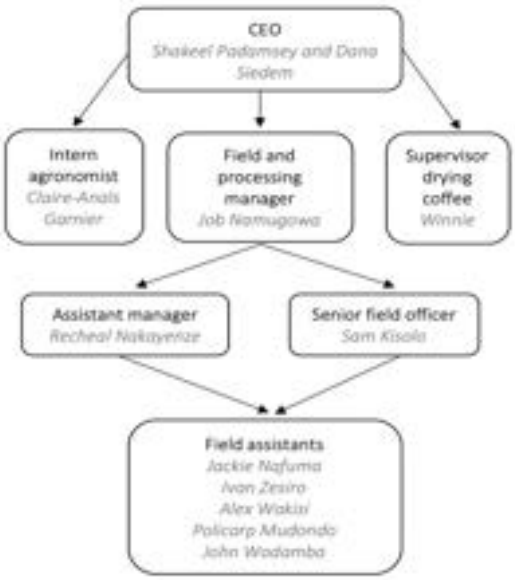

Figure 5/ TCG organizational chart. Source: Author

TCG is led by its founders Shakeel and Dana. They manage its general organization, coffee certification and coffee export.

In Mbale, Winnie takes care of the transfer of coffee to the capital and the classification of coffee. At the same time, she trained in Kampala on coffee quality.

The managers mainly manage the process of collecting, cleaning and drying coffee as well as training assistants.

The assistants, divided according to altitudes (high, medium and low altitudes), are responsible for training farmers.

3. Challenges and company strategy

To provide high-quality, ethical coffee, The Coffee Gardens is reducing its losses: mature berries but damaged (by diseases or pests) and loyalfarmers, not bound by a contract.

Indeed, when farmers bring their harvest to the collection station, the selection of compliant coffee berries is based solely on a colorimetric criterion, as shown in Annex 4. Thus, to reduce the number of damaged mature berries and therefore its losses, the company encourages good cultural practices and conducts awareness-raising actions to combat diseases and pests.

In addition, like many agricultural producers in Africa, Farmers have little power and are vulnerable to market variability. Indeed, even though they produce the raw material, they are the last level of the supply chain.

Figure 6/ List of The Coffee Gardens program offerings. Source: R. Asselin et al. 2022

Added to this is the fact that coffee cultivation is sensitive to weather variations and harvests fluctuate according to the seasons. As a result, market prices fluctuate, making the financial situation of farmers unstable.

To combat this, one of TCG's key strategies is to make a point of loyalty to their producers through social programs. The aim is to encourage them to invest in coffee cultivation. To do this, TCG invests in its farmers by training them on various aspects (environments, practices ...) to make them and their community autonomous. To this end, it proposes various social programmes shown in figure 6 below:

4. Zone of actIvity Main

Figure 7/ Relief map of the main TCG action area. Source: Google Maps

Figure 7 shows TCG's main area of activity: framed in blue, the operations center is in Mbale where meetings with managers or partners are organized;he coffee collection and micro-processing station is located in the village of Chambongo. Its position and the range offarmers working with TCG are shown here in red.

5. Presentation of the missions

After the harvest period, the workload of farmers and the team is less. TCG then took the opportunity to prepare for the next season. For this, itmoves its main station and trainsfarmers on the proper maintenance of coffee trees, to limit its losses. As a result, itconfirms its establishment in the area.

This is also the time for managers to take their leave inEurope. Thus, during their absence my role is to be the relay on the ground for the period from 01.05.2022 to 31.07.2022. My missions are then part of the two objectives mentioned above.

The first mission is on the treatment of coffee shelling water. Increasingits number of farmers TCG moves to Bumwawule village. The new site is located on the Chambongo border and will have a greater production capacity. Indeed, thecurrent micro-treatment station does not treat and it is then an opportunity to set up a more efficient station. In this report, this mission will not be developed but is in Annex 5.

The objective of the second mission is to reduce the number of ripe but infested berries (by a pest or disease) by training farmers on the good performance of their coffee trees. Thus, my mission is to support a training program for farmers. To this end, a guide listing good practices will be developed. It is intended for assistants who, supported by managers, will have to train farmers.

The main challenge here is to offer a practical and synthetic interface and content. In addition, since assistants have received a minimum level of education, it is important to adapt this support to their abilities. Indeed, the guide deals with technical or scientific themes for example. My role is then to popularize this knowledge by using vocabulary and easily understandable sentences.

In addition, the guide is written in English, which is not my mother tongue and will be translated orally by the farmers' assistants into the local dialect, Lugisu. It will be important to communicate scientific knowledge to them in a clear and simple way so that they can in turn deliver the right messages to farmers.

6. A guide to the maintenance of coffee trees: realities on the ground and implementation

- Realities on the ground

Moving from Mbale to Chambongo requires organizing with the whole team because a manager has to accompany me on the field. The weather conditions also count because in rainy weather, the tracks are impassable, even dangerous. In addition, the journey lasts 1h30 and the roadsmust be passable by motorcycle, especially on the steep paths for Chambongo. Therefore, justifying my coming to the whole team is important.

- Contextualization

To offer a guide adapted to farmers and corresponding to TCG's expectations, it was first necessary to: target the expectations of the company, understand therealities of farmers and above all, understand the context in which I was going to evolve. For this, I asked myself:

"How can you produce a guide without knowing all the realities of farmers?"

"How to investigate in the field with complex logistics?"

Thus, to understand my environment and answer thesequestions, I relied on different resources:

- Personal bibliographic research
- The document "*AO coffee 100301 Internal Stakeholders' Feedback* " in Appendix 7
- Field surveys of managers/farmers, example of a set of questions in Annex 8

Thus, this first phase of contextualization and reflection makes it possible to develop a first version of the guide. This phase is essential to take a step back and understand the agricultural dynamics of the study area.

- Implementation of the guide

Once the contextualization work is done, the guide is presented to the entire team. This second phase took place in several stages:

1. Presentation of a first version of the guide to managers
2. Presentation to assistants
3. Putting it into practice in the field

III. RESULT 1: AGRICULTURAL DYNAMICS, COFFEE AND FARM TYPES

This part is based on personal literature research as well as interviews with Sam Kisolo and Francis Wanyina Bwayo.

1. History of coffee in Uganda

To get an overview of the history of coffee in the country, here is Figure 8 opposite:

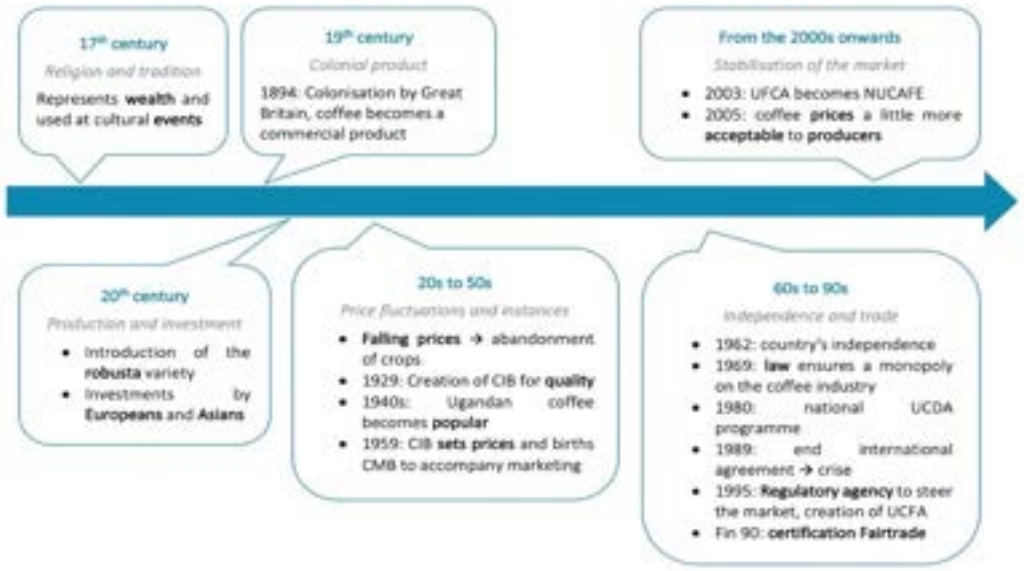

Figure 8/ Timeline of the history of coffee in Uganda. Spring: AAuthor

In the seventeenth century, in the kingdoms of Buganda, Ankole and Buyoro that constitute present-day Uganda, coffee is considered a sign of wealth or used in traditional medicine. Colonized by the British Empire, it is in the nineteenth century that coffee is marketed.

In the early twentieth century, Arabica coffee was grown on a small scale by small farmers around Lake Victoria or on large farms owned by European and Asian investors. In 1920, the price of coffee fell and pushed to abandon its cultivation but Great Britain reacted and created the CIB (Coffee Industry Board) in 1929. It ensures the quality of coffee and the CMB (Coffee Marketing Board) in 1959 is created to accompany the marketing of coffee.

In 1962, the country became independent and wanted to invest in coffee. Thus, in the 70s, he passed a law giving the CMB the monopoly of the industry. Then, in 1980, the UCDA (Uganda Coffee Development Authority) program was launched, the objectives of which were to: modernize production or rehabilitate processing facilities, for example.

Thus, production increased sharply until 1990 and stopped following the termination of the International Coffee Agreement. For example, the Uganda Coffee Farmers Association (UCFA) was established in 1995 and serves as a regulatory agency and market pilot. The coffee sector is privatized and liberalized in all OPCW (Inter-African Coffee Organisation) member countries, without government control and with minimal regulation.

Finally, UCFA becomes NUCAFE (National Union of Coffee Agribussinessesand Farm Entreprise). It helps and trains farmers to improve the quality of their coffee and accompanies them in negotiations on selling prices to buyers. Today, the price of coffee is still controlled by UCDA and multinationals dominate the market selling coffee worldwide (Ministry of Agriculture, Animal Industry and Fisheries, 2015). (Coffee Seed, 2019)

2. Coffee in the Mbale region

- Introduction of the Arabica variety in the region

Before the introduction of coffee, the town of Mbale was an important purchasing point for the elephant ivory trade. The Arab populations went there in particular to trade. When introduced by settlers, coffee became a cash crop because Ugandans do not consume it. In the region, the main ethnic groups are the Bantu and the Sabin who grow the Arabica variety.

Thus, the locals began to grow coffee on Mount Elgon for export. Some have tried to identify fertile places to plant coffee and have climbed to altitude to provide the best conditions for this crop. These new locations also made it possible to have new perfumes and aromas that are an added value for its marketing.

In addition, the money collected through this cash crop has played a significant role in the education of the local population. Indeed, she was able to send her children to school thanks to a certificate issued after the sale of the café where the amount received was indicated. It was then used as evidence to justify the parents' financial capacity to be able to afford their children's school fees.

Nowadays, coffee has an important place in the region because large private collection and export companies such as Bugisu Cooperative Union for example, have settled and have the monopoly of coffee. The locals continue to grow food crops and use coffee as a cash crop and sell it mainly to large private companies.

- Geography and economy

As previously observed in Figure 7, Mbale is a border area in Kenya, so itslocation is strategic for the exchange of goods. T he roads are paramount in these exchanges and Figure 9 below shows the main roads in Uganda. It isnoted that all theseroads converge on the capital Kampala, the place of exportand import of goods.

Thanks to this map, we see that Mbale is located at the crossroads between Kenya, northern and western Uganda. A single main road connects Mbale to its capital Kampala and a single main road, bypassing Mount Elgon, connects it to Kenya.

We also see that the west of the country is better served by main roads. This is partly explained by the presence of nature reserves, attracting white tourists: European and American. The east of the country has less tourist attractiveness, but the ascent of Mount Elgon and the juxtaposed Kenyan nature reserve nevertheless attract a minority of these tourists.

Also, as we can see on the map in Annex 8, Arabica coffee grown in the East is concentrated in the Mount Elgon area while in the West of the country, the cultivation area is more extensive. However, even if the road network serves the West better, it remains far from the capital. In Mbale, for example, goods arrive more quickly at local markets because of the proximity of Mount Elgon. In addition, the state of the roads is very important and the road linking Mbale to the capital is in better condition and shorter than the one linking it to Kasese for example.

Thus, the location of Mbale is of strategic interest in the transport and tradeof goods for Ugandan national and international trade.

Figure 9/ Map of major roads in Uganda. Source: Logcluster

- Land acquisition and farmer profile

In the region, the acquisition of plots is done by purchase or inheritance. Anyone can buy land and even in different places; altitudes/ villages. Theinheritance is more complex because there are many families (between 5 to 10 children) which, in the siblings, gives rise to : interest in cash crops (coffee, maize, etc.) or the framingof plots (divided equally between each boy).). For more details on the family organization of agricultural work, see Annex 9.

Thus , farmers have their plots spread over the whole village or on different altitudes. Depending on the size of their plots, there are different profiles:

- Small farmer: less than 1 hectare of coffee
- Medium farmer: between 1 and 2 hectares of coffee
- Large farmer: more than 2 hectares of coffee

It is also possible to rent or lend land between village members as the sense of community is present in this area. They may be renewed annually and paid either in currency or for services rendered.

- Agricultural activities and diagram of a coffee system

In the region according to the topography, we distinguish different cultures:

- In the plain: plantain, robusta coffee, rice (relatively rare), beans ...
- Altitudes: plantain, arabica coffee, tomato, beans ...

Thus, the figure 10 below gives a schematic overview from the organization of'un system agroforestry associated with 3 strata. Dans, this system, on distinguishes several vegetative strata where the cultures present have interests different. They are described in the table 1 next:

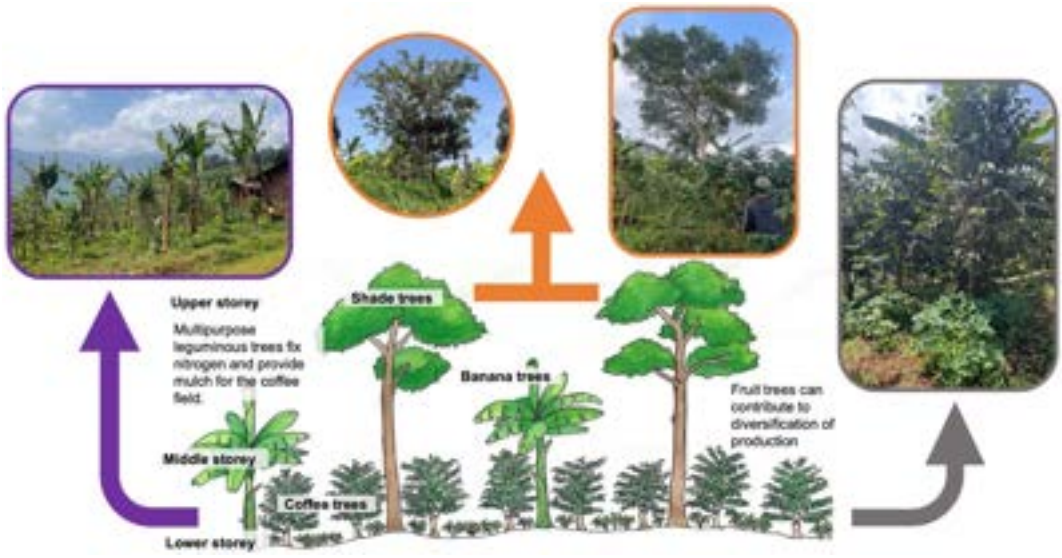

Figure 10/ Schematic representation of an agroforestry system associated with 3 strata. Source: Author

	Lower stratum	Intermediate stratum	Upper stratum
Height	0 < 0.8 m (depending on the species cultivated)	0.8 < 2 m	> 2 m
Type of crop	Self-consumption + Local sales	Self-consumption + export	Sale + Local sale + Shading
Species present	Legumes: Bean, pea, peanut Bulb: onions, garlic Tuber: Yam here *"Coco Yam"*, carrots, potatoes Cereal: corn Solanacea: tomato, eggplant Other: "*skomawitch",* passion fruit	Arabica coffee	Banana and shade tree: avocado, "*Gukuyou*", "*Gusavasse*", "*Gugniamaniama* ", "*Tatouse* "

Table 1/ Table of crop types of a coffee system according to vegetative strata. Source: Author

As Table 1 shows, within coffee gardens there is a great diversity of cultivation, especially on the lower stratum. Indeed, crop rotation differs depending on the cropping calendar, the configuration of the plot or the financial / vital needs of the farmer.

It also sees that the crops are intended for own consumption or sale; in local or international markets (especially coffee). More details on the organization of markets and the choice of crops are provided in 10. Cash crops are, for example, maize or potatoes driven by motorcycle cultivation and are consumed by the population, unlike coffee, which is rarely consumed.

- Age, origin of plants and quality of coffee seeds

On the plots, coffee plants can be found at different stages of their life cycle: from the state of young shoots to a 40-year-old tree. Indeed, farmers make sure to renew their generations of coffee trees because the coffee tree gives different yields depending on its age:

- Young: between 5 and 20 years: the tree has a small canopy and good yields, but its berries are not of very good quality
- Elderly: more than 20 years: the canopy tree is more developed, yields are lower, but the berries are of good quality

Note that the approximate age of the cafiers of farmers working with TCG are on average less than 30 years old: the trees are not too old and even if they have lower yields, the quality of their berries is better, something that TCG is looking for. Regarding the origin of coffee plants, farmers have different ways of obtaining them:

- Use their own seeds, see Annex 11 for the germination process
- Buy/trade between farmers
- Buy in a coffee nursery

Thus, many unclassified varietiescirculate which makes the traceability and classification of Arabica coffee difficult. Indeed, the Ugandan government has not imposed strict regulations and control on the origin of seeds: absence of border controls, seed certification agreement without real control for example ... This does not invite farmers to turn to nurseries and encourages them to use their own seeds.

- Agricultural and coffee dynamics

In the region, around Mbale, we notice the main crops are those of banana trees, tomatoes, it is the cultivation of bananas that is the majority. The agricultural activities of farmers are organized around the cultivation of coffee. Indeed, it punctuates their work because the berry harvest season extends from August to February and requires a lot of attention as well as labor. This is the time when the peak of work is the most important.

Indeed, this culture requires a lot of vigilance and monitoring because:

- Manual work because it is not mechanized
- Harvest at the right time
- Monitor remote/nearby plots
- Maintains

But they do all this because there is a huge economic interest since they do not consume coffee so everything for sale

Farmers are indeed not mechanized, and the picking of berries is weekly: on the branches, the berries are at different stages of ripening. It is therefore necessary for farmers to be sharp to pick the berries at the right time; nor too ripe or too ripe.

This workload is important both for farmers growing on plots close to their place of residence (surveillance) and is accentuated for those with plots spread throughout the village or at different altitudes because they must travel more distance.

During the off-season, farmers take care of their plots and maintain their trees: they plant new plants, prune, cut, treat against pests and diseases ... The different techniques are detailed. This interview prepares for the following season and aims to obtain a better harvest than the previous one.

Finally, the coffee tree cultivation, makes it possible to generate a more or less important income to farmers. Depending on their earnings, they can invest differently in their agricultural activities such as raising chickens, cows or goats but also growing coffee or others. As a result, they must also devote time to these different agricultural activities.

IV. RESULT 2: AN ILLUSTRATION

To understand how a coffee system works, accompanied by a translator, I interviewed farmers. Note that some data will not be complete.

1. Family trajectory

- Presentation of the farm and agricultural activities

A field survey in the village of Chambongo, interviewed a farming couple. The figure 11 Below describes their agricultural operation:

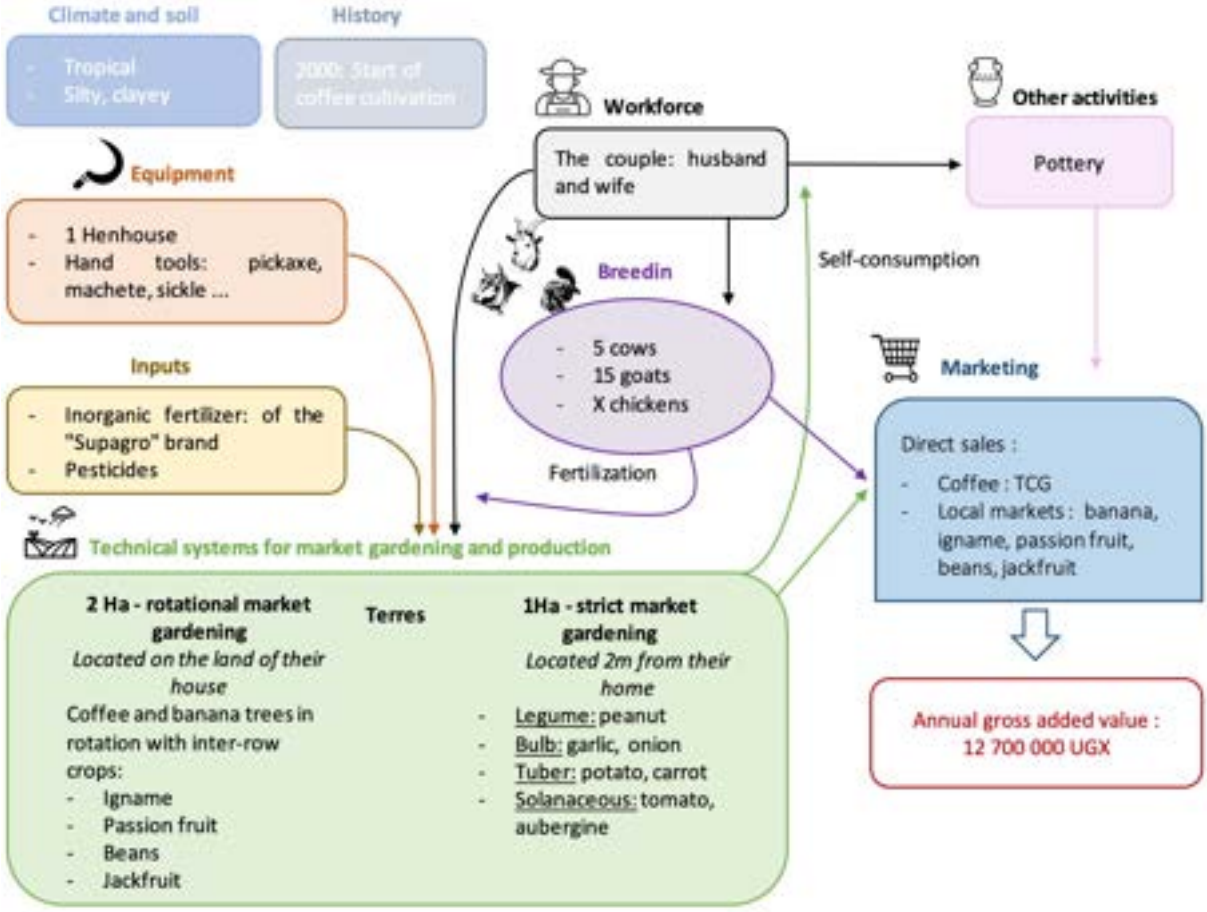

Figure 11/ Operating diagram of the holding. Source: Author

The farmer inherited half a hectare and over the years bought the rest of his plots from his neighbours. There are two cultivation systems on its plots: strict market gardening on the plot of 1 Ha and market gardening in rotation with the cultivation of coffee and banana. Most of the crops on the farm are food crops for own consumption and coffee is the main cash crop.

Before starting coffee cultivation in 2000, thepair grewcabbage, sunflowers and tomatoes, crops with a high demand for sunshine. When he realized the financial interest of growing coffee, he adapted his farm to his needs: plantingshade trees and inter-row food crops.

Then, the location of their coffee crop is strategic: placed on the largest plot and located next to their home. This makes it easier to monitor their coffee berries, coveted for their high value. Indeed, as there is no physical delimitation, during the harvest season, individuals enter their plot to steal coffee berries. This loss represents about 5 kg, which is not significant.

Regarding the plot of 1 hectare, its production is intended for their personal consumption. However, farmers grow garlic and onions, some of which are destined for sale in markets.

As for weed management, it is the husband who manually weeds his plots. It takes him about 3 weeks to weed them completely. In addition, weeds grow back quickly: the vegetation cover returns between a week and a month approximately. He performs this task during the rainy season and composts the organic waste generated by this cutting or sometimes adds it to the diet of his animals.

Other agricultural activities allow the couple to have a financial contribution during the off-season of coffee. Indeed, even if they take care of them a little every day, their animals are intended for sale. They allow them, for example, to pay for their grandchildren's school or to help their neighbours financially. Pottery is mainly practiced during this off-peak period.

Finally, even though their children (two) have started their own homes, the couple continue to help them financially, by sharing their crops or buying them food, clothes for their grandchildren for example. They also bought them 5 hectares in the same village so that they could cultivate them. After their death, the total of the inherited plots will be divided in two.

- Plot organization, the place of coffee in the farm

Figure 12/ Aerial photograph of a farm in Chamgongo village. Source: Author

The couple has been growing coffee for 22 years and working with TCG for 4 years. According to them, theThey do not have an excellent yield but they produce good quality berries, which corresponds to the expectations of the company. In the long term, farmers want to acquire more land for continue to invest in coffee cultivation. The figure 12 opposite represents their current operation.

On the plot of 2 Ha, the rows between coffee trees are irregular: some are very glued to each other, and others are more spaced. This difference in configuration is explained, for example, by the absence of inter-row crops at the time of observation: after a harvest or the land is left to rest. Farmers know the location of each of their crops and plant them in their respective locations. There are, however, crops like yam that grow haphazardly on the plot, which does not bother farmers.

In addition, on their plots there are coffee plants at different stages of their life cycle, ranging from young plants to 30-year-old trees. Here, farmers use their own seeds or stump their own trees. This practice allows them to regenerate their coffee plants and be autonomous on their seeds. As a result, farmers have dedicated a space to the germination of their coffee seed.

2. The territory of the holding

We will see here the different practices and problems that farmers have on their plots:

➔ Fertilizers

On their farm and as described in Figure 11, farmers use organic fertilizers on their plot. Year-round, they use 4 bags of 100 kg that cost them nothing because they use the waste generated by their

activities: dead leaves, manure ... They apply it on their entire plot, and they apply it during the harvest and to boost the growth of their crops for example.

Inorganic fertilizer is applied only to coffee plants to boost their growth or during the harvest season, to boost their productivity. The product used is Supagro and 3 bottles of 1L are used per year for the operation. The price of a bottle is 60,000 Ugandan shilling.

Appendix 12 presents farmers' practices around inputs.

➔ Pesticide

To fight pests and diseases, farmers use a pesticide: the Ranger. This treatment is intended for coffee trees but when they apply it, farmers extend it to the entire plot.

Indeed, it is applied preventively at least in January, before flowering against coffee pests such as stem borer and *berry borer* but also serves to prevent other diseases on the other crops of the couple. A year, 3 bottles from 1L to 60,000 Ugandan shillings are used by the couple. For more information on diseases affecting coffee, refer to Appendix 13.

➔ Soil erosion

Finally, as we saw in Figure 14 above, the land in the village has a steep slope. Thus, the farming couple faces problems of soil erosion. Appendix 14 describes soil erosion control practices.

3. Focus on the coffee growing system

We were able to see a diversity of culture within the plots. This diversity promotes interactions between different crops: nutrients, sun/shade, pollination (important for the taste of coffee) and also avoids the rapid transmission of diseases. As a result, in these family farming systems, there is no monospecific coffee crop. On the other hand, some farmers practice monospecific coffee crops for training or experimental purposes, but the proportions remain insignificant. This is not the case for the farmers studied.

In addition, depending on the strata, there are different functions:

- Lower stratum: depending on the plant families of the inter-row crops, the crop derives different benefits such as:
    - Nutrient mobilization
    - Disease and pest control
    - Vegetation cover to limit weed growth
    - Nitrogen fixation from air
- Intermediate layer: the intermediate height between the strata helps limit the spread of diseases: too dense foliage can spread diseases and mold. Thus, sufficient spacing means sufficient aeration and limitation of diseases and less competition for resources.
- Upper stratum: canopy shade is essential to provide the shade needed for coffee cultivation. In addition, the banana tree during drought episodes, the water stored in the trunk can be mobilized by the coffee tree located nearby. Shade trees are planted for the shade they provide to coffee trees, but some are used as timber, heating wood or for traditional medicine.

Thus, as we see on this plot, there are different cultural dynamics:

- Banana: as soon as the tree produces its fruits, they are harvested, and the tree is cut. The number of bananas produced depends on the variety of the tree. From the same strain, it takes about 3 months to grow back and then allows the couple to have bananas all year round.

- Yams: these plants are part of their diet, and it is rare that they sell them. In addition, it is the roots that are consumed and it is then necessary to wait 1 to 2 years before harvesting the plant to give the roots time to develop. They can harvest it all year round, depending on their needs.
- Jackfruit: this tree takes many years to develop and can be planted at any time of the year. Depending on its productivity, it can be harvested one to several times a year

Also, after harvesting a crop such as beans, farmers weed and mulch on the crop's site. This practice aims to bring nutrients back to the soil and not leave it bare.

Thus, on the basis of the various data observed, the annual GVA of this farm was calculated, details of the calculations are given in Annex 15. We see that the couple earns about 12,700,000 UGX or US$3,370 per year and US$280 per month. According to the World Bank in 2021, the annual income of a Ugandan inhabitant is US$840, which corresponds to US$70 per month. Thus, farmers have an income 4 times higher than the country average.

However, the calculation of this GVA does not make it possible to say whether the whole holding is profitable for farmers because it does not consider the costs and income from the 1 ha plot, livestock and intermediate consumption for the farm.

V. RESULTS 3: THE GUIDE TO GOOD PRACTICES FOR DRIVING COFFEE

In this part, we will see the different phases of construction of the guide which is found in full in Appendix 16.

1. Construction of the report

Before starting the writing of this report, the documents mentioned above were shared with me by my internship supervisor and personal research was carried out. This facilitated the understanding of the context of the internship: issues around the coffee tree as well as that of the country and the region. Here is what these different sources of information brought me:

- Personal bibliographic searches:

To understand the place of coffee on a global scale and in Uganda. However, few bibliographic resources have been found on the eastern region of the country. A visit to the museum of Mbale and in particular the meeting of Francis Wanyina Bwayo, the founder of the museum allowed to learn more about the coffee dynamics in the region.

- The "*AO coffee 100301 Internal Stakeholders' Feedback* " document:

This document provides information on good observations to adopt in coffee crops to optimize yield, resources and land use. It deals with various topics such as: weeding, shade optimization for coffee or soil pH control. It is very complete and has allowed the understanding of the various issues around the coffee tree such as the management of diseases and pests, maintenance practices or its needs. However, not all data is filled in in some sections because it is an internal document of a company. It was communicated to TCG by a contact.

As a result, these first sources of information have given a first basis on which the guide is based. Then,field visits with managers were organized. These interviews allowed us to get to know the whole team better. However, they were carried out late but still made it possible to understand who the guide was going to address.

Indeed, the guide is intended for assistants who will be trained from the guide. The objective is to give them scientific and technical knowledge on the maintenance of coffee trees. Even if farmers apply good practices for the maintenance of their crop, the assistants bring them this "more scientific". Thus, in addition to providing knowledge to the assistants, the guide supports their discourse with farmers and will be reinforced in their management methods on their plots. It can then be improved by adding complementary themes or notions.

In addition, at therme, TCG wants the assistants to be autonomous in the field with the guide and without, once they know him by heart know him to be comfortable enough and do without him in the field. Then add more knowledge as they become more comfortable

2. Putting the guide into practice in the field

Once a first version of the guide is made. It is presented to the various members of TCG in this chronological order:

1. Presentation of the guide to managers: advice on the presentation and vocabulary to use and selection of priority topics to be addressed such as tree care, disease and pest management or the importance of shade in a coffee garden

2. Presentation to assistants: the first version of the guide is presented to the assistants to ensure their understanding and clarify concepts, if necessary
3. Practice in the field: once the guide has been validated by the entire team and understood by the assistants, a field visit is organized. Its objective was to see if the theoretical knowledge of the guide is applicable to the realities on the ground. This is also the time to see if the attendees manage to explain to farmers the different themes addressed.

This implementation of the guide makes it possible to see if the proposed support is understood by the assistants but especially adapted to its users. Especially since TCG wanted to address various themes to make a general guide on the management of coffee systems. The support must then be synthetic, accessible and pleasant to read by the assistants.

To do this, a layout work and simple language is adopted. Thus, the use of photos, diagrams or color codes made the medium attractive. To facilitate its reading, it was necessary to adopt a simple vocabulary and short sentences.

3. Taking a step back

As we have seen, the implementation of the guide was divided into two parts: writing and field testing. Thus, the guide was built on the basis of documents, advice from managers and my internship tutor. Expert advice hasled to the identification of major biotic/abiotic constraints in a coffee garden system. They matter because, having been in the field a few times, I did not know all the problems that farmers face. As a result, benefiting from their experiences and knowledge of the field made it possible to target the important themes to be addressed in the guide.

Indeed, my visits were periodic and finally, there was no direct interview with the assistants or farmers to ask them the preferential themes to be treated. As a result, the guide is largely based on scientific theoretical knowledge and on all the field experiences of the team: the managers and the company's PCG.

Finally, the guide allowed me to synthesize scientific knowledge on coffee maintenance practices by producing a guide for assistants responsible for training farmers. Its themes are focused on the maintenance of the cafier so that it produces berries of good quality and not damaged by diseases or pests. Thus, the main aim of the guide is to improve or encourage farmers' practices for the benefit of TCG.

VI. DISCUSSION AND CONCLUSION

To conclude, this professional experience allowed me to acquire various knowledge both in agronomy and the coffee sector in Uganda. Indeed, my various personal research and my experience in the field allowed me to discover coffee farming systems in family farming. Thus, I apprehended the complexity of the issues around this culture and had an overview of the cultural practices, the collection and thetransformation of coffee.

During the writing of the guide, I was faced with a challenge: to deal with various topics around coffee cultivation and to offer an accessible and pleasant support. Also, I had to do this in English, which improved my writing skills in that language. However, the drafting of this report was mainly based on documents provided by TCG and the team's expert opinion. On the other hand, despitethe constraint of the terrain: long journey and obligation to be accompanied, I should have gone there more often. This would have allowed me to form my own opinion on the needs of the assistants and to be proactive as to the subjects treated. On the other hand, thismission allowed me to confront myself with different realities by working on the content and form of the guide but also with the realities on the ground.

In my case study of a family farm, I discovered a coffee system. I have seen that it is complex to obtain information, especially when it comes to quantifying it. Indeed, during my interview, the assistant to whom I spoke in English translated my questions to the farmers into the local language. This filtered the information, playing into the accuracy of the data. In addition, following my request, this meeting was organized beforehand by the team which did not give me the choice on the type of farmer to interview. Thus, the meeting was first with the wife and then the husband, who took over the interview. Added to this is the fact that the interview took place at the end of the internship period, delaying my understanding of the family farming systems of the region.

Finally, the absence of my managers and the difficult access to the field should not have been an obstacle to my internship. I should have turned more to the team present on site and listening to me. Therefore, for my next professional experiences, I will try to take more initiative by having more confidence in myself. This experience remains positive because I have done a general understanding work on coffee farms in the Mount Elgon region and has made me grow personally.

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VIII. ANNEXES

Table of Contents

ANNEX 1 - Ideal agronomic conditions for growing robusta and arabica varieties

The warm tropical climate is ideal for coffee. Indeed, it needs abundant rainfall, generally between 1,500 and 3,000 mm for optimal growth. It grows ideally on rich, well-drained volcanic soil, as in Uganda (L. Sanchez Hernandez, 2016):

Ideal condition	Robusta coffee	Arabica coffee
Altitude	Sea level 800-1500 masl	1300-2300 masl
Terrain	Flat or gently sloping	Flat or gently sloping
Temperature	18 – 27°C	15 – 24°C
Soil type	Deep, well drained fertile loamy soils (rich in organic matter and exchangeable bases, particularly potassium)	Deep, well drained fertile and slightly acidic loamy soils (of pH 4.5 to 5)
Rainfall	1200-1500 mm/year and well distributed for a period of about 9 months	1200-1500 mm/year and well distributed over a period of about 9 months

Table/ Description of ideal growing conditions for Robusta and Arabica coffees. Source: Ministry of Agriculture, Animal Industry and Fisheries, 2015

The two varieties differ in taste, yield and disease resistance:

- Arabica has a superior taste, sweeter and milder than Robusta, with notes of chocolate and sugar and often fruit or berry nuances. Although they thrive at higher altitudes, Arabica coffee trees are susceptible to pests and diseases and generally produce lower yields than Robusta. Breeding programmes focus first on flavour, then on higher yields and resistance to pests and diseases. Arabica coffee trades at a much higher price than Robusta, making it more financially attractive to grow Arabica.
- Robusta contains more caffeine than Arabica and has a stronger, pungent and bitter taste, with grainy or rubbery overtones. Despite its less refined flavour, Robusta is widely used in espresso blends because it produces a better crema (the creamy layer found on top of an espresso) than Arabica. Robusta grows at lower altitudes and the trees are also hardier, more resistant to disease and produce higher yields. Robusta breeding programmes are heavily focused on yield. It trades at a much lower price than Arabica because it grows on the plains and has a 35% higher yield. Also, the tree is easier to cultivate, which makes Robusta an attractive crop for farmers.

Two years after planting, the first coffee harvest can usually take place. However, the tree reaches its optimum yield in four or five years. In terms of bean quality, it will produce lower quality beans for 20 years but with a high yield, and conversely, will produce higher quality beans with lower yields in the other 20 years.

Both varieties produce cherries containing two beans or flat seeds. They are surrounded by pulp and a parchment-like skin. Under the parchment the beans are surrounded by a thin membrane or integument. It is the beans that are processed and consumed as a drink.

Finally, coffee trees can be planted in monoculture or not. Since most coffee is grown by smallholders, they grow food crops between the rows of coffee trees to optimise the use of their plot (Ministry of Agriculture, Animal Industry and Fisheries, 2015).

The map in the opposite figure shows the distribution between Robusta and Arabica varieties in Uganda:

Figure/ Mapping of Uganda's regions according to different robusta or arabica coffee crops. Source: Ministry of Agriculture, Animal Industry and Fisheries, 2015

We can see then that in Uganda, the Robusta variety is mostly grown in the central plateau and the lake basin region. The Arabica variety is grown in the highland areas in the west and east of the country. In relation to Table 2, we can see that the high-altitude regions correspond well to Arabica coffee areas while the lower altitude areas correspond to Robusta coffee.

Thus, the main coffee variety studied in the area is Arabica. Indeed, the climate and the high altitude offered by the Mount Elgon Mountain range provide the right conditions for its cultivation. In addition, the coffee produced is renowned for its quality, notably thanks to its own appellation which is a guarantee of quality for its locally grown coffee (Ministry of Agriculture, Animal Industry and Fisheries, 2015).

ANNEX 2 - Introduction of the arabica variety on Mount Elgon and the economic interest for the populations

Before the introduction of coffee, the town of Mbale was an important buying point for the elephant ivory trade. Arab populations used to go there to trade. When coffee was introduced by the settlers, it became a cash crop as Ugandans do not consume it. In the region, the main ethnic groups are the Bantu and Sabin who grow the Arabica variety.

Thus, the locals started to grow coffee on Mount Elgon for export. Some tried to identify fertile areas to plant coffee and moved up to higher altitudes to provide the best conditions for this crop. These new locations also allowed for new flavours and aromas which are an added value for its marketing. In addition, the money received from this cash crop has played a significant role in the education of the local population.

Indeed, they were able to send their children to school: a certificate was issued after the sale of the coffee that justified the amount earned. This certificate was the proof of the parents' financial capacity to pay for their children's schooling.

Nowadays, coffee has an important place in the region because large private collection and export companies, such as Bugisu Cooperative Union, have established themselves and have a monopoly on coffee. The locals, on the other hand, continue to grow food crops and use coffee as a cash crop, selling it mainly to these large private companies (testimony of Francis Wanyina Bwayo).

- Organisation of the collection

As shown in the figure below, the domestic coffee marketing circuit starts with small producers. They have the possibility to sell their product to different entities: speculators, collection centres or buying agents. Most of the coffee is collected by private collection centres, which then sell their stocks to the 230 coffee factories in the country. On the other hand, producers sell their harvest directly to factories in limited quantities or to unlicensed speculators who buy opportunistically for resale to factories. Secondly, coffee export companies, often branches or subsidiaries of large foreign trading companies, sell most of their coffee to international buyers in consuming countries. They can also buy directly from producers, collection centres and factories through their buying agents.

Only a small amount of coffee reaches the Ugandan domestic market through sales to local roasters. Indeed, there are about 20 licensed roasters who buy the rejects, which cannot be sold on the export market. As in other OPCW member countries, the roasting business is not well developed in Uganda and the equipment used is generally old (over 10 years).

This diagram details the different actors TCG works with during the different stages of coffee marketing:

Figure/ The stages from collection to export of coffee. Source: TCG

The harvest season runs from September to February. The figure on the right describes the different stages from the harvesting of the coffee to its export:

Figure/ Diagram of the different stages from collection to export of coffee. Source: Author

1

During the harvest season, the various farmers bring their coffee berries to the coffee collection stations, of which there are four. The berries are directly weighed and sorted according to their appearance. Once the unfit berries are eliminated, at the Chambongo station, the selected berries are put through a machine that removes their first shell. Then, to remove the seed coat, the berries are soaked in water. This fermentation process removes the membrane around the berry, which is then dried for the first time at the station.

2

The coffee is then sent to Mbale to the premises of Greate Lakes Coffee Company. There it is dried a second time in solar dryers, as the altitude does not allow for complete drying. During this stage, a second sorting is carried out to remove any stones or seeds that do not comply with the standards: too small, broken, etc.

It should be noted that during the entire harvest period, the batches of coffee are controlled. One batch of coffee corresponds to one day of harvest. Indeed, even if 90% of the farmers have the same variety of Arabica coffee, each day presents different circumstances, which makes the taste vary.

Thus, a sample of each batch is sent to the Greate Lakes Coffee Company site in Kampala where quality tests are carried out, the details of which can be found in Appendix 1.2. These quality controls are very important, in particular for the traceability of the coffee, to define the different classes of coffee according to their flavour, but also to quickly identify defective coffees or contamination...

3

When the harvest season is over, the batches are grouped and identified according to the different flavour classes that have been defined. Before leaving Mbale, the coffee has to undergo a rigorous humidity control. Indeed, this factor is mainly controlled to ensure its good conservation. Indeed, if fungi develop, this would damage the taste and quality of the coffee.

4

At the capital, the coffee is then evaluated according to criteria such as size, colour and shape, the process is described in Annex 1.2. This evaluation allows the different types of coffee to be levelled and their selling prices to be defined.

The last step before the coffee is exported is to obtain a certificate issued by the UCDA, which regulates the export of coffee. This certificate validates and authorises the export of the coffee.

5

Finally, before buying the company's coffee, customers are tested to see which type of coffee meets their standards.

- Quality control of coffee at TCG

Sorting and certification of coffee beans before export

The green coffee beans (because not yet cooked) arrive from Mbale, ordered according to his day of collection. In Kampala, the lots follow the following route:

1. Arrival of coffee at Greates Lakes Coffee Company in the coffee production section
2. Weigh coffee: check if the starting weight (Mbale) is the same as the one at the finish (Kampala)
3. Quality control: grain quality, taste
4. 1st machine: this machine is used to remove the thin film of skin remaining around the grain: parchment (can be white, yellow, brown)
5. 2nd machine: classification of coffee beans is done according to their:
    - Size: the machine has standard calibrations;
    - Form: During its formation, the grain can be configured differently:
    - Peaberry: the grain has not been separated and forms a sphere (cheaper price)
    - "Normal berry": one side flat and another spherical side (higher price)

- Color: the lighter the grain, the less taste it has because it is less formed less. The color criteria are:
    - Normal color: compliant
    - Light green: non-compliant
    - Discolor brown/ yellow/ black: not compliant for export. However, these grains are kept to be sold on local markets.

6. Packaging: the coffee is packaged according to its level. The coffee is put in a standardized plastic bag: grainpro bag specially designed to protect it from moisture and diseases
7. Inspection of coffee by the UCDA to validate its export according to standards and approves the export. The UCDA certifies the quality of the coffee, so this is a crucial step. The criteria are as follows:
    - Quality
    - Waist
    - Taste of coffee
8. 2nd package: Once the certification is obtained, the bags are put in a second bag to physically protect the grainpro bags
9. Shipping coffee beans: on each grainpro bag, there is a QRcode. When scanned by customers, they have direct access to the coffee history of their bag.

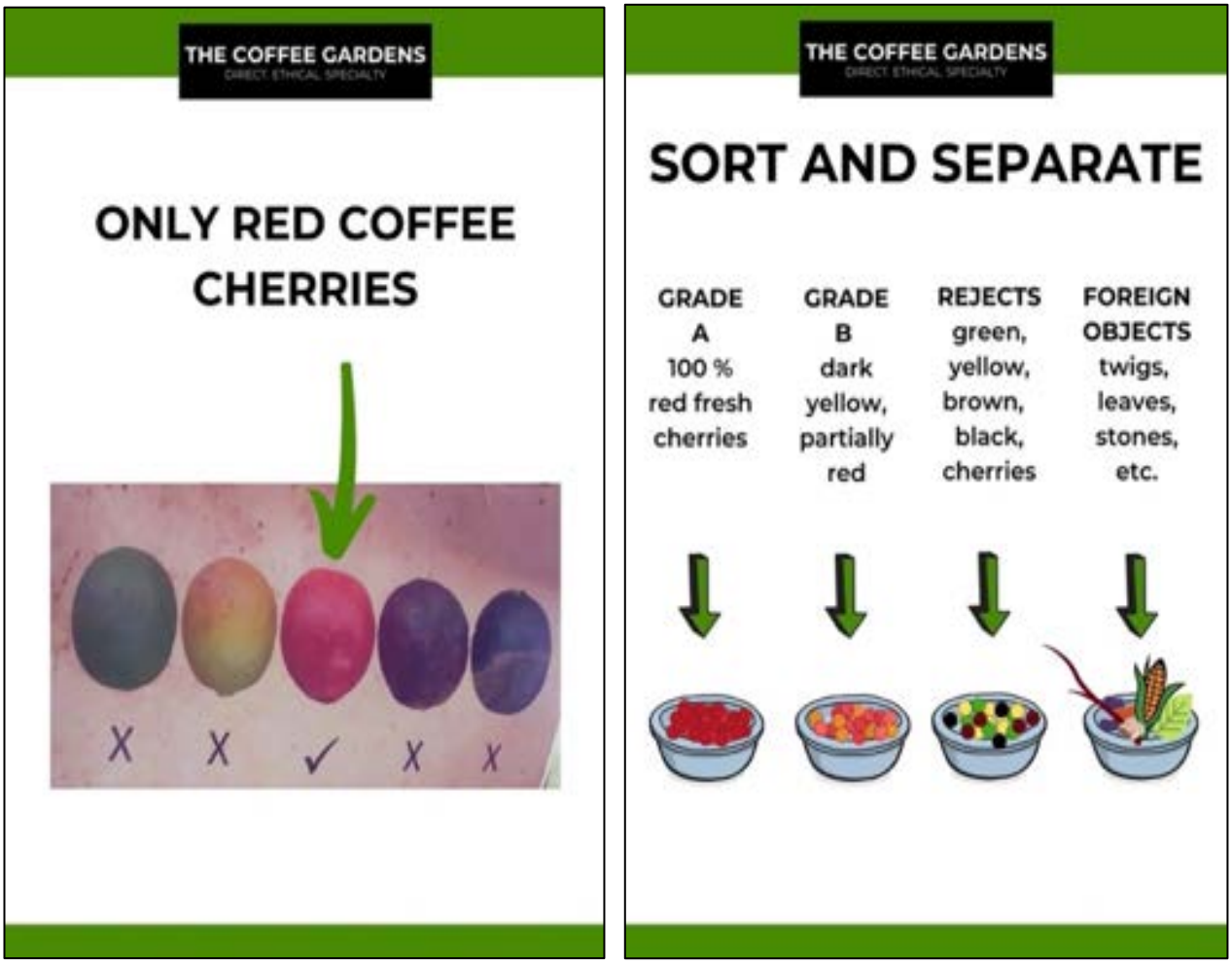
Quality testing and grading of coffee beans

The different stages of testing and grading of the coffee beans are

- Selection of the sample
- Cooking of the coffee: between 8 and 10 minutes depending on the humidity and density of the coffee (check carried out beforehand)
- The beans are ground
- Weighing of the ground coffee: 14g of coffee per cup, the quality process requires that 5 cups are served. The dosage is done according to the capacity of the cup.
- Addition of boiling water: here the cups are always the same and are filled to the brim
- Infusion: 4 minutes
- Ground coffee is pushed to the surface: during the brewing process, ground coffee is on the surface. It is then gently pushed downwards. The technique aims to push back the thickness formed by the ground coffee with a spoon so that it can sink to the bottom of the cup
- Testing the coffee by the tester: this is the only person who tests the coffee. However, in our case the manager also tests the coffee so that she can give feedback on the taste and quality to the whole team. The scoring criteria are :
    - Arôme
    - Saveur
    - Le corps : comment il est senti sur la langue
    - Acidité
    - Douceur
    - Cleaness of the cup
    - Balance : entre tous ces critères

Depending on its score, the coffee is classified as Speciality coffee; Premium coffee; Commercial coffee.

During the harvest season, samples are sent to Kampala to check the quality and to identify good and poor quality batches.



Instructions for sorting coffee berries. Source: The Coffee Gardens

In order to understand the water treatment process of the TCG plant and the issues surrounding its new installation, we will first present the plant and then in a second time we will describe the coffee shelling process. Finally, we will see the different wastewater treatment process solutions proposed.

Background and issues

Indeed, a large amount of water is used during this coffee shelling process: 1 kilo of coffee berries requires between 7 to 11.5 liters of water (L. Sanchez Hernandez, 2016). In addition,coffee wastewater is acidic which transforms the water into a yellowish and smelly substance in a few hours. There are also a lot of solid particles that easily clog the facilities and the tank. As a result, this new facility presents the following challenges:

1. Despite the lack of national regulations, do not pollute the environments: soil, watercourses ...
2. Adapt the treatment process to the new space: the land will be larger but other infrastructure is planned and a watercourse is located near the site of the new station

Presentation of the station

In total, TCG has 5 coffee berry collection stations spread over different altitudes. The main station is located in the village of Chambongo where the process of shelling the coffee berries is operated.

As TCG wanted to increase its capacity and create spaces to house their staff during the season, the company moved its main station 250 m to a more spacious site in Bumwawule, a village on the border of Chambongo.

The figure below shows the current location of the station indicated by a red dot as well as the location of the new station by an orange dot:

Figure/ Aerial photo of the current station and the next one. Source: Google Maps

Presentation of the coffee husking process

Presentation of the coffee husking process

TCG's coffee husking process is described in the figure opposite:

Figure/ Diagram of the different stages of coffee berry hulling. Source: Atelier Braam

To shell their coffee berries, TCG uses the wet method. This method keeps the freshness of the grains and their aromatic complex.

To do this, the coffee beans pass through a pulping machine and are then placed in fermentation tanks for 24 to 48 hours. After that, they are rinsed and put to dry for about 2 to 3 weeks. We obtain the "*café parch*" whose parchment will be removed to have green coffee beans.

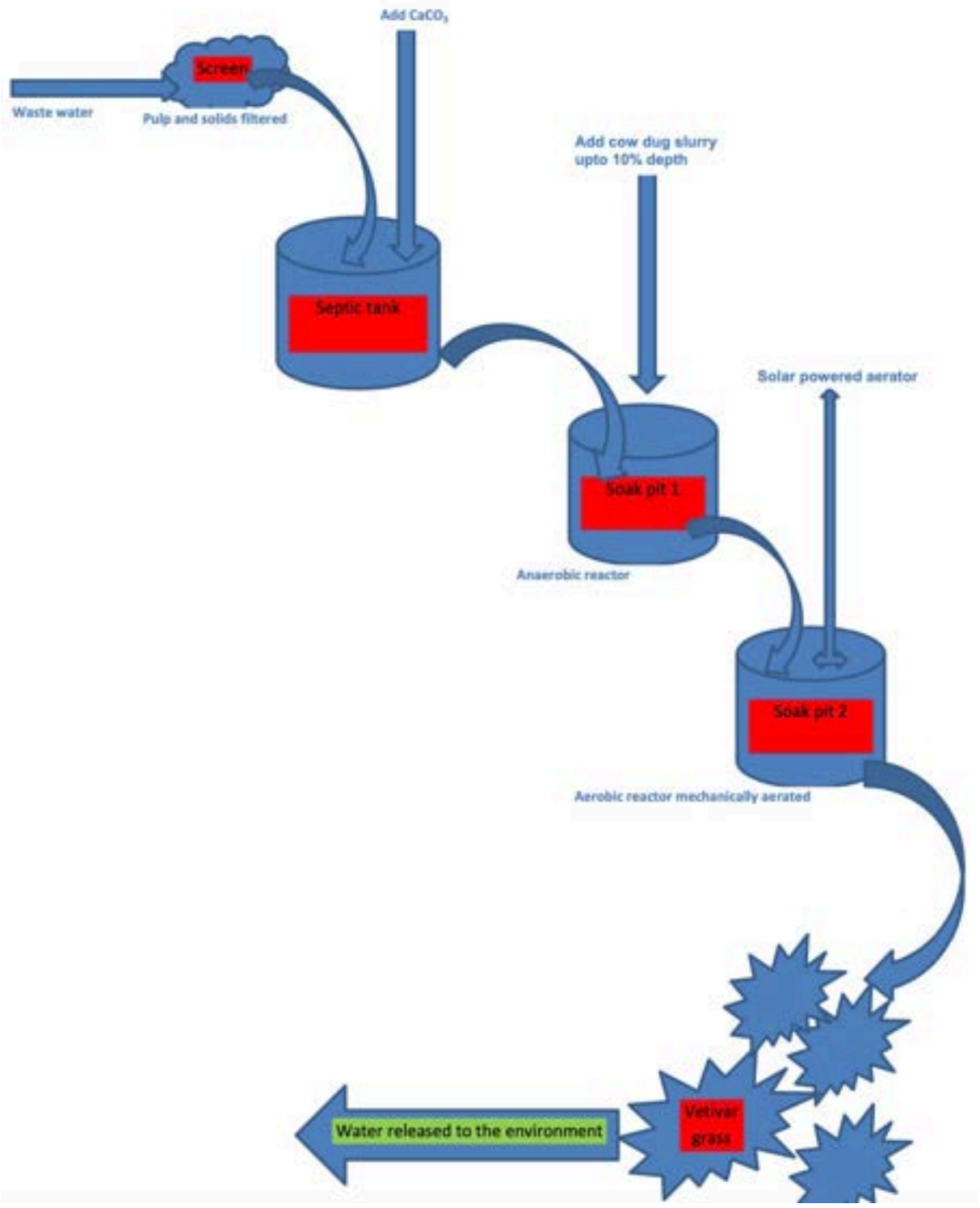
Finally, for 1 kg of coffee berries this process requires less than 2 liters of water.

Wastewater Treatment Overview

1. The current water treatment process

Thus, as seen previously the process of shelling coffee berries requires water. This fermentation water must be treated before being discharged into the environment so as not to degrade them or pollute nearby homes and fields.

This process is shown schematically in the following figure:



Figure/ Schematic representation of fermentation water treatment. Source: TCG

The first step in this process is the filtration of the coarser elements.

Then the acidity of the coffee wastewater is neutralized with calcium carbonate. This is because the acidity of the water kills microorganisms and plants that eliminate and absorb water contamination. In addition, acidity transforms coffee wastewater into a yellowish, smelly substance within a few hours. Thus, a neutral pH of 7 is a prerequisite for eliminating contamination during the second treatment and for minimizing odors.

The third step is to place the water in an anaerobic tank so that the fermentation process ends. This generates a lot of fine particles which, mixed with sand, clog the installations.

Finally, the water is filtered by the roots of vetiners before being discharged 12 m further into a river.

- The challenges of coffee wastewater treatment

For TCG, the installation of this new station presents challenges at different levels:

- TCG's ethical values and a taste for challenge

TCG wants to establish itself in a sustainable way in the region and wants to minimize its impact on the environment. Indeed, the company pays particular attention to the consequences that pollution can have for the inhabitants or fields located around their activity.

Also, only the large coffee companies have sufficient financial capacity to invest in the treatment of their coffee wastewater. For example, they can have more space and then use certain remediation techniques. Thus, TCG cannot take an example from them because the company does not have the same means. Moreover, in Uganda, there is no medium-sized company with efficient coffee wastewater treatment facilities. For TCG, this is a real challenge because there is no example of a company on which TCG can draw inspiration. As a result, TCG wants to be the first medium-sized company to treat its coffee wastewater efficiently.

- The process itself

This coffee wastewater treatment plant treats different streams of water from the plant:

→ Water used for everyday uses

→ Water used to separate diseased berries from good berries

→ Coffee husking water

Thus, the water used for the daily uses of the station such as hand washing for example does not present a significant problem.

However, the water used to separate diseased berries from good berries contains some sugar. Thus, this adds a quantity of water to be treated in the process but also sugar that will encourage even more the phenomenon of fermentation.

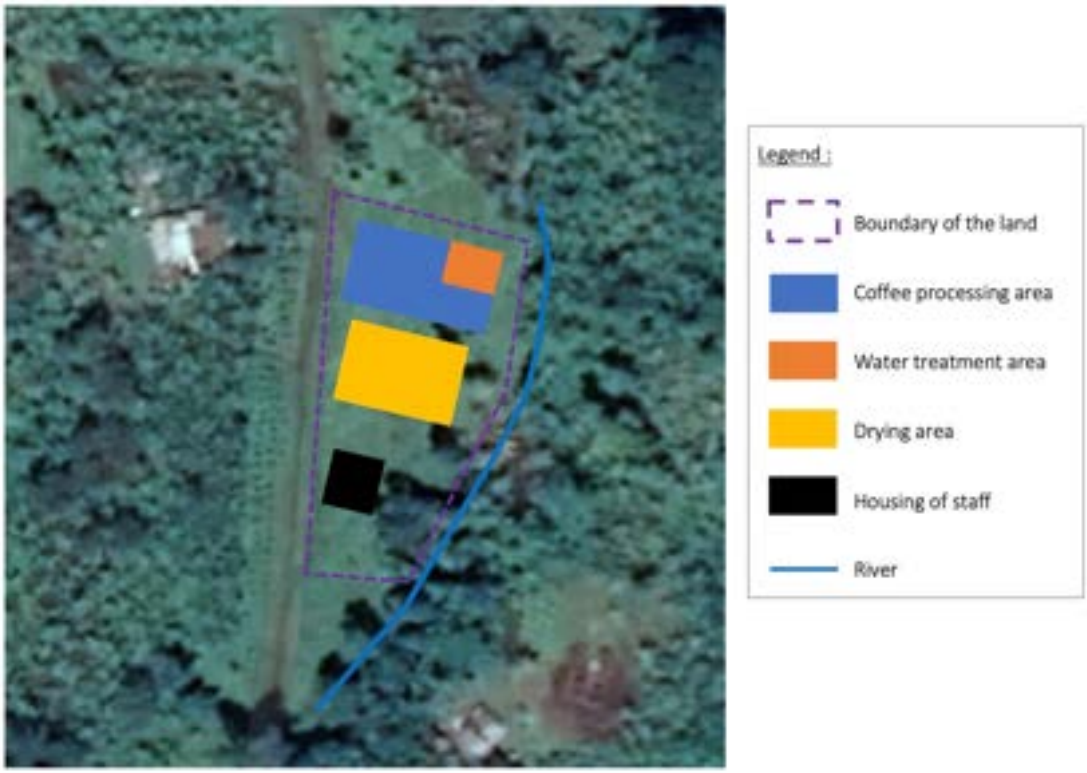
In addition, in the current plant, even if the fermentation process is not completely finished, the water is discharged into the river because the storage space is not sufficient. Therefore, the installation of the new coffee wastewater treatment plant is an opportunity to find solutions to:

→ Finish the fermentation process cleanly

→ Reuse fine sludge

- The new location

Although the site of the new plant is larger, the area dedicated to the treatment of wastewater from the café will not be very large and is close to a river, houses and fields as shown in the figure on the right:



Figure/ Schematic plan of the new station. Source: Author

- Lack of regulation at national level

In Uganda, there are no strict regulations on wastewater from wastewater treatment plants. Therefore, it is a challenge for the company because there are no real standards to meet.

However, in border countries such as Rwanda, there are precise regulations on these discharge standards. Indeed, in this country the rules for wastewater treatment are established and are strict. TCG therefore wishes to rely on the regulations of this country for its new plant.

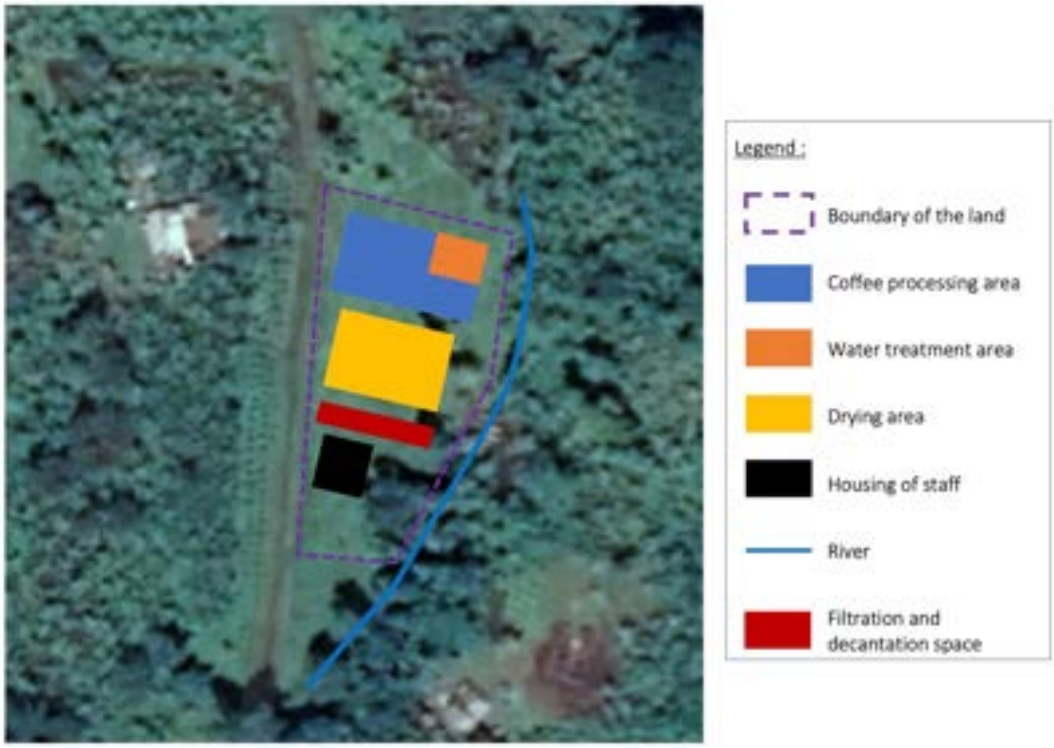
The different solutions proposed

For the installation of the new coffee wastewater treatment plant, TCG has the possibility between two solutions:

- Separating the coffee wastewater treatment process

As the space between the location of the wastewater treatment plant is close to the river, the proposed solution is to continue the fine particle filtration process further downstream in the field.

Having more space would make it possible to put stages of filtering plants such as vetiver and allow fine particles to settle. On the figure opposite, we can see schematically where this new treatment step would be located:

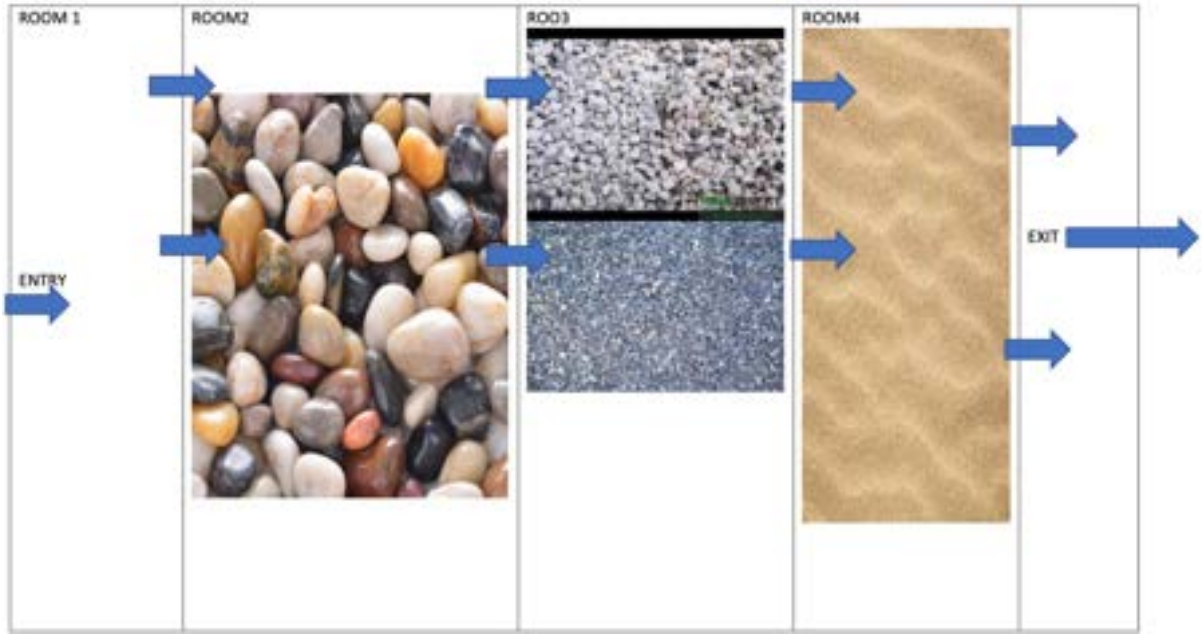


Figure/ Schematic plan of the new plant with the area dedicated to the filtration and decantation of fine particles. Source: Author

- Modification of the coffee wastewater treatment process

This solution proposes to modify the coffee wastewater treatment process. Thanks to his professional contacts, the director of TCG was able to organize meetings with a company based in Rwanda the *Rwanda Training Company*.

During the exchanges, TCG was able to share its various problems and challenges encountered during the construction of their new station and *Rwanda Training Company* was able to respond to them but also share their own treatment process. It is schematized in the figure opposite:



Figure/ Diagram of the coffee wastewater treatment process. Source: Rwanda Trading Company

Description of the different stages of coffee wastewater treatment:

- Room 1: in this first section, the wastewater comes in and is mixed with lime
- Room 2: this step consists of passing the water through medium-sized pebbles
- Room 3: the water is once again filtered by smaller pebbles this time
- Room 4: in this last step, the water passes through sand and small pebbles before being discharged

However, the internship ended before approving the final solution for the station. On the other hand, once the new coffee wastewater treatment solution is validated and the construction work is finished, it will then be necessary to set up a watch because the aerobic process requires constant vigilance. For this, it will be necessary to train staff.

COFFEE ADOPTION OBSERVATIONS - KENYA (with intent to spread to E. Africa and all coffee growing countries)
Intent: optimize yield, resource and land use

Concept and purpose of Adoption Observations:
1) efficiently and consistently diagnose the condition of coffee plots in order to determine interventions needed to reach a targeted yield in different farming systems
2) to monitor the quality of interventions to understand progress towards reaching the targets.

Audience for this document: technical people that perform Adoption Observations i.e. agronomists and coaches working with coffee farmers.

Assumed competences of users: extensive experience and knowledge of all elements of coffee farming pertaining to Plant Material (Criteria 1), Farm Condition (Criteria 2-4), Good Agricultural Practices (Criteria 5-10) and Soil Fertility Management (Criteria 11-15). For successful and efficient application of Adoption Observations the users must be trained and calibrated on the interpretation of the criteria and the judgement of these criteria in the field.

Considerations for Data collectors:
1) adoption Observations do not rate the effort or intent that farmers or workers have, but only judge the quality of interventions that can be observed at the moment of the field visit
2) Data collectors of Adoption Observations must understand that each of the 15 Adoption Observations are independent from each other; observers should not interpret their observations but merely record their observations in an 'Adoption Observation app' or in the FarmGrow program; they must also realize that Adoption Observations do not rate the effort or intent that farmers or workers have, but only judge the quality of interventions that can be observed at the moment of the field visit

Conditions to perform Adoption Observations: note that all Adoption Observations must be made within the same short window of time (i.e. 2 weeks) and it is advisible to plan to collect Adoption Observations when conditions for observations are good. In principle all Adoption Observations can be performed at any time as long as visibility is good and the condition of the trees allow to observe all specific Adoption Observation Criteria. Some conditions may impair observations such as:
• visibility and accessibility: Adoption Observations should not be made when it is raining, or when it is dark such as in the late afternoon. Plots on hill-sides may be very slippery when it rains and traversing a plot is not possible.
• seasonal (weather) conditions mask some of the Adoption Observations such as tree health and other criteria which may be difficult to observe during a severe drought.
• E. Africa: observations should not be made during a severe dry season (i.e. February - March) or until 4 weeks after the severe dry season has ended and rains have started to avoid the impact of drought conditions on the Adoption Observations.

Plots and Farm: The user will first cross the whole coffee farm by transect walk to get a basic idea on the farm condition. In case the trees are largely similar in condition, the whole farm can be mapped as a `plot`. In case trees are very heterogenous in condition to expect different recommendations, two or more different `plots` can be mapped.

Data entry: Adoption Observations are recorded in an appropriate 'app' for diagnostics or monitoring under the FarmGrow program. Particular recommendations can be made, a business plan developed and its implementation assessed again in a next round of Adoption Observations.

Lay-out of this document: there are 4 'chapters'. Each chapter includes a short introduction and between 1 to 5 of Adoption Observations. The Adoption Observations may include technical information to explain the rationale and mechanism to collect information if this is not generally well understood.

	Rating	1. Plant Material, Genetics Plant material genetics with potential to support targeted yield

Concept and explanation of criteria: Plant material determines what the yield potential of a mature coffee tree is when the farm condition, agricultural practices and soil conditions are all good. It is not possible for a tree to produce more than it's genetic potential no matter how good the agronomic practices or soil condition are. The only mechanism to address plant material potential is by replanting or grafting with plant material that has higher potential.
• the yield potential will only manifest itself when the root system, trunk and stem(s) of a coffee tree are all mature
• Note that the targeted yield potential chosen for Adoption Observations is significantly below the maximum potential of the chosen varieties in their respective geographies, to allow for sub-optimal smallholder farm management.
• Climate change effects can impact the potential of plant material as the climatological conditions for which specific hybrids or clones are bred have changed, and there may bbe a need for replanting with drought or disease resistant varieties, or varieties that are particularly suited to yield in certain climatic conditions

Arabica vs Robusta-
• Arabica has a superior smoother, sweeter taste than Robusta, with flavour notes of chocolate and sugar and often hints of fruits or berries. Arabica trees thrive on higher altitudes, but the trees are susceptible to pests and disease and generally produce lower yields than Robusta. Breeding programs focus on flavor first, and then on higher yield and pest and disease resistance. Arabica coffee is traded at much higher price than Robusta coffee, making the choice of Arabica farming attractive.
• Robusta contains more caffeine than Arabica and has a stronger, harsher and more bitter taste, with grainy or rubbery overtones but in spite of a less refined flavour, Robusta is widely used in espresso blends as it produces a better crema (the creamy layer found on top of an espresso shot) than Arabica. Robusta thrive on lower altitudes and the trees are also hardier, more resistant to disease and produce better yields than Arabica. Robusta breeding programs have strong focus on yield. Robusta is traded at a significantly lower price than Arabica, but as the tree thrives in lowlands, its' yield is 35% higher and the tree is easier to cultivate hence Robusta coffee is an attractive crop for farmers.

Monoculture (shaded) coffee farms vs agroforestry farms: the focus on monoculture (shaded) coffee farming is to optimize yield from coffee, which requires significant amount of sunlight to reach the coffee canopy for photosynthesis while the number of coffee trees are optimized. The focus in agroforestry farms is to derive near-optimized yield from coffee but agroforestry products (fruits, nuts, timber) will also contribute to the farm income and therefore more or larger agroforestry trees are tolerated (even if this compromises planting area for coffee trees or casts relatively heavy shade on nearby coffee trees). As a rule of thumb we tolerate 25% less yield from 15% fewer coffee trees (as other coffee trees fairly close to agroforestry trees get less sunlight) which is compensated by income from agroforestry products. Note that the reduction in yield due to lesser coffee trees and higher shade must not be confused with the 'compensation mechanism' - see planting density.

Spacing and plant performance: the planting density does not have an impact on the genetic yield potential of a coffee tree, but may have an impact on the performance of different varieities or clones. The table below on 'yield objectives' does not consider sub-optimal spacing but only optimal spacing within the boundaries of 'the yield compensation mechanism' (see AO #3 on planting density) that allows optimal plant performance. The yield per tree on diversified and non-diversified plots is the same, but the difference is the number of coffee trees per acre or hectare. For agroforestry spacing there are 15% fewer coffee trees and 25% less yield.

Varieties and plotting: to protect farmers from the risk of cultivating single varieties that could all be susceptible to a certain pest and disease or climatological change, farmers must plant different varieties/clones in a plot:
• Note that in this document we use the word 'variety and 'hybrid' intermittently for sexually reproduced plants (seeds) with desired traits while we use the word 'clone' for any plant which is asexually reproduced (rooted cuttings, grafts, somatic embryogenesis).
• Arabica and Robusta should not be mixed as the beans are delivered to different (flavor) markets at different prices but in different plots
• Trees with incompatible optimal spacing (including the compensation mechanism) should not be planted together but in different plots

How to rate trees for their potential: it is very difficult to determine the potential of plant material through observation - therefore the best way to rate plant material is by identification of it's hybrid parentage or by clone. If this information is not available we use proxy mechanisms to determine or rate the potential plant material from it's best performance ever (the highest historical yield). Note that rating of plant material potential is different from plant material performance as performance is influenced by agro-ecological, soil and climatological factors as well as the quality of farm management. For this reason, if the variety or clone is not known, the place from where the plant material is obtained is the determining factor, unless demonstrated yield indicates better plant material than its' source suggests.
• Plant material can be distributed as selected hybrid / clonal seedlings, as scions for top working (field grafting) or rooted cuttings.

Qualified institutes: plant material should be sourced from government organizations tasked with production or distribution of coffee plant material and/or private nurseries or cooperatives appointed or approved by the Government (a.k.a. certified sources). In case such certified sources do not exist, plant material must be sourced from planting material producers with proven track records.

Rainforest Alliance certification: if farmers are certified by the Rainforest Alliance, they will need to comply with mandatory criteria of the standard with regards to plant material (i.e. no GMO).

Rationale for multiple varieties or clones: genetically diverse plant material should be used in a farm to avoid potential problems with pollination of (self) incompatible trees, and to ensure not all trees are equally vulnerable to the same pests and diseases. For existing farms we allow only one or two varieties or clones on a plot or farm but for replanting or stumping, farmers must adhere to the use of different varieties of clones.

Planting material specific densities: conventional plant material should not be planted in high density patterns (aka as unconventional). Such varieties will grow large and branches will enter canopies of neighbouring trees while yield will be reduced due to competion for light and root space (nutrients, water). Plant material bred for planting in high densities can also be planted in conventional densities as the trees will simply grow bigger over time and can also be grown in multistemmed system.

Flavor and Yield: plant material with a high flavor profile but lower yield should only be considered if markets for this flavor is assured, and a premium is paid that compensates for the reduction in yield.

Yield Objectives

Cherry yield	Conventional spacing				High density planting (+25% yield)			
	Non diversified farms		diversified farms i.e. agroforestry		Non diversified farms		diversified farms i.e. agroforestry	
	kg/acre	mt/ha	kg/acre	mt/ha	kg/acre	mt/ha	kg/acre	mt/ha
Arabica	7,000	17.3	5,950	14.7	8,750	21.6	7,450	18.4
Robusta	9,500	23.3	8,075	19.8	11,900	29.1	10,100	24.7

Green Berry Equiv.	Conventional spacing				High density planting (+25% yield)			
	Non diversified farms		diversified farms i.e. agroforestry		Non diversified farms		diversified farms i.e. agroforestry	
	kg/acre	mt/ha	kg/acre	mt/ha	kg/acre	mt/ha	kg/acre	mt/ha
Arabica	1,150	2.9	1,000	2.5	1,450	3.6	1,250	3.1
Robusta	1,600	3.9	1,350	3.3	2,000	4.9	1,700	4.1

Cherry yield	Conventional spacing				High density planting (+25% yield)			
	Non diversified		diversified farms		Non diversified		diversified farms	
	kg/acre	mt/ha	kg/acre	mt/ha	kg/acre	mt/ha	kg/acre	mt/ha
Arabica	5,000 - 7,000	12.5 - 17.3	4,250 - 5,950	10.6 - 14.7	6,250 - 8,750	15.6 - 21.6	5,300 - 7,450	13.3 - 18.4
Robusta	6,750 - 9,500	16.9 - 23.3	5,750 - 8,075	14.4 - 19.8	8,450 - 11,900	21.1 - 29.1	7,200 - 10,100	18.0 - 24.7

Green Berry Equiv.	Conventional spacing				High density planting (+25% yield)			
	Non diversified		diversified farms		Non diversified		diversified farms	
	kg/acre	mt/ha	kg/acre	mt/ha	kg/acre	mt/ha	kg/acre	mt/ha
Arabica	830 - 1,150	2.1 - 2.9	710 - 1,000	1.8. - 2.5	1,050 - 1,450	2.6 - 3.6	880 - 1,250	2.2 - 3.1
Robusta	1,125 - 1,600	2.8 - 3.9	950 - 1,350	2.4 - 3.3	1,400 - 2,000	3.5 - 4.9	1,200 - 1,700	3.0 - 4.1

Cherry yield	Conventional spacing				High density planting (+25% yield)			
	Non diversified		diversified farms		Non diversified		diversified farms	
	kg/acre	mt/ha	kg/acre	mt/ha	kg/acre	mt/ha	kg/acre	mt/ha
Arabica	<5,000	<12.5	<4,250	<10.6	<6,250	<15.6	<5,300	<13.3
Robusta	<6,750	<16.9	<5,750	<14.4	<8,450	<21.1	<7,200	<18.0

Green Berry Equiv.	Conventional spacing				High density planting (+25% yield)			
	Non diversified		diversified farms		Non diversified		diversified farms	
	kg/acre	mt/ha	kg/acre	mt/ha	kg/acre	mt/ha	kg/acre	mt/ha
Arabica	<830	<2.1	<710	<1.8	<1,050	<2.6	<880	<2.2
Robusta	<1,125	<2.8	<950	<2.4	<1,400	<3.5	<1,200	<3.0

Note: cherries are the fresh harvest from the coffee tree, Green Bean Equivalent are the processed but unroasted coffee beans. The ratio of cherries to Green Bean Equivalent is 6:1

Note: there are 15% fewer coffee trees on a diversified or agroforestry farm but yield is 25% less as coffee trees close to agroforestry trees get less sunlight

Note: high density planting (with selected suitable plant material) can result in 25% higher yield

Note: yield of Robusta coffee is 35% higher than yield of Arabica coffee"

Good	**Interview:** Plant material supports yield targets as in the table above • ≥80% of planting material used is in accordance with a list of recommended varieties or clones (by Government Institute or other qualified sources) for that particular agro ecological zone and where possible supported by receipts or other documentation or credible recall from the farmer that his highest yield ever reached yield targets for 'good' AND • Obtained from a certified nursery /source AND • ≥3 different varieties or clones on the farm (may be spread over different plots) and not more than 75% of one single variety or clone **Field confirmation:** • Compare own field observations with farmers response on origin of the planting material
Medium	**Interview:** Plant material supports yield targets as in the table above • ≥80% of planting material used is in accordance with a list of recommended varieties (by Government Institute or other qualified sources) for that particular agro ecological zone and where possible supported by receipts or other documentation or credible recall from the farmer that his highest yield ever reached yield targets for 'medium' AND • Obtained from a certified nursery /source AND • ≥2 different varieties or clones on the farm (may be spread over different plots) and not more than 75% of one single variety or clone **Field confirmation:** Compare own field observations with farmers response on origin of the planting material
Bad	**Interview:** Plant material supports yield targets as in the table above • <80% of planting material used is in accordance with a list of recommended varieties or clones (by Government Institute or other qualified sources) for that particular agro ecological zone and where possible supported by receipts or other documentation OR • Obtained from a certified nursery /source OR • 1 variety or clone on the farm **Field confirmation:** • Compare own field observations with farmers response on origin of the planting material

Rating	2. Age of tree the age of the root system, trunks and main stems.
Concept and explanation of the Tree Age criteria: the genetic production potential of coffee trees will only manifest itself at maturity, and is compromised by root stock/trunk age and stem age. As tree age, they produce less coffee and at some point they can no longer be rehabilitated back to profitable yields. Therefore farm renovation by replanting and farm rehabilitation by stumping makes economic sense. Renovation through replanting of farms or plots with good productivity can be staggered over a number of years to ease the investment pressure on the farming family. It is important that renovation and rejuvenation is always accompanied by good agricultural practices to prevent early decline in yield. **Replanting age and cycle timing:** • the root system and trunk must be replanted at a maximum age before they lose their capacity to support the genetic yield potential of the tree, or when the root system or trunk are not in good condition, • the stems of coffee trees must be rehabilitated regularly by stumping or grafting as after a certain age the production capacity of stems and their branches declines. The age of the stems when they need to be renovated is called 'cycle timing'. **Risk of replanting too early when coffee trees are still performing**: from a Return-on-Investment point of view it is not an issue if farms are renovated through replanting before the existing root systems and/or trunks ~~trees~~ are in (serious) decline as newer varieties will have higher yield and/or higher pest and disease tolerance or resistance which can compensate the drop in production during farm renovation. **Technical notes on stumping:** stems need to be replaced with a regular cycle, either through replacement with grafts to change plant genetics (renovation) or by rejuvenation of existing plant material through stumping of the trees. For grafting and stumping, care must be taken that the removal of the old stem is done through a slanting smooth cut of the old stem at an angle that ensures water flows off the cut area and away from the trunk while keeping the cutting wound as small as possible. If the water run-off from the cut is left to accumulate on the tree trunk, it may cause rotting. **Under discussion:** The most productive age of coffee trees is between 7-20 years and 30 years is the maximum age after which yield can be significantly compromised.	
Good	**Interview:** • under discussion: root system and trunk ≤20 or (30) years old since planting as a seedling AND • main stems ≤8 years old since the last change of cycle **Field Observation:** • Confirmation of information from interview
Bad	**Interview:** • under discussion: root system and trunk >20 or > 30 years since planting as a seedling OR • main stems > 8 years old since change of cycle **Field Observation:** • Confirmation of information from interview
Rating	**3. Tree density:** **Coffee and Shade tree density in a monoculture, shaded coffee farm and a shaded diversified/agroforestry farm**

Concept and explanation of the Tree Density criteria: tree density must be managed to optimize land and/or labor use for maximum revenue

Rationale for densities: to achieve high income targets from coffee alone, the coffee trees must be planted to optimize the available land. Optimal densities can be different for (i) conventional and improved plant material and (ii) for monoculture coffee where all revenue is delivered from coffee vs an agroforestry system where agroforestry trees also deliver revenue.

Compensation mechanism for coffee tree density: when a coffee tree is allowed more space the individual trees can be allowed to grow bigger and wider or possibly with more stems and each coffee tree will produce more cherries. When coffee trees are planted close together the individual trees should be kept smaller and each tree will produce less than when it was allowed more space but the higher tree density compensates for the lower yield per tree. There are limits to how much a coffee tree can produce beyond a certain spacing while coffee trees that are planted too closely toghether will compete for sunlight, nutrients and water and the yield per tree will be significantly reduced. Within the boundaries of too wide or too narrow spacing the optimal spacing depends on the plant material, the agro-ecological and geographical situation and a farmers' preference.

Conventional and non-conventional or improved plant material planting density: conventional plant material should not be planted in high density patterns as the trees will grow large, branches will enter canopies of other trees and yield is reduced due to competion for light and root space for nutrients and water uptake. Non-conventional or improved plant material should be planted in the recommended (higher) density to avoid an opportunity loss due to less than optimal spacing, but this plant material can also be used for grafting on trunks and stems that are planted in conventional density as the compensation mechanism of the tree will allow it to grow bigger and improve production per acre.

- Change from conventional density to non-conventional or high density without full replanting: if existing trees are planted in rows and at density of around 9x9 feet (3x3 m), then a new tree can be planted between a square of existing plants

Factors to consider for tree density (see table on impact on yield in AO 1)

- Yield on diversified or agroforestry farms is 15% less than yield on non-diversified or monoculture farms - the loss of income is compensated from agroforestry products
- High density planting with selected suitable plant material will result in higher yield

Spacing guidance:

- 400 trees/acre (1,000 trees/ha) corresponds to distance between coffee trees: 11x10 feet (3.3 x 3 m)
- 650 trees/acre ((1,625 trees/ha) corresponds to distance between coffee trees: 9 x 7.5 or 8 x 8.5 o r 7 x 9.8 or 6 x 11.5 feet (2.7X2.3 or 2.4x2.6 m)
- 1,150 trees/acre (2,875 trees/ha) corresponds to distance between coffee trees: 6x6.5, 7x5.5 or 8x4.8 feet (1.8x2 or 2.1 x1.7 or 2.4x 1.4 m)
- 1,333 trees/acre (3333 trees/ha) corresponds to distance between coffee trees: 0.70.7 or 0.6x0.8 or 0.5x1.0 feet (1.75x1.75 or 1.5x2.0 or 1.2x2.5 m)

Good	**Monoculture** **Observation - Arabica coffee** • Conventional: 400 - 650 coffee trees/acre (1,000 - 1,625 coffee trees/ha) or improved varieties 400 - 1,333 coffee trees/acre (1,000 - 3,333 coffee trees/ha) AND •>50% of trees are planted in rows AND •<10% missing trees **Observation - Robusta coffee** • tbc: Conventional: 400 - 650 coffee trees/acre (1,000 - 1,625 trees/ha) or tbc. Improved varieties 400 - 1,333 coffee trees/acre (1,000 - 3,333 trees/ha) AND •>50% of trees are planted in rows AND •<10% missing trees	**Agroforestry** **Observation - Arabica coffee** • Conventional: 340 -650 coffee trees/acre (850 - 1,625/ coffee trees/ha) or improved varieties 340 - 1,150 coffee trees/acre (850 - 2,875 coffee trees/ha) AND •>50% of trees are planted in rows AND •<10% missing trees **Observation - Robusta coffee** • tbc Conventional: 340 -650 coffee trees/acre (850 - 1,625/ coffee trees/ha) or improved varieties 340 - 1,150 coffee trees/acre (850 - 2,875 coffee trees/ha) AND •>50% of trees are planted in rows AND •<10% missing trees
Bad	**Monoculture** **Observation - Arabica coffee** • Conventional: <400 or >650 coffee trees/acre (<1,000 or > 1,625 trees/ha) or Improved varieties <400 or >1,333 coffee trees/acre (<1,000 or > 3,333 trees/ha) OR • ≤50% of trees are planted in rows OR • ≥10% missing trees **Observation - Robusta coffee** • Conventional: <400 or >650 coffee trees/acre (<1,000 or > 1,625 trees/ha) or Improved varieties <400 or >1,333 coffee trees/acre (<1,000 or > 3,333 trees/ha) OR •≤50% of trees are planted in rows AND •≥10% missing trees	**Agroforestry** **Observation - Arabica coffee** • Conventional: <340 or >650 coffee trees/acre (<850 ot >1,625/ coffee treesha) or improved varieties <340 or > 1,150 coffee trees/acre (<850 or > 2,875 coffee trees/ha) AND •>50% of trees are planted in rows AND •<10% missing trees **Observation - Robusta coffee** • Conventional: <340 or >650 coffee trees/acre (<850 ot >1,625/ coffee trees/ha) or improved varieties <340 or > 1,150 coffee trees/acre (<850 or > 2,875 coffee trees/ha) OR • ≤50% of trees are planted in rows OR • ≥10% missing trees
Rating	**4. Tree Health - as seen on a whole plot level:** **the general condition of coffee trees with regards to irreversible damage caused by pests, diseases or mechanical damage resulting in large numbers of unproductive trees**	

Concept and explanation of Tree Health criteria: This criterium aims to determine whether a significant number of coffee trees on a plot are diseased or damaged to a point where their condition cannot be reversed with reasonable effort, the production of the whole plot cannot reach its' targeted yield. The only option to reach targeted yield is to stump, graft or replant the whole plot, depending on the damage.

Definitions of tree health, and differences between (i) Tree Health observations, (ii) Pest, Disease & Sanitation observations and (iii) Debilitating Disease observations

- Definition of tree Health: the percentage of trees in a plot that are diseased beyond cure, including structural damage or architecture of the trees, or damaged beyond repair (non-reversible tree health issues). Damage includes physical damage caused by wind or felling of large trees resulting in broken stems and/or main branches or damaged bark, or stems rotting from stagnant water.
- Difference between tree health and Pest, Disease & Sanitation: the issues in Pest, Disease & Sanitation are reversible; the pests or diseases can be controlled, and trees can be brought back to their production potential. For example, a significant number trees may be affected by leaf rust, but if the trees are recovering from the pest or disease attack, the issue is dealt with under Pest, Disease and Sanitation and not under tree health. Once too many coffee trees have suffered from a pest or disease attacking the vegetative parts of the tree so and cannot be rehabilitated (root, trunk, stem) the issue will be recorded under Tree health and no longer under Pest, Disease and Sanitation
- Difference between tree health and Debilitating Disease: Debilitating Diseases are monitored on individual trees, the disease is not treatable and will lead to tree death or minimal production within a year and the disease will also spread over the whole plot within one or two years. When a debilitating disease is identified, the diseased trees and three circles of trees around the diseased trees must be destroyed, and depending on the disease a delay in replanting may be necessary.

Important note: Tree Health observations do not include trees that are in poor health due to old age or bad soil fertility (i.e. physical soil, nutrient deficiency) as those observations will be included in 'tree age' or 'soil fertility'

Conditions that can cause Bad Tree Health: (i) flat and/or rough cut during rejuvenation and/or stumping which may lead to rotting of the main trunk, (ii) unmanaged infection by stem and twig borers, (iii) significant loss of primary branches, (iv) drying up of coffee trees, roots exposed by soil erosion, (v) weather issues, i.e. regular long draught, floods or lightning strikes or linked to climate change that cannot be addressed by Climate Smart Agriculture

Good	**Field observation:** • ≥80% of main trunks, branches, leaves with no irreversible physical / structural / rotting / P&D damage AND • still able to graft or rejuvenate
Bad	**Field observation:** • <80% of main trunks, branches, leaves with no irreversible physical / structural / rotting / P&D damage OR • no longer able to graft or rejuvenate
Rating	**5. Debilitating Disease:** **a disease that that cannot be cured or reversed and spreads fast**

Concept and explanation of Debilitating Disease criteria: a debilitating disease is a disease that cannot be cured and that will severely damage or kill a large number of trees on the farm, thus resulting in reduced yield and production.

As debilitating diseases cannot be cured and the disease will spread it is important to destroy the diseased trees, depending on the disease a number of trees in close proximity to the diseased trees. For example, if a tree is diagnosed with a debilitating disease, then this tree, and all trees in three circles around this tree must be destroyed at soonest including their root systems. Depending on the disease, the farm may be replanted after a certain amount of time with coffee or with other crops

Examples of dibilitating diseases: Coffee Wilt, Fusarium (bark & root disease), Amillaria (root rot), Nematodes and Bacterial Blight of coffee (Solai/Elgon dieback) and others

Definitions of Debilitating Disease, and differences between (i) Tree Health observations, (ii) Pest, Disease & Sanitation observations and (iii) Debilitating Disease observations

- Definition of Debilitating Disease: Debilitating Diseases are monitored on individual trees. The disease is not treatable and will lead to tree death or minimal production within a year and the disease will also spread over the whole plot within one or two years. When a debilitating disease is identified, the diseased trees and three circles of trees around the diseased trees must be destroyed, and depending on the disease a delay in replanting may be necessary.
- Difference between Debilitating Disease and Pest, Disease & Sanitation: the issues in Pest, Disease & Sanitation are reversible; the pests or diseases can be controlled, and trees can be brought back to their production potential. For example, a significant number trees may be affected by leaf rust, but if the trees are recovering from the pest or disease attack, the issue is dealt with under Pest, Disease and Sanitation.
- Difference between Debilitating Disease and Tree Health: Tree Health covers the percentage of trees in a plot that are diseased beyond cure, including structural damage or architecture of the trees, or damaged beyond repair (non-reversible tree health issues). Damage includes physical damage caused by wind or felling of large trees resulting in broken stems and/or main branches or damaged bark, or stems rotting from stagnant water.

Good	**Field observation:** • NO coffee trees show observable symptoms of debilitating disease
Bad	**Field observation:** • One or more coffee trees show observable symptoms of debilitating disease
Rating	**6. Pruning:** **optimizing canopy and branches for light capture and use of nutrients to support tree growth and crop production**

Concept and explanation of Pruning criteria: Pruning is a key agronomic practice focussed on optimizing resource allocation for production, pest & disease management and husbandry by removing certain parts of the tree on cyclical basis. Unpruned trees are unable to reach target yields due to a range of inefficiencies in the plant physiology. Vegetative parts will compete for nutrients with fruit bearing parts. Excessive folliage will hamper air flow and create a microclimate favoured by fungi and other pests. Excessive folliage will also shield other leaves from direct sunlight and compicate husbandry. Branches touching the soil give access to pests & diseases while branches that are too long limit physical access and dead branches block access to other branches and can host pest & diseases. Rejuvenation cuts too low to the ground are exposed to P&D from splashing of rain drops while a cut that is too high reduces the potential bearing range on the stem. Horizontal rejuvenation cuts can hold stagnant water and lead to rotting stems. Uncontrolled stems that grow on the edge of the cut on the trunk after rejuvenation become weak and can break or create infection of the cut. Suckers take up nutrients without contributing to expected yield. Uncapped trees grow beyond reach for manual harvesting with risk of breaking the bearing stem or branches. **The pruning cycle is characterised by 3 phases each with the following objectives:** **Formation pruning:** (i) maintain the architecture of the coffee tree to easen harvesting and phytosanitary treatments, and (ii) maintain balance of the tree between vegetative growth and fruit production **Maintenance pruning:** (i) eliminate all dead wood, unproductive branches and suckers i.e. vertically growing shoots, (ii) ensure correct aeration to reduce the impact of pests and disease and (iii) ensure access to sunlight to encourage floral induction **Rejuvenation pruning** (i) restart the production cycle of the tree, (ii) encourage the growth of new stems with higher vigour and (iii) encourage the growth of fruit-bearing branches. **Considerations:** (i) no differentiation is made between single stem and multi stem systems. All practices remain relevant with the exception of `the number of stems growing', (ii) no differentiation is made between the capped and non capped systems. All practices remain relevant with the exception of the `bearing height` and (iii) • No differentiation is made on mature and rejuvenated stems. All practices remain relevant with the exception of the `stems branching` and nature of the `cut`.	
Good	**Field observation** major criteria that >80% of trees must have: • 1-3 main stems AND • main stems branching off 30- 50cms from the ground (if rejuvenated) AND • main stems branching >5cm from surface (if rejuvenated) AND • 30-50 degree smooth slanting cut outwards (if rejuvenated) AND • ≤ 2 primary branches touching the ground (if not yet bearing age) AND • ≤ 2 primary branches crisscrossing AND • ≤ 2 dead/dry/diseased branches AND • No suckers or water shoots >10 cm long (unless for rejuvenation/replacement) AND • all primary branches clearly visible AND • ≥ 80% of cherries borne on primary and secondary branches (unless capped system) • good aeration under and inside the tree canopy AND • ≥75% of leaves capture direct (sun)light AND • ≤25% of canopy touches and interferes with the plants next to it AND • ≤ 2m bearing height
Medium	**Field observation** major criteria that >80% of trees must have: • 1-4 main stems AND • main stems branching off <30cm or >50cms from the ground (if rejuvenated) AND • main stems branching >5cm from surface (if rejuvenated) AND • 30-50 degree smooth slanting cut outwards (if rejuvenated) AND • ≤4 primary branches touching the ground (if not yet bearing age)AND • ≤4 primary branches crisscrossing AND • ≤4 dead/dry/diseased branches AND • ≤4 suckers or water shoots >10 cm long (unless for rejuvenation/replacement) AND • < 80% of cherries borne on primary and secondary branches (unless capped system) AND • good aeration under and inside the tree canopy AND • 50-75% of leaves capture direct (sun)light AND • 25≤50% of canopy touches and interferes with the plants next to it • >2 m bearing height

Bad	**Field observation** major criteria that >80% of trees must have: • >4 main stems OR • main stems branching off <30cm or >50cms from the ground (if rejuvenated) OR • main stems branching <5cm from surface (if rejuvenated) OR • <30 or >50 degree non slanting, or rough cut or inwards cut (if rejuvenated) OR • >4 primary branches touching the ground (if not yet bearing age) OR • >4 primary many branches crisscrossing OR • >4 many dead/dry/diseased branches OR • >4 suckers or water shoots >10 cm long (unless for rejuvenation/replacement) OR • < 80% of cherries borne on primary and secondary branches (unless capped system) OR • lack of aeration under and inside the tree canopy • <50% of leaves capture direct (sun)light OR • >50% of canopy touches and interferes with the plants next to it OR • >2 m bearing height
Rating	**7. Pest, Disease and Sanitation:** **the pest, disease and sanitation conditions that support or limit yield potential of the planting material**
Concept and explanation of Pest, Disease and Sanitation criteria: Pest and Disease Observations measure the combined incidence of pests and diseases that reduce the immediate productivity of the tree; the pest and disease problem can be corrected. **Crop Loss:** is the observable loss or reduction of the crop yield, defined both in terms of quantity and quality, that can occur in the field (pre-harvest). While pest and disease infection and damage from last year may still impact the trees' ability to produce coffee cherries, such impact is not observable, therefore we only rate the losses directly attributable to observable pests, diseases and losses. **Definition of Pest, Disease and Sanitation, and differences between (i) Tree Health observations, (ii) Pest, Disease & Sanitation observations and (iii) Debilitating Disease observations** • Definition of Pest, Disease and Sanitation: treatible or avoidable infection or infestation of the tree or the cherries by pests such as insects or rodents, or diseases such as microbial infections, viruses and fungi. Pest and Disease actions target control of a pest or disease while sanitation prevents the presence or spread of a pest or diseae by removing the habitats or vectors for the spread of such pests and diseases • Pests and Diseases: for the purpose of the Adoption Observations, we consider animals and insects as pests and we consider fungi, bacteria and viruses as diseases. Pests and diseases are typically controlled through cultural practices such as removal of diseased fruits and tissue or the control through application of natural or synthetic pesticides. The most important and prevalent pests and diseases in coffee are: thrips, coffee leaf rust, Bacterial Blight of Coffee and coffee berry disease. • Sanitation: for the purpose of Adoption Observations, we consider epiphytes such as mosses, ferns and mistletoes as sanitation issues, as well as presence of diseased plant material on the ground near the trees that may host pests and/or diseases. Sanitation is typically done through removal of the epiphytes or diseased plant material. Depending on the nature of the epiphytes or diseased plant material, these must be removed away from the trees or in some cases, removed from the plot. • Difference between Tree Health and Pest, Disease & Sanitation: the issues in Pest, Disease & Sanitation are reversible; the pests or diseases can be controlled, and trees can be brought back to their production potential. For example, a significant number trees may be affected by leaf rust, but if the trees are recovering from the pest or disease attack, the issue is dealt with under Pest, Disease and Sanitation and not under tree health. Once too many coffee trees have suffered from a pest or disease that attacks the vegetative parts of the tree that cannot be rehabilitated (root, trunk, stem), the issue will be recorded under Tree health and no longer under Pest, Disease and Sanitation • Difference between Debilitating Disease and Pest, Disease & Sanitation: Debilitating Diseases are monitored on individual trees, the disease is not treatable and will lead to tree death or minimal production within a year and the disease will also spread over the whole plot within one or two years. When a debilitating disease is identified, the diseased trees and three circles of trees around the diseased trees must be destroyed, and depending on the disease a delay in replanting may be necessary. • Note: if pests and disease issues that damage the plant tissue itself are not controlled for a more than a season, the damage to the plant tissue may become so severe that the tree will never recover and return to its's earlier vigor and capacity to sustain high yields - and if more than 20% of trees are damaged to this extent, the plot issue (and the required interventions) move from AO 7 pest, disease and sanitation to AO 4: tree health. On the other hand, pest or diseases that attack the coffee cherry but do not damage the tree itself, have no long term negative impact. **Use of Chemicals, protection of people and environment:** the Adoption Observations look at the results of Pest & Disease control and Sanitation whilst supporting: • Rational Use of Pesticides: a 'sentinel system' to decide on the need and/or timing of pesticide applications may be used provided the system minimizes losses as well as calendar spraying does. If sentinel system does not exist, calendar spraying will be used. • Choice of Pesticides: the least toxic but effective pesticides must be used whilst a good Return on Investment must still be possible. Only pesticides approved for use by the Rainforest Alliance may be used • Application of Pesticides: it is reccommended to use the doses and application systems as well as the timing for application as mentioned on the packaging of the pesticides • Protection of People and Environment: it is recommended to use the safety, health and packaging disposal recommendations from the Rainforest Alliance standard	
Good	**Field observation** **Pest and Disease ~~and Sanitation~~** •≤ 10% recent damage/infection on the cherries on the trees that should have been harvested already due to all treatable pests and diseases combined and estimated as % of healthy cherries on the tree AND **Sanitation** •≤ 10% of the trees on the farm have unsellable old or diseased berries on the ground and/or in the trees that should have been removed during the last harvesting round AND •≤ 10% of the trees have diseased plant material, mosses or epiphytes on the trees AND • Fresh prunings that are left on the ground are not infected with pests and diseases AND • Stumped wood is removed from the plot **Interview for confirmation** • Confirm with farmer that no P&D have been overlooked

Medium	**Field observation** **Pest and Disease ~~and Sanitation~~** •10 - 25% recent damage/infection on the cherries on the trees that should have been harvested already due to all treatable pests and diseases combined and estimated as % of healthy cherries on the tree AND **Sanitation** •10-25% of the trees on the farm have unsellable old or diseased berries on the ground and/or in the trees that should have been removed during the last harvesting round AND •10-25% of the trees have diseased plant material, mosses or epiphytes in the trees AND • Fresh prunings that are left on the ground are not infected with pests and diseases AND • Stumped wood is removed from the plot **Interview for confirmation** •Confirm with farmer that no P&D have been overlook
Bad	Field observation Pest and Disease and Sanitation •>25% recent damage/infection on the cherries on the trees that shuuld have been harvested already due to all treatable pests and diseases combined and estimated as % of healthy cherries on the tree AND **Sanitation** •>25% of the trees on the farm have unsellable old or diseased berries on the ground and/or in the trees that should have been removed during the last harvesing round OR •>25% of the trees have diseased plant material, mosses or epiphytes in the trees OR • Fresh prunings that left on the ground are infected with pests and diseases OR • Stumped wood is left in the plot **Interview for confirmation** • Confirm with farmer that no P&D have been overlooked.
Rating	**8. Weeding:** **reducing habitats for pest and disease, avoiding competition for water and nutrients and making access to coffee trees easy**
Concept and explanation of Weeding criteria: Weeds absorb nutrients and moisture that otherwise would be available to the coffee trees. Weeds prevent farm access for farm management, implementation of interventions and can harbour pests & diseases. **Considerations:** **Perennial grasses and sedges are the most competitive weeds affecting coffee growth.** There is large diversity within the different weed species and some might have very minimal effect on the coffee productivity. Weeds can also serve as natural vegetation hence they can can provide a habitat for beneficial insects. Unfortunately it requires a lot of knowledge to identify different species and therefore we do not differentiate within the scope of this AO. **Removal of weeds by hand is best:** Manual weed management (by hoe) results in the production of splits of rooting material (rhizomes, stolons, corms) of the perennial weeds which boosts regrowth. Use of the hoe beyond the first centimers of the soil also damages the coffee roots, disturbs soil life and accelerates the drying of soil moisture. Use of herbicides can be cost effective however might conflict with the principles of Regenerative Agriculture. Hand weeding is most effective but requires significant labor to cover the total farm area. **Herbicides:** use of herbicides is efficient but incorrect use can lead to damage of the coffee trees. In addition, many organizations as well as the principles of regenerative agriculture do not not allow the use of herbicides as it disrupts microbial, insect and plant ecosystems and the herbicides used may lead to pollution of the environment. **Cultivated Area:** This refers to the whole plot in which coffee is grown including; under the coffee trees, in between the rows, as well as all open spaces. During observations for weeding, the areas that may not be suitable for coffee to grow within the plot in focus such as boulders/or rocks, marshy areas, e.t.c, or areas left without coffee by farmer such as footpaths e.t.c will not be considered as part of the cultivated area.	
Good	**Field observation (only cultivated area)** • ≤50% of areas has weeds AND • weeds ≤20 cm high AND • weeds not flowering AND • No evidence of disturbing of superficial coffee roots or soil disturbance under the canopy
Bad	**Field observation (only cultivated area)** • >50% of areas has weeds OR • weeds ≥20 cm high OR • weeds flowering OR • Evidence of disturbing of superficial coffee roots or soil disturbance under the canopy

Rating	9. Harvesting: timely, regular and complete harvest to maximize production & value
Concept and explanation of Harvesting criteria: Timely and selective harvesting ensures that the maximum of non-diseased cherries can be harvested when they are ripe but not over-ripe. **Considerations**: Incomplete or delayed harvesting provides shelter for pests and diseases and results in cherries to ripen beyond the optimal stage which limits its market value (leading to sour beans / foxy beans defect). Premature harvesting equally limits the weight of the harvest because the cherry is not fully mature as well limits the market value (leading to black beans, floater beans defect). Timely harvesting targets mature cherries which are characterised by deep red color, sweet in taste and able to be squeezed between both thumb & finger. **Strip harvesting** tends to take place when labor is limited and the harvesting cycle can not be adhered to. All cherries on a branch are pulled off simultaneously which leads to a large variation in ripeness of the harvested product. Additionally this practice damaged the tissue on the branch which affects yield in the next cropping cycle. This AO focuses on hand picking at this time, but may be expanded to include mechanical harvesting later.	
Good	**Field observation:** • No evidence of strip harvesting AND • ≤5% trees with overripes / dry berries remaining on tree AND • Sellable berries seen on ≤1% of the ground under the tree canopy
Bad	**Field observation:** • Evidence of strip harvesting OR • >5% trees with overripes / dry berries remaining on tree OR • Sellable berries seen on >1% of the ground under the tree canopy
Rating	**10. Shade:** **optimized shade level for coffee trees to reach targeted yield**
Concept and explanation of Shade criteria: Coffee grew originally below the forest canopy but yield can be maximalised by growing coffee under full sunshine under optimal management. Such yields require high rates of photosynthesis hence high nutrient availability in the soil while there is a considerable risk of drought-stress on coffee trees. These yield levels are usually hard to maintain. **Shading has the following objectives:** (i) buffering of temperature fluctuations (both hot and frost) and shelter from wind and creation of a micro climate (ii) production of plant litter as organic mulch and thus reduction of weed growth (iii) protection from top soil erosion (iv) development of optimal aromatic compounds inside the bean due slower growth and maturation period that increases levels of natural sugars (v) recycling nutrients that are seated deep in the soil (vi) providing a habitat for other beneficial plants and birds and (vii) may also have other economic benefits such as fruit, timber, etc. **The optimal shade level** is largely dependent on the yield ambitions, risk exposure, latitude of the growing area and management strategy. As a rough rule of thumb, coffee requires an average of 2200-2400 h of sunlight per year and only heavy shade is a limiting yield factor. Negative effects from shade can be prevented by (i) lopping of shade branches (ii) selecting compatible shade trees, (iii) planting the shade trees at a distance from coffee trees so that root systemns do not compete and (iv) keeping space between shade & coffee canopy. **Recording of shade/agroforestry tree presence in the field:** because it takes time to achieve canopy development and achieve the shade target, we include newly planted trees and we assess shade level based on the future shading expected from the seedlings. **Compatibility of shade and agroforestry trees**: only compatible shade or agroforestry trees may be interplanted with coffee trees. Compatible shade or agroforestry trees do not compete for root space, water or nutrients with the coffee trees and they do not host pests and diseases for which coffee trees are vulnerable. More guidance about compatible tree species can be found in the Shade Catalog (https://www.shadecoffee.org/) **Spacing of shade trees:** Spacing of compatible shade trees should be advised by the size of their canopy at maturity. Shade trees with dense canopies may be pruned regularly to reduce the density of the canopy. **Measurement method for shade percentage:** Shade level is measured as a percentage of shade area falling onto the total plot area. **Note** that Rainforest Alliance criteria for shade must be respected as well to ensure market access.	
Good	**Field observation:** • 30-50% shade (estimated as if all shade trees are mature) for ≥80% of coffee trees AND • ≥ 50% of shade trees are evenly distributed on the plot i.e. in rows and/or on the boundary AND • Shade trees are compatible with coffee i.e. no host of disease, no competition for root or canopy space, no breaking branches AND • ≥ 1.5 meters in height between canopy of the shade trees (when mature) and the coffee trees
Bad	**Field observation:** • <30% or >50% shade (estimated as if all shade trees are mature) reaching the canopy of ≥80% of coffee trees OR • < 50% of shade trees are evenly distributed on the plot i.e. not in rows and/or on the boundary OR • Shade trees are not compatible with coffee i.e. host of disease, competition for root or canopy space, or breaking branches OR • < 1.5 meters in height between canopy of the shade trees (when mature) and the coffee trees

Rating	11. Physical condition of the soil: identification of physical soil conditions that support or limit coffee yield
Concept and explanation of criteria: we monitor physical soil condition to understand water and nutrient availability and root system development of the coffee trees and avoid planting or renovating trees on soils that are not promising for high yielding coffee trees. **Physical soil condition is the foundation** which will directly affect the ability to (i) hold & avail moisture (ii) hold & avail nutrients (iii) allow roots to penetrate & anchor. Coffee plants grow well in alluvial and colluvial soils with a loose texture as in volcanic soils. Soil depth should be at least 2 m to allow tap root development and ensure water supply. Shallow soils limit growth due to water stress during the dry season. While 90% of coffee roots develop in the upper 30 cm layer, they can grow up to 3m deep. Soil texture should ideally hold less than 30% of sand and less than 70% of clay in order to contain & avail sufficent moisture. Gravel strata which consists of pebbles or gravel should not be over 15-cm thick for the roots to be able to penetrate. The water table should be at least 1.5 m below the soil surface. **Challenges:** • The physical soil condition is mostly determined by what the soil structure and texture is - the interventions to change the physical soil conditions are either limited or very costly or labor intensive • many farmers find themselves on land that is only moderately or unsuitable for cultivation fo coffee but for many reasons alternatives to coffee farming may not exist (i.e. land tenure, absence of markets for other crops). Coffee farming on moderately suitable soil may deliver significant income for farmers but it is unlikely that 'living income' can be reached on such soils. Coffee farming on unsuitable soils should be avoided and alternatives should be sought, if available at all, as coffee farming will never deliver a 'living income' **A practical test which can be conducted in the field to get an understanding of soil characteristics:** Touch/roll test for soil texture; (i) if the soil is more than 70% sand you will not be able to form a cylinder more than 5 cm long and 1.5 cm in diameter, it will not form a ring, and it will have many cracks in it and fall apart, (ii) if the soil is more than 40% clay your sample will form easily into a smooth cylinder around 10 - 15 cm long and about 0.5 cm n diameter, with no cracks or fissures in the side or (iii) if the soil is a type of loam, you will be able to form a cylinder 10-15 cm in diameter and to form a ring, but the ring will have many cracks in the outer edge.	
Good	**Field observation:** • no signs of erosion, no roots visible on the surface AND • few rocks on farm surface or in the ground: the soil contains ≤35% gravel as measured by 3 holes of 30 cm deep per plot AND • soil is neither too sandy nor argyllic as measured by the 'touch/roll test' on soil from 3 holes of 30 cm deep per plot AND • well drained soil either naturally or through drainage canals so that coffee tree trees are never exposed to >3 days of floods AND • slopes >5 degrees: the plot has anti erosion measures in place
Bad	**Field observation:** • signs of erosion, roots visible on the surface OR • many rocks on farm surface or in the groundthe soil contains >35% gravel as measured by 3 holes of 30 cm deep per plot OR • soil is either too sandy or argyllic as measured by the 'touch/roll test' on soil from 3 holes of 30 cm deep per plot OR • poorly drained soil so that coffee tree trees are exposed to >3 days of floods OR • slopes >5 degrees: plot has no anti erosion measures in place
Rating	**12. Soil Health (through organic matter and microbial activity):** **observations monitor whether sufficient organic matter is available to improve general soil health.**
Concept and explanation of Soil Health criteria: observations monitor whether sufficient organic matter is available in various stages of decay and whether insect and worm activities can be observed, as a proxy to microbial activity to support nutrient transport to, and uptake of nutrients by root systems. **Soil health is important** as it serves the following functions: (i) hold & avail nutrients (ii) hold & avail moisture (iii) buffering of acidification (iv) decompositon of material into readily available nutrients (v) fixate carbon. The health of soil is the first priority with regards to soil fertility as unhealthy soils cannot deliver nutrients to plant roots even if nutrients are abundantly available • Coffee thrives in healthy soils with >2% organic carbon however below 0.8% organic carbon its production will be severly limited. **Assessment of soil health:** • Soil health can be assessed above ground by proxy through observing the various stages of organic material decay in the top soil layer as a result of the presence of worms and other visible soil fauna. • Soil Organic Matter below ground can be assessed by doing a field test that estimates the presence of organic matter in the soil. Under review: this test is conducted as follows: (i) add soil into a container i.e. plastic bottle (ii) add water and if available with a spoonful of salt (iii) Shake vigourously for 1 min (iv) let the sediments settle for at least 10 minutes and measure the thickness of the top layer floating on top as a function of the total sediment combined with the sand, silt and clay particles at the bottom of the container. Also to confirm: Let it stand for 4h (v) shake again for 1 min (vi) let it stand for another hour **Considerations** • Interventions on soil health may take time to manifest itself and require considerable labor but only moderate financial investment • Organic matter will reinforce the effect of synthetic fertilizers thereby reducing the volume requiered to achieve the same effect on yield.	
Good	**Field observation:** • Coffee prunings are left in the plot AND • Organic material is evenly spread on the plot >30cm from coffee stems AND • ≥80% of soil under the coffee canopy is covered by multiple layers of decaying organic material (indicating a well spread ecosystem for soil life such as visible worms, worm castings, insect activity)

Bad	**Field observation:** • Coffee prunings are taken from the field OR • Organic material is not evenly spread on the farm ≤ 30cm from coffee stems OR • <80% of soil under the coffee canopy is covered by multiple layers of decaying organic material (indicating an insufficiently spread ecosystem for soil life such as visible worms, worm castings, insect activity)
Rating	**13. Nutrients, Nutrient Ratios and Formulation of fertilizers and soil amendments** **Focus on replenishment of nutrients through organic and inorganic inputs for optimized nutrient ratios and maintaining soil health**

Concept and explanation of criteria: The Adoption Observations for nutrients, nutrient ratios and formulation of inputs indicate the various organic and inorganic nutrients and soil amendment products and the ratios in which they should be applied to create and maintain a healthy and productive farm.

Function of nutrients: some nutrients are needed to support tree vegetative growth. Once trees are mature and are pruned regularly for size, only a modest volume of nutrients are needed to sustain the trees' vegetative growth especially if leaf litter and pruning debris is left in the farm. An increase of the yield target from mature trees therefore mostly targets the nutrient replenishment needs that result from harvesting, but when trees are stumped there is a significant need for additional nutrients

Concept of nutrient replenishment - use of organic and inorganic inputs: healthy and productive soils require both organic material for soil health and organic or inorganic nutrients and soil amendment products in the right ratios. There may be a need to (i) add nutrients that are depleted until soil is restored, (ii) to replenish nutrients that are taken from the field by harvest or by removal of (diseased) organic material from the field, or (iii) a need to optimize soil to deliver the nutrients in the optimal ratio to support high coffee yield and vegetative growth. Note that even high natural soil fertility may not be optimal for all crops, and additional nutrients or soil amendment products may be needed

Determining the nutrients to replenish vs removal of nutrients:
• Nutrients in trees and fruits: a coffee tree requires nutrients to grow to maturity, but once mature and regularly pruned with pruning debris left in the field, coffee trees require only modest volumes of nutrients to maintain their vegetative vigor.
• Nutrients in cherries: from the moment a coffee tree starts producing cherries (consisting of bean, parch, pulp, mucilage and skin), these cherries are removed from the field. The bean is exported and most often the parchment, mucilage, skin and pulp is discarded and not composted. Basically all the nutrients in the cherry are lost to the ecosystem, and to maintain future yield these nutrients need to be replenished.
• The amount of nutrients that need to be applied to compensate for 1,000 kg of cherries is much higher than the nutrient contents of the coffee cherries, and in addition the ratios of nutrients removed and the ratios of nutrients that need to be brought back are not the same, due to differences in solubility of nutrients, their transport in the soil and easy or poor uptake of nutrients by root systems, as well as issues of nutrients lost to the atmosphere as gas or to the soil through leakage and seepage. Therefore we must assume that only around 55 - 65% of nutrients are actually taken up by the plant and that various nutrients become depleted from the soil at different rates.

Ratios of nutrients removed vs nutrients to replenish:
• Nutrients for plant growth: the plant needs 238 kg of nutrients for vegetative growth of the root system, trunk, stems, branches and leaves to reach maturity. The ratio of nutrients in the and leaves in ratio 34 N, 6 P, 38 K, 14 Ca, 5 Mg and 3 S with some micro nutrients (for a total of 82 kg N, 15 kg P, 90 Kg K, 33 kg Ca, 12 kg Mg and 6 kg S). Note that the nutrient ratios for plant growth are not the same as for nutrient replenishment for fruits - there is a higher need for P, Ca and Mg
• Nutrients removed in coffee cherries including pulp and skin are in ratios as follows: 30 N, 3 P, 35 K, 3 Ca, 3 Mg, 3 S, and very small ratios of Zn, B and Mo.
• Trace elements such as Fe, Cu, Mn, Mo, Si, Na, Co etc. are used in chemical processes in the plant and around root systems, and some elements removed but in such small volumes that replenishment is rarely necessary. .
• nutrient ratio in fertilizer should be 22 N, 6 P, 12K, 1.3 Ca, 1 Mg, 2.5 S, 0.15 Zn, 0.15 B and 0,002 Mo

Use of organic and inorganic inputs for soil health and nutrirent replenishment:
• Organic material such as manure or raw, mulched or composted organic material or organic fertilizer are necessary for soil health. Organic material also delivers nutrients but at low levels, and not in the ratio between nutrients that crops require.
• Nutrient replenishment with organic material only is possible but requires large volumes of organic material, high labor resources to transport and process it, and high technical skills to deliver the correct ratios between nutrients
• Determine the right ratio of nutrients: organic material is highly heterogeneous between different sources of livestock, vegetation and crop residues. It is important to monitor which organic material is used and what ratios or volumes of nutrients these deliver. There are no simple 'rules' to put together different organic materials in the right volumes to achieve nutrient replenishment.

• Inorganic fertilizer is a (cost) efficient way to bring various nutrients in the right ratios to the farm while transporting comparatively low volumes. But inorganic fertilizer can have negative effects such as (i) risk of imbalance of nutrients in the soil if the ratio of nutrients is not correct, (ii) risk of compacting the soil if not enough organic material is applied as well,(iii) risk of run-off of nutrients into water steams creating eutrophication (mineral enrichment that alters the ecosystem balance and causes harmful algal blooms, dead zones, and kills fish and other aquatic animals) , (iv) acidification especially if Ammonia-N fertilizer is used, (v) inorganic fertilizer does not promote microbial activity
• Other soil amendments sch as lime or dolomite (or huge volumes of organic material) may be needed to address soil acidification

Recommended fertilizer formulation based on nutrient replenishment needs and the different levels of nutrient loss and tree uptake of nutrients: while ideally, fertilizer would be optimized for different soil structures, nutrient availability and different production targets; but delivery of a wide range of fertilizers would be costly and would add complexity for the users whom are not soil experts. Therefore we accept that fertilizer may not be optimized for all conditions and following formulations are acceptable - assuuming that all pruning debris is left close to the coffee trees and that pulp, mucilage and parchment are not brought back to the field.
• various specific complete fertilizer formulations (i.e. Yara Mila Java and MEA + TA) indicate that the best ratio for nutrients is 22 N, 6 P, 12 K, 1.3 Ca and 2.5 S
• additional Calcium Nitrate (CaN, containing 25.5% Ca and 15.5% N in Nitrate form with possible additional micronutrients such as Zn) may be used for additional N and for additional Ca to counteract soil acidification

Future potential for nutrient recycling of pulp, mucilage and parchment: the nutrient content of a coffee cherrie is roughly 50% in the bean and 50% in the pulp, mucilage and parchment. The pulp is lost in the washing process and the mucilage and parchment are usually discarded as waste. New pulp treatment systems are under development that can reduce the acidity of the pulp and the high biological and chemical demand for oxygen oxidation and fermentation to form compost, and to address the high levels of polyphenols in the pulp which are not wanted as tree nutrients. Until such systems become available to smallholder farmers we will focus our recommendations for nutrient replenishment on full replacement of the whole cherry, including bean, pulp, mucilag and parchment.

Nutrient specific comments:
• N should not be applied as Ammonia (NH4+) as is the case in Urea and common NPK fertilizers, as it acidifies the soil. N should be applied as Nitrate (NO3-) but note that Nitrate cannot be blended with P2O5 and K2O as there will be a chemical reaction, and these nutrients need to be bagged separately. .
• N, P and K can be applied as single or compound fertilizer whilst Nitrate N fertilizer, which is preferred as it is much less acidifying than Ammonia N, is usually applied as a single fertilizer with Calcium as co-ion. P can be applied as Rock Phosphate or as Super Phosphate but care must be taken that the source of Phosphate is clear of heavy metals. K can be applied as KCl but at very high doses there may be over-abundance of Cl- which can decrease soil fertility or in extreme cases cause crop toxicity.
• The three secondary nutrients Ca, Mg and S are needed iin modest volume only and potential negative effect of these nutrients and their companion ions is very moderate if any
• Micronutrients are applied in very small doses but they are necessary for the chemical functions in the plant

Good	**Inorganic well balanced fertilizer as main source of nutrients for Mature trees (≥ 5 years after planting):** Interview: **Fertilizer: required nutrients in optimal ratios:** • use of complete coffee fertilizer (i.e. Yara Mila Java or a similar fertilizer brand/blend) OR - if complete coffee fertilizer is not available: use of NPK fertilizer with sufficient dose of lime/dolomite/CaN to counteract soil acidification caused by Ammmonia-N plus other sources of additional N, P, K, Ca, Mg, S and micro nutrients to deliver all nutrients in ratios similar to complete coffee fertilizer **Additional soil fertility interventions** • appropriate dose of raw plant organic material, composted manure or organic fertilizer for soil health • appropriate dose of lime/dolomite or high volumes of organic material when pH is below 5.5 Observation • <5% of plot area showing or suspected of nutrient deficiencies.	**Inorganic well balanced fertilizer as main source of nutrients for Young trees (<5 yrs old):** Interview: **Fertilizer: required nutrients in optimal ratios:** • at planting: use of complete coffee fertilizer (i.e. Yara Mila Java or a similar fertilizer brand/blend) with additional P, Ca and Mg. OR - if complete coffee fertilizer is not available: use of NPK fertilizer with sufficient dose of lime/dolomite/CaN to counteract soil acidification caused by Ammmonia-N plus other sources of additional N, P, K, Ca, Mg, S and micro nutrients, and additional P Ca and Mg to deliver all nutrients in ratios similar to complete coffee fertilizer • at fruit bearing but immature age: use of complete coffee fertilizer (i.e. Yara Mila Java or a similar fertilizer brand/blend) including Zn and B with modest additional P, Ca and Mg. OR - if complete coffee fertilizer is not available: use of NPK fertilizer with sufficient dose of lime/dolomite/CaN to counteract soil acidification caused by Ammmonia-N plus other sources of N, P, K, Ca, Mg, S and micro nutrients, and modest additional P Ca and Mg to deliver all nutrients in ratios similar to complete coffee fertilizer • Y5 onwards: as per mature tree **Additional soil fertility interventions** • appropriate dose of raw plant organic material, composted manure or organic fertilizer for soil health • appropriate dose of lime/dolomite or high volumes of organic material when pH is below 5.5 Observation • <5% of plot area showing or suspected of nutrient deficiencies.
	Future: Focus on coffee pulp recycling and additional fertilizer, with additional organic matter as the main source of well balanced nutrients for Mature trees (≥ 5 years after planting or ≥ 18 months after stumping): **Mature trees** Not yet applicable	**Future: Focus on coffee pulp recycling and additional fertilizer, with additional organic matter as the main source of well balanced nutrients for Mature trees (≥ 5 years after planting or ≥ 18 months after stumping):** **Young trees:** Not yet applicable

	Focus on organic matter as the main source of well balanced nutrients for Mature trees (≥ 5 years): Interview: Deliver the maximum dose of nutrients needed through organic matter, and if available though use of composted coffee pulp and skin. **Note:** if coffee pulp is recycled, the nutrient replenishment needs with (mostly) organic material are 65% of all nutrients, with focus on delivering N and P as those nutrients are not well represented in coffee pulp. Additional soil fertility interventions - • appropriate dose of lime/dolomite or high volumes of organic material when pH is below 5.5 **Observation** • <5% of plot area showing or suspected of nutrient deficiencies)	**Focus on organic matter as the main source of well balanced nutrients** for Young trees (< 5 years): Interview: Deliver the maximum dose of nutrients through organic fertilizer and if available the use of coffee pulp and skin: if coffee pulp is recycled, the nutrient replenishment needs with (mostly) organic material are 65% of all nutrients, with focus on delivering N and P as those nutrients are not well represented in coffee pulp. Additional soil fertility interventions - • appropriate dose of lime/dolomite or high volumes of organic material when pH is below 5.5 **Observation** • <5% of plot area showing or suspected of nutrient deficiencies
Medium		
Bad		

14. Application of soil nutrition inputs
Volumes and application of organic, inorganic and soil amendment inputs for efficient nutrient replenishment - fertilizer, organic matter, lime and dolomite

Concept and explanation of criteria: the required volumes of various inputs, the methods and timing to apply these inputs, either as fertilizer, organic matter or other soil amendments, to meet the needs of coffee trees and support their yield potential.

Function of nutrients and application: some nutrients are needed to support tree vegetative growth and nutrients will deplete slower or faster depending on their volume in the soil. Once trees are mature and are pruned regularly for size, only a modest volume of nutrients are needed to sustain the trees' vegetative growth especially if leaf litter and pruning debris is left in the farm. An increase of the yield target from mature trees therefore mostly targets the nutrient replenishment needs that result from harvesting, but when trees are stumped there is a significant need for additional nutrients

Soil applied fertilizer vs foliar fertilizer: soil applied fertilizer takes time to distribute in the soil and to be taken up by the root system, but it is an efficient way to apply Macro nutrients (N, P, K) as the volumes needed are hiigh, and for Secondary nutrients (Ca, Mg, S) as the volume requirements are still significant. Once fertilizer soil application is done regularly and the nutrients are absorbed in the soil, the speed of uptake of macro nutrients is not very relevant. On the other hand, Foliar fertilizer acts fast, but the volumes that can be applied lend this application best to the micro nutrients such as Zn, B, Cu, Mo or if so desired, give the tree a quick but small boost of secondary nutrients.

Lag time between soil fertility interventions and impact: the impact of soil applied fertilizer, organic matter and lime/dolomite can take two or even three years if the soils were highly deficit of nutrients or microbial activity or when pH was below 5.3

Measurement of doses: units for hectare or tree application: fertilizer use is often expressed in mt/ha or acre/year but as a rule of thumb, 1 ‰ (0.1% of the recommendation per hectare or acre) can be used as target dose per coffee tree.

Fertilizer volumes: 80 kg/acre (200 kg/ha) of fertilizer is needed to replenish nutrients that were removed from the field in 1 mt of cherries, including the pulp and skin. This considers the fact that roughly 50 of fertilizer is made up of filler needed to form small pallets and separate the nutrients, as well as the leakage, seepage, loss of nutrients to the atmosphere and poor nutrient transport in the soil and/or uptake by the plant, as well as the technical considerations for fertilizer blending.

Fertilizer practicalities and recommended fertilizer blends: Ideally, fertilizer would be optimized for different soil structures, nutrient availability and different production targets; but delivery of a wide range of fertilizers would be costly and would add complexity for the users whom are not soil experts. Therefore we accept that fertilizer may not be optimized for all conditions.
• use special coffee fertilizer where it exists, with following nutrients in roughly these ratios: 22 N, 6 P, 12 K, 1.3 Ca and 2.5 S, wiht additional micronutrients if available.
• where such fertilizer does not exist, farmers may use similar formulations to get as close as possible to the nutrient specifications and with additional single nutrient fertilizers where such nutrients are lacking. Foliar fertilizer can be used for micronutrients.
• CaN (25% Ca, 15.5% N nearly all in Nitrate form) may also be used in places where lime/dolomite is scarce and /or too costly or as a source of N where the fertilizer formulation used is low on N.
• use organic matter to promote soil health

Fertilizer Return on Investment
• Specialized fertilizer for coffee exists in some places and may deliver all the required nutrients in one bag. Where it does not exist, farmers may use the available formulations to get as close as possible to the nutrient specifications including foliar fertilizers.
• fertilizer is expensive and needs to be applied at significant volumes - it is therefore important to apply fertilizer only on plots that will deliver a return on investment in the short or medium term according to the planning by the farmer
• Where fertilizer is not optimized for soil conditions, it may be possible to 'overdose' a little bit to ensure that the nutrients that are least available in the soil are brought to a level to support high coffee yield which may result in moderate over-availability of other nutrients. The cost of

Good	**Application of non-organic well balanced fertilizer as main source of nutrients for Mature trees (≥ 5 years)** Interview: **Fertilizer** • 80 kg/acre (200 kg/ha) of Yara Mila Java or similar complete coffee fertilizer for replenishment of yield of 400 kg of GBE or 2400 kg of cherries per acre (respectively 1 mt or 6 mt per ha). If such complete coffee fertilizer is not avvailable, use 70 kg of NPK and 15 kg of additional nutrients as described in AO 13 (nutrient ratios) • applied within 1 foot (30 cm) from the edges of the canopy under the leaf litter or superficially buried in the soil • applied twice per year at the onset of the rains (not applicable if fertilizer is not made available by supplier) **Additional inputs** • 200 kg/acre of raw plant organic material or 100 kg/acre of compost, composted manure or organic fertilizer (to maintain soil health and microbial activity but not for nutrient replenishment) • 400 - 800 kg of lime/dolomite/acre when pH is below 5.5	**Application of non-organic well balanced fertilizer as main source of nutrients: for Young trees (<5 yrs old)** Interview: **Fertilizer:** • at planting - per tree ≥100g of complete coffee fertilizer (i.e. Yara Mila Java or a similar fertilizer brand/blend) with 100gms of lime/dolomite or Nitrabor and 100g of TSP/SSP and 20kgs of composted manure or plant based compost or if such complete coffee fertilizer is not available, use 80 g of NPK per tree with 20 g of additional nutrients missing in such NPK vs a complete fertilzer and use 50 g/tree of lime or dolomite (pissibly CaN) to compensate for soil acidification. • Y1-Y4: ≥100g of complete coffee fertilizer (i.e. Yara Mila Java or a similar fertilizer brand/blend) with additional lime/dolomite or Nitrabor and ≥20kgs manure/compost or if such complete fertilizer is not available 80 g of NPK per tree with 20 g of additional nutrients missing in such NPK vs a complete fertilzer and use 50 g/tree of lime or dolomite (pissibly CaN) to compensate for soil acidification. • and applied as fertilizer for mature trees Additional inputs • 200 kg/acre of raw plant organic material or 100 kg/acre of compost, composted manure or organic fertilizer (to maintain soil health and microbial activity but not for nutrient replenishment) • 400 - 800 kg of lime/dolomite/acre when pH is below 5.5
	Future: Focus on coffee pulp recycling and additional fertilizer, with additional organic matter as the main source of well balanced nutrients for Mature trees (≥ 5 years after planting or ≥ 18 months after stumping): **Mature trees** Not yet applicable	**Future: Focus on coffee pulp recycling and additional fertilizer, with additional organic matter as the main source of well balanced nutrients for Mature trees (≥ 5 years after planting or ≥ 18 months after stumping):** **Young trees:** Not yet applicable
	Focus on organic matter as the main source of well balanced nutrients for Mature trees (≥ 5 years): Interview: • Deliver the maximum dose of nutrients needed through organic matter, and if available though use of composted coffee pulp and skin. Note that due to the diversity of organiic matter and the difference in nutrient content, volumes cannot be given **AND** Use addittional fertilizer to replenish nutrients missing from all organic matter together or to adjust ratios between nutrients Note: • if coffee pulp is recycled, the nutrient replenishment needs with (mostly) organic material are 65% of all nutrients, with focus on delivering N and P as those nutrients are not well represented in coffee pulp. • ensure that manure is composted, and avoid very high doses of composted manure Additional soil fertility interventions - • appropriate dose of lime/dolomite or high volumes of organic material when pH is below 5.5 **Observation** • <5% of plot area showing or suspected of nutrient deficiencies)	**Focus on organic matter as the main source of well balanced nutrients** for Young trees (< 5 years): Interview: • Deliver the maximum dose of nutrients needed through organic matter, and if available though use of composted coffee pulp and skin. Note that due to the diversity of organiic matter and the difference in nutrient content, volumes cannot be given AND Use addittional fertilizer to replenish nutrients missing from all organic matter together or to adjust ratios between nutrients Note: • if coffee pulp is recycled, the nutrient replenishment needs with (mostly) organic material are 65% of all nutrients, with focus on delivering N and P as those nutrients are not well represented in coffee pulp. • ensure that manure is composted, and avoid very high doses of composted manure Additional soil fertility interventions - • appropriate dose of lime/dolomite or high volumes of organic material when pH is below 5.5 Observation • <5% of plot area showing or suspected of nutrient deficiencies)
Medium		

Bad		
	15 Soil acidity (pH) **Optimal pH level for coffee trees**	
	Concept: Soil acidity has a direct effect on the availability of nutrients to the coffee tree and can therefore be a big limitating factor of coffee productivity. Outside the optimum pH range, some nutrients that coffee trees need will become less readily available to the tree due to lower microbial activity or chemical interactions from other elements, resulting in slower nutrient transport and lower uptake by the plant. **Measurement:** Acidity is expressed as pH which follows a logarithmic scale which implies that a 1 point change implies a tenfold difference of acidity. Acid soils are below 7 and alcalic soils are above 7 on the pH scale. Measurement can take place by submitting soil samples to a laboratory for chemical analysis or alternatively by a hand held divice that is pushed into the soil and delivers an immediate readout. **Considerations**: • Coffee thrives in slightly acidic soils with pH between a range of 5.3-6.5. For pH below 5.3 certain minerals will no longer be available for uptake by the roots, and other minerals (Al, Fe) that are toxic become available in ferralitic red soils with pH <5.5 soil water there may be a concern for heavy metal toxicity, the pH considered ideal for coffee growing is 5.5-6.5. Low pH also limits bacterial activity - hence it slows down the breakdown of organic material and the vigor and productivity of the cofffee trees will decline. Changing soil acidity or pH this is a slow mechanism: it can take years if the pH needs to be changed significantly. An "overdose" with an acidifying product (i.e. aluminum sulphate or sulfuric acid) or with an alkaloid material to make the soil less acidic (i.e. calcium, lime, dolomite, rock phosphate but also selected organic matter) does not result in a more rapid change in pH when such an overdose can be detrimental to other soil health and nutrient conditions . • It is always better to prevent soil acidification than to repair it, as pH change is slow and materials such as lime, dolomite or rock phosphate are very expensive in some countries while large volumes of organic matter are needed to change the pH.	
Good	**field measurement:** • pH 5.5 ≤ 6.5 range	
Bad	**field measurement:** • pH <5.5 or >6.5	

Tram of questions

- History
  - History of coffee in the region
  - What happened when coffee was introduced? (if introduced)
- Population
  - Where do the people of the mountains/villages come from? Have they always lived here? What is their story?
  - What is the main ethnic group? minority?
  - How long have they been there to grow crops on the mountain?
  - The village is new?
  - Do young people stay in agriculture? Do they want to go to the city?
- The Agricultural System

Farms

- Are all farms the same? (Size, family; how much per family)
- What does a plot of coffee look like? What other types of crops are found there or is it monospecific?
- What are the main associations in the plots? List the different types of crops:
- Is other crops food merchant?
- The different profiles of operators:
- Where does this difference come from? Depending on the size of the farms? Altitudes? What makes this difference?
- A farm can be on several altitudes or a farm is in one place?

Inputs/ Practices

- Inputs: what are the practices? They use it on their entire plot? Different types depending on the crop?
- What technical problems do they encounter with inputs?
- Erosion problem: is it a real persistent problem? What techniques are already in place? Are there erosion problems due to cultural practices?
- The main practices that are similar: no protection, overdose of inputs etc ...

Coffee

- Can they make a living from coffee? What do they live on mainly? breeding?
- Do they encounter problems especially with coffee or other crops?
- On average, are coffee trees young or old? Are they well maintained?
- What are the biggest/biggest pests?

Map of main roads and cities in Uganda :

Map of main roads in Uganda Source: Logcluster

ANNEX 9 - Family organisation of agricultural work

In families, the workload is divided between husband and wife. However, men have more decision-making power over culture than women, for example. Indeed, they are the ones who manage the marketing, sales and finance processes of the household. However, this is not always the case and women may have more responsibilities in certain situations:

- Women manage the agricultural activity because the husband has died
- Some husbands want their wives to know how to sell
- Mutual agreement in the organization of the activity

On the other hand, it is possible that the children help or work on the family farm. Indeed, government schools are fee-paying and their involvement in agricultural activity depends greatly on the financial ability of their parents to be able to send them to school. Thus, out-of-school children work full-time on the farm and different dynamics are observed for schoolchildren:

- The least studious children at school are more solicited by their parents to stay working on the farm: after school or on weekends. Most of the time, they are the ones who take over the farm because of the interesting financial contribution that coffee cultivation brings or they settle on their own
- More studious children who have ambitions to make a career in the city and subsequently invest in cash crops such as coffee and corn. They employ farmers to tend their plantations

ANNEX 10 - Markets and local organisation

Farmers also determine their crops based on fluctuating markets. For example, for coffee, a few years ago, prices were low, which prompted farmers to abandon this crop. They then diversified their crops to try to have an income roughly equivalent to that earned with growing coffee.

In addition, this great variability means that when farmers invested in coffee cultivation, prices were different from when they sold their crop. Thus, depending on the fluctuation of the markets, they may have a profit or a deficit in relation to their investment. So when farmers invest and produce coffee, they don't know if it will be profitable for them.

In addition, in local markets, prices are not the same from one village to another because they vary according to the weather, the quantity available on the market or the cost of transport for example. Also, the fact that prices are not fixed and that they differ from one village to another does not allow farmers to have a real insight into demand and prices. Added to this is poor circulation and a lack of availability of real-time information.

Often, it is large farmers who drive their plots in monoculture and allocate their crops for sale on local markets or for export.

ANNEX 11 – The germination process

The farmer selects the berries of the trees according to their performance. It isolates them and germinates them in particular conditions: sheltered, damp earth ... When the plant measures between 12 and 14 cm, the farmer plants the new plant on the plot. Very special attention is paid to the plant: control of weeds close to the plant and inputs are applied to boost its growth and prevent potential diseases. In addition, seedlings are preferably planted near a banana tree so that it can enjoy its shade. The best time for germination is in November and December, and the time of the plant in the plot is in May.

ANNEX 12 – Practices and sources of inputs

The vast majority of inputs are used by all farmers working with TCG. They allow them to ensure the good growth of their crops and to fight against diseases and pests for example. They are then essential to ensure a good harvest for farmers and therefore an income. There are two types of inputs:

- Organic: manure composed of a mixture of dead leaves, excrement, ashes, pulp from coffee cleaning ...
- Inorganic: chemical fertilizers (Nitrate, Phosphorus, K potassium; Calcium Ammonia Nitrate), fungicides, pesticides ...

Their use depends on the intention of the farmers and often they combine them. For example, in general, inorganic fertilizers are applied to young coffee plants to boost their growth or for example, a fungicide can be applied as a preventive action to a disease. Also, as the plots are multispecific, the application of a fertilizer benefits the entire plot.

In addition, even if the combination of crops makes it possible to effectively protect the plot from certain diseases and pests by avoiding the spread of seedlings to seedlings for example, when a diseased plant is observed, pesticides are applied. This practice aims to preserve the balance established between the different crops of the plot. Indeed, the poor condition of a plant could allow pests or diseases to penetrate the plot, which would have negative repercussions on the entire crop.

However, input efficiency is not fully guaranteed and farmers may face the following main technical problems :

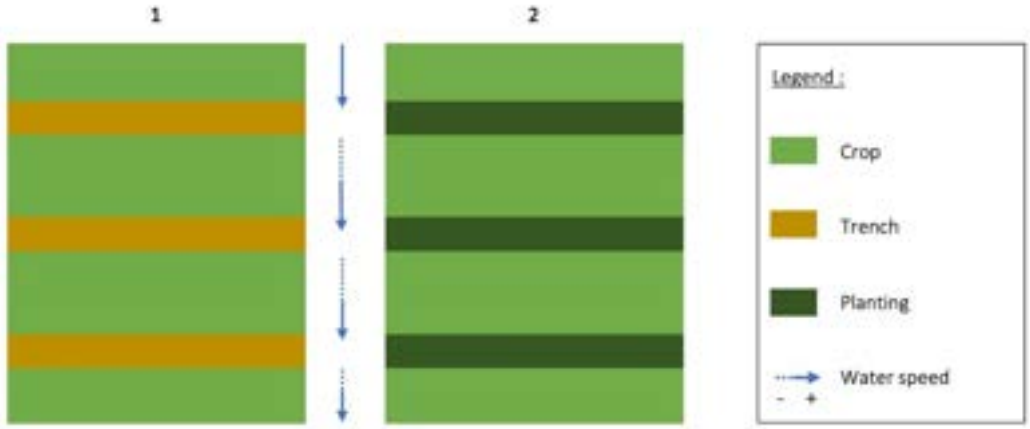
- Not having the expected results: they do not know why and do not have real solutions because they do not have access to an expert / agronomist who is able to study and analyze their practices
- Fake products: fake products can circulate and they can have negative effects on the crop: plants infected with a disease for example
- Poor application of products: even if trained, farmers do not have the right reflexes during application. This may be due to a lack of rigor: the quantity applied varies according to the stock, if it is more or less full

On their plots, farmers frequently have the following diseases and pests:

- *Coffee Wilt Disease*: this fungus prevents water from circulating in the tree and affects it at any age
- *Coffee Berry Disease*: this fungus dries out, stiffens and rots coffee berries. It infects coffee berries at different stages of development: from the beginning of growth until the berry is ripe
- *White Coffee Stem Borer*: this beetle digs the trunk of the coffee tree to feed on its sap and then cuts it off from its nutrient intake.
- *Berry Borer*: this beetle pierces green coffee berries to lay its eggs

As the plots are located on mountain-sloping terrain, their incidence is high, leading to significant erosion phenomena, especially during intense rainfall events. Indeed, the steeper the slope is inclined, the faster the speed of the runoff water increases, which erodes the soil.

Therefore, to combat soil erosion, the objective of farmers is to cut off the speed of runoff water. Within the plots, we find techniques 1 and 2 represented schematically in the figure:



Figure/ Schematic representation of the different techniques for soil erosion control in crops. Source: Author

1. Open environment: dig trenches in the plot: before each trench, the speed is maximum but is stopped by the hole in the trench. Thus, at each beginning of the trench, the speed is minimal. The soil that has been transported by water is then removed with a shovel and reused for the plants because it is loaded with nutrients. Thus, soil erosion is slowed down.
2. Closed environment: Planting plants in the plot: the example of vetiver whose benefits are detailed in Appendix 2. The dense, deep and vertical roots of this plant retain the soil. However, the soil cannot be reused for its nutrients but the runoff water is cleaned by the roots.
   On the other hand, this plant is not used by all farmers. Cenchrus purpureus (elephant grass) is used but has fewer advantages because its roots are horizontal and competition for nutrients occurs with other crops in the plot.

The spacing between trenches or rows of vetivers, for example, depends on the incidence and configuration of the plot. It is usually between 20 and 25 m.

In terms of workload, the least intense is technique 1 because technique 2 requires maintenance. Indeed, even if the leaves can be used as fodder or for households: objects, fire, cutting is more restrictive.

- Example of soil erosion control by a plant: *vetiver grass*

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Controle the erosion by the vetiver grass

This plant is used in many countries of the world to limit soil erosion and to clean up water. It is fast growing and adapts to all types of climates and conditions : poor soils, drought, flooding, fire, etc. It has many advantages for you :

Agricultural benefits
- Easy to maintain and can be cut by hand
- Cheap and easy to plant : usually roots or slips are ripped off the main clump and jabbed into the ground like seedlings
- No competition and yield loss with horizontally rooted crops, no yield loss

Water
- The roots retain runoff and groundwater and stabilise the soil
- Cleans water: pollution
- Water retained for use by nearby crops

Environment
- Non-invasive : Currently, this plant is propagated mainly by root division or slips
- Prevents weeds (invasive plants)

Various uses
- Animals :
  - Fodder for livestock
  - Animal bedding
- Stubble
- Mattress filling, mats, baskets

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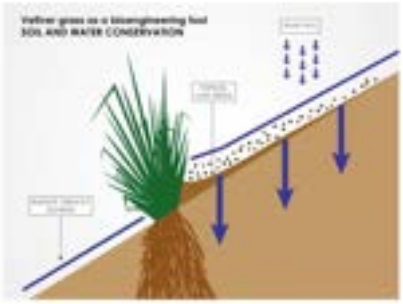
N°1 How to plant it

1. Planting at the beginning of the rainy season
2. Plant one or more rows of vetiver along the slope of your field, following the contour
3. Dig up a clump of vetiver with a spade. Then separate the clump into individual stems with their roots. These are called cuttings.
4. Cut the ends of each cutting 15 to 20 centimetres above the base. Cut the roots 10 centimetres below the base. This will prevent the vetiver from drying out.
5. Plant and water thoroughly, immediately afterwards.



In this picture you can see that this plant is well established in the soil with its deep roots. It then holds the soil, which prevents erosion, especially when it rains.

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N°2 How to plant it

1. Flowering inflorescence
2. Pot with coarse soil
3. Water to saturation
4. Cover with fine soil
5. Fix inflorescence on the rod
6. Bending the inflorescence
7. Tie the bag
8. Keep a hole in side of the bag
9. Vibrate the stem to shed the spikelets
10. Remove the bag and germination occurred 20 days after bagging
11. Covered with fine soil and water
12. Seedlings 150 days after bagging
13. Seedlings
14. Transplant seedlings in field
15. Vetiver grass 40 days after planting
16. No seed-born vetiver plants were found between the rows 15 years after establishment of vetiver turf

Source : Auteur

The table opposite, represents the cultural calendar of the farmers' farm for the year 2021 on the plot of 2 Ha. This plot was chosen because it is the one that brings a significant income to the couple. However, it is necessary to take into account the approximation or lack of certain data.

Culture	Sowing date	Number of plants on the plot	Harvest date	Kg/ branches/ bags harvested per year	Selling price (Ugandan Shilling, UGX)
Banana	After harvesting, cutting the tree	80 to 100/ ha	Every 3 months	50 branches	1 branch = 13,000 UGX
Coffee	40 years	300	August to February	10,000 kg of berries produced	1,200 UGX/ kg
Yam	No seedlings	/	Depending on their needs	2 bags	80,000/ bag
Passion fruit	April	5 shrubs	1 year after planting date	20 kg/ season	5,000 UGX / kg
Bean	March	/	2 seasons: June/ July and August/ November	50 kg	3,000 UGX/ kg
Jackfruit	No particular season	10	Variable: one to several times a year	No sales in the year 2021	The price varies depending on the size of the fruit; between 5,000 and 10,000 UGX

Table/ 2021 crop calendar of the farm. Source: Author

- Study of the Gross Value Added of the holding

In order to know if in 2021, the plot of 2 ha was profitable for the couple, we will rely on the data in the table, the previous information and the formula below to calculate the Gross Value Added:

Gross Value Added = Gross Product – Intermediate Consumption

With:

- Gross product = total sum of the gain obtained from the sale of the production of the plot
- Intermediate consumption = total sum of inputs

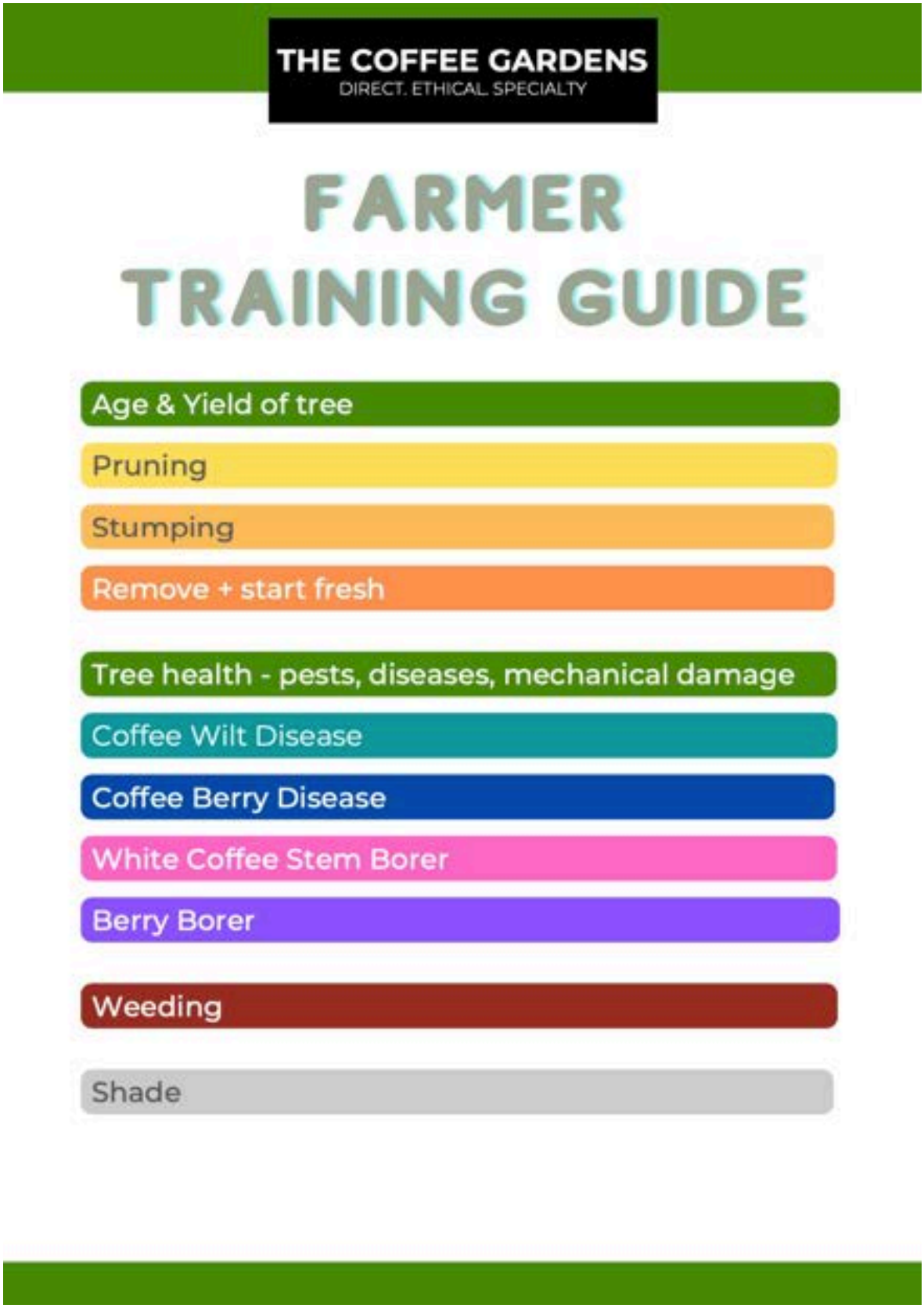
	Gross products	Prices in Ugandan Shilling (UGX)	Intermediate consumption	Prices in Ugandan Shilling (UGX)
	Banana	50*13,000 = 650,000	Inorganic fertilizer	3*60,000 = 180,000
	Coffee	10,000*1,200 = 12,000,0000		
	Yam	2*80,000 = 160,000		
	Passion fruit	20*5,000 = 100,000	Pesticide	3*60,000 =180,000
	Beans	50*3,000 = 150,000		
Total (UGX)	13 060 000		360 000	
GVA calculation (UGX)	= 12,700,000			

Table / summary table of the farm data and calculation of the Gross Value Added of the farm for the year 2021. Source: Author

In 2021, according to the World Bank, the gross national annual income of a Ugandan inhabitant is US$840, which corresponds to US$70 per month (World Bank 2022). Here, the couple earns about US$3,370 per year, or about US$280 per month. Thus, with this plot alone, farmers have a monthly income 4 times higher than the country average.

Personally, the farmer finds that his life is rather hard because he has to take care of his plots daily and especially, when he has a low monthly income. This situation happens during the off-season of coffee, because as we can see in the table above, this crop is the one that pays the most.

However, the calculation of this GVA does not make it possible to say whether the whole holding is profitable for farmers because it does not take into account the costs and income from the 1 ha plot, livestock and intermediate consumption for the farm.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TRAINING GUIDE
Age & Yield of tree
Pruning
Stumping
Remove + start fresh
Tree health - pests, diseases, mechanical damage
Coffee Wilt Disease
Coffee Berry Disease
White Coffee Stem Borer
Berry Borer
Weeding
Shade

Age & Yield of tree

The age of the coffee tree affects its production: the older it is, the less it produces.
Depending on its age, I can encourage its growth or reproduce it but how do I know what to do ?

Pruning

Pruning optimizes canopy and branches for light capture and use of nutrients to support ideal tree growth and crop production.

Efficient: there is competition between the vegetative (leaves and branches) and fruiting parts of the tree.
Pruning is the strategic removal of unwanted or unproductive parts of the tree. It serves to optimise the tree's production, manage pests and diseases. Picture 1
Unpruned trees cannot achieve target yields because they are less

It is then necessary to monitor :
The mass of leaves because too many leaves means :
- Less air circulation, which is favourable to the development of fungi and other parasites
- Lack of access to the sun for other leaves

The condition of the branches because :
- By touching the ground, they give access to pests and diseases
- Dead branches block access to other branches and can harbour pests and diseases

Picture 1 - How to prune ?

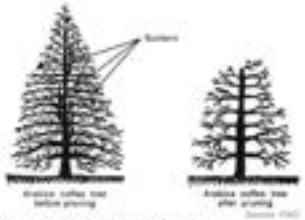
The pruning cycle is characterised by 3 phases with the following objectives :

Formation pruning :
- To maintain the shape of the coffee tree to make harvesting and chemical treatments easier
- Maintain the tree's balance between vegetative growth and fruit production

Maintenance pruning : (Picture 2 & 3)
- Remove all dead wood, unproductive branches and vertical shoots
- Ensure proper aeration to reduce the impact of pests and diseases
- Ensure access to sunlight to promote floral induction/ flower growth

Rejuvenation pruning :
- Restart the tree's production cycle
- Encourage the growth of new, more vigorous stems
- Encourage the growth of fruiting branches

Picture 2 - Maintenance pruning tree



Picture 3 - Maintenance pruning branches

Stumping

Stumping is recommended for all old long and unproductive trunks in order to encourage fresh, stronger and more productive stems - Picture 1
A pruning saw is the most effective tool for pruning. It leaves a "clean cut" and allows the plant to recuperate faster than if pruning was carried out with a machete. - Picture 2

Picture 1 - Stumping of old coffee stems

Picture 2 - Uses the right tool

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Stumping

To cut a coffee tree correctly you need to : - *Picture 3*

- Use a pruning saw
- Cut at 1 foot from the ground
- Cut at a 45° angle to the rising sun

Picture 3 - Stumping of old coffee stems

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Remove + start fresh

Remove + start fresh

This practice is used to **regenerate** your coffee trees and to fight against parasites and diseases.

Before planting, make sure you have **removed everything** : trunk and roots (especially if the tree is diseased) and replant from a healthy seedling. *Picture 1*

Make sure you select a seedling either from your own **nursery** garden of from a **certified** coffee nursery operator.

Picture 1 - Proper production of coffee seedlings

Do not use undergrowths from fallen berries under the coffee trees as planting material!

Why ?

- As we are sure of health
- As we are sure of the variety
- Because it's less resistant
- We don't spread diseases

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Remove + start fresh

When to plant ?

The best moment in the year to do this is around **April**.

When you plant, your shoot should have minimum 4 primary leaves which are green and broad. *Picture 2*

Picture 2 - Different stages of coffee germination

The seedling must be mulched. *Picture 3*

Picture 3 - Proper mulching seedlings of coffee

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Remove + start fresh

How to plant it ?

Before planting, the **soil** should be **prepared**, preferably with organic fertiliser, and a hole should be dug to the right size. Once the coffee plant has been planted, it is important to ensure that it grows well. *Picture 4*

Picture 4 - How to plant the coffee shoot correctly ?

1. Dig the planting hole 2 feet by 2 feet wide

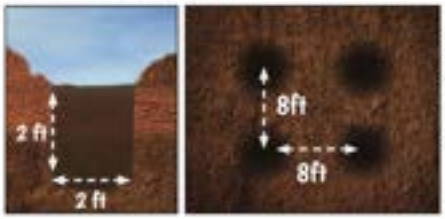
2. Mix the topsoil with 1 basin of manure or compost

3. Plant the seedling

4. Create a small shade and lay out mulch around the seedling to keep the soil moist

5. Water the seedling regularly

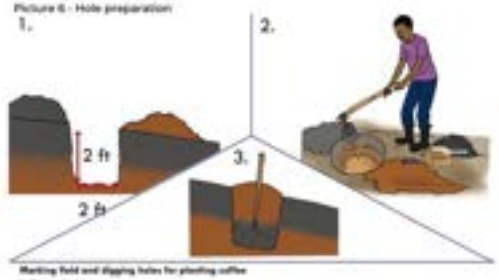
The ideal hole size is : *Picture 5*



Picture 5 - Ideal depth for planting the coffee plant and minimum spacing between each plant

Detailed steps for hole preparation and planting : Picture 6 & 7

Picture 6 - Hole preparation

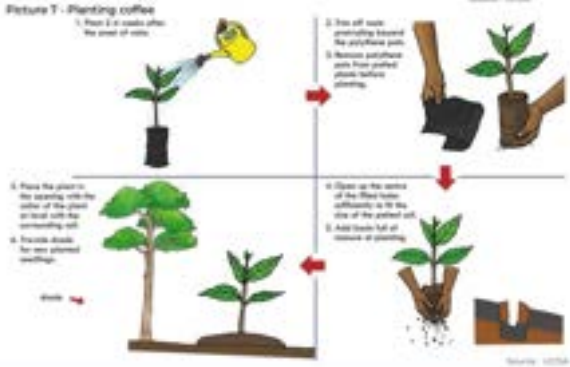


Marking field and digging holes for planting coffee

1. Dig round holes
2. Heap the fertile topsoil separate from the subsoil
3. Refill the holes with topsoil mixed with a basin of manure and a handful of NKP or DAP fertilizer.
4. Heap the soil above the ground level to allow for sinking when the soil settles.
5. Mark positions where the coffee plants will be planted with pegs.

Source : ICCO

Picture 7 - Planting coffee



Source : ICCO

Tree health - pests, diseases, mechanical damage

It is very important to monitor the health of the trees on the whole plot. Damage can have both reversible and irreversible effects that will prevent the tree from reaching maximum production yield.

A tree can be damaged in different ways:

- Environment: wind, felling (broken or rotting stems, damaged bark)
- Pests and diseases: damage has different impacts:
  - Reversible: the tree has recovered from the pest or disease attack because the problem has been treated
  - Irreversible: the tree has not recovered from the pest or disease attack because it cannot be rehabilitated (root, trunk, stem have suffered)

When an irreversible disease is identified, the tree and the tree circles around it should be destroyed.

Field observation	
😀	• All trunks, branches, leaves with no irreversible physical / structural / rotting / Pest & Diseases damage AND • Still able to rejuvenate
😐	• My tree have no or little physical damage ? There is some reversible damage and need actions (see section "the main pests")
☹️	• Most of main trunks, branches, leaves with irreversible physical / structural / rotting / P&D damage OR • No longer able to rejuvenate → Remove + start fresh

The main pests are :

- Coffee Wilt Disease
- White Coffee Stem Borer
- Coffee Berry Disease
- Berry Borer

Coffee Wilt Disease

This fungus prevents water from circulating in the tree and affects it at any age. After the first symptoms appear, it can kill it in a few weeks for young plants and between 6 and 15 months for older ones.

Symptoms

By the time symptoms appear, it is too late to save the plant. The visible symptoms are :

- Wilting and early ripening of berries
- Yellow leaves
- The bark of the trunk has cracks and may swell
- A blue/black discoloration of the wood under the bark is visible, it is more pronounced at the base of the stem - Picture 1

Picture 1 - Blue-black staining of wood beneath the bark on a section of stem affected by coffee wilt disease

Source : Cabi.org

How does it survive and spread?

At the end of the rainy season, small black structures can be seen - Picture 2 : this is the fungus making itself known. It spreads to other coffee trees or survives by staying in the soil or on dead plant material (branches, leaves etc.)

Picture 2 - Small black structures in the crevices of tree bark

Source : Cabi.org

How to fight it?

- Preventive measures :
  - Do not store diseased wood (firewood)
  - Clear a large strip of land in front of the disease, possibly planting another crop
  - Do not damage the trunk of the tree, e.g. when clearing it
  - Quickly treat all wounds with a suitable disinfectant or fungicide: especially those near the ground (stem, trunk, root). Mix half of oxychloride and chlorothalonil. Fungicides containing these products are recommended: : Dithianon, Anilazine, Cobox, Funguran
- *Suppress the disease :*

Affected trees spread infection. It is necessary to react immediately :

- Uproot and burn the tree and those around it, even if they appear healthy
- Do not drag destroyed trees among healthy trees
- After destroying the diseased trees, leave the land to rest or plant another crop
- Replant coffee at least 2 years later

Coffee Berry Disease

This fungus dries, stiffens and rots coffee berries. It infects coffee berries at different stages of development: from the beginning of growth until the berry is ripe. The beans are destroyed and the berries turn black and fall off or remain on the coffee plant as **mummified** berries. Some berries fall off after developing some active **lesions**.

The effects of the fungus are reversible, but plant tissues can be infected within 5 hours of germination. It thrives in moist conditions and in warm, dry weather.

Symptoms

The characteristic symptom is the development of small, water-filled lesions on the young berries which quickly become dark brown or black and slightly sunken. They enlarge to cover the whole berry and in about 1 week they rot. *Picture 1*

Picture 1 : Different stages of the disease on the same branch

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Coffee Berry Disease

They can be seen on several parts of the tree:

- Branches: lesions appear on the young stems of the berries, causing them to fall off before the lesions appear on the berry itself
- Flower petals: in conditions of high humidity, brown lesions appear
- Berries: appearance of lesions with pale pink structures. Depending on the stage of development of the berry, there are different symptoms:

Growth stage	Vulnerability	Colour	Reversibility
Pinhead (first month)	Berries are more resistant	Pale brownish, corky lesions	Yes, the berry can heal completely. The fungus can wait until the berry is sensitive enough to infect it (when it starts to ripen)
Green berries 4 to 6 weeks after flowering *Picture 2*	Most vulnerable berries	Dark, sunken lesions	
Ripening berries	Vulnerable berries		
Mature green berries 16 to 18 weeks after flowering	Berries are more resistant		

Picture 2 : Coffee Berry Disease on an immature berry

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Coffee Berry Disease

How does it survive and spread?

The fungus proliferates on the maturing bark of coffee twigs: this is when the fungus population is highest. This is the main source of epidemics that develop after flowering and at the beginning of the rainy season.

As the season progresses and the developing berries become infected, the disease can spread. In addition, when trees are close to each other, the disease spreads more easily.

The least vulnerable time is when the bark is immature and green.

How to fight it?

To control the fungus, a combination of control methods is needed:

- Cultural control :
  - Spacing and pruning of coffee trees: avoid accumulation of moisture conducive to the development of the fungus
  - Prevent the tree canopy from becoming too dense
  - Eliminate all diseased berries: even dry ones, as all infected berries are a source of disease
- Chemical control

Chemical control plays an important role and is often done with fungicides such as copper. Fungicides should be applied every three to four weeks during the rainy season to protect the developing berries.

White Coffee Stem Borer

This pest is an insect (beetle) that is 3 - 3.5 cm long and has a grey body with a dark brown patch on each side of its back. The head and thorax are dark coloured and it has very long and obvious antennae (2 - 3 cm long). *Picture 1*

Picture 1 - Adult white coffee stem borer

Symptoms

- 1 cm holes in the stem of the tree
- Rings on the stem or bark eaten by the larva or wood chips on the ground next to the stem
- Yellowing, wilting and leaf drop

There are different levels of damage depending on age:

- Young trees are most susceptible to damage and those under two years old are often killed
- At more than three or four years of age: the damage is yellowing and wilting of the leaves. Even if the tree is not killed, the yield is so low that it is not worth keeping - *Picture 2*

Picture 2 - Yellowing of leaves on a coffee tree due to infestation by white coffee stem borer

How does it spread?

The female lays her eggs once or twice a day for about a month, under the bark of the coffee tree stem.

The eggs are cream-coloured and about 5 mm long and hatch after 3 weeks. The mature larvae measure between 3 and 5 cm and feed on the bark by tunneling into the wood. *Picture 3 & 4*

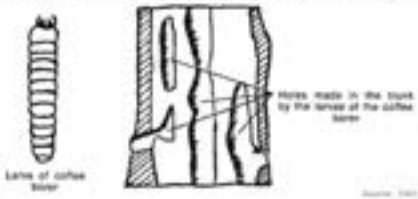
As an adult, the pest emerges from the stem about one to two weeks after the start of the rains. It climbs to the top of the tree and feeds on the green bark, shoots, leaf stems and green berries before flying off.

Damage is greater in the **larval stage** than in the adult stage.

Coffee trees grown on shallow or eroded soils or near shade trees are more likely to be attacked by this pest.

Picture 3 - Larva of coffee white stem borer burrowing in a coffee stem

Picture 4 - Scheme of a trunk cut by the larva of coffee white stem borer



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White Coffee Stem Borer

How to fight it?

- Cultural control :
  - Maintain your coffee trees well, healthy and vigorous and provide them with all the necessary nutrients
  - Wrap the base of the tree stems with banana fibres
  - Smooth the bark 50 cm from the ground to eliminate cracks in the bark and discourage females from laying eggs:
    - Use a rough rag or dried corn cob. Be careful not to damage the tree
    - Block the tunnels with mud
    - Insert a metal beam into the tunnels made by the larva to kill it
  - Uproot and destroy infected trees: burn before the rainy season
- Biological control:

This pest has many natural enemies:

  - Larvae can be attacked in their galleries by woodpeckers and ants
  - The insect *Aprostocetus - Picture 5* can parasitise between the egg and larval stages
- Chemical control :
  - Insecticides containing Fipronil to be applied 50 cm before the main stem with a brush, just before the beginning of the rains
  - Lime solution (10%): effective and more environmentally friendly
  - Fumigant paste containing aluminium phosphide to be injected into the holes has proved to be effective

Picture 5 - Picture of an Aprostocetus

Berry Borer

This pest is a black insect (beetle) measuring 2 mm long - *Picture 1*. The adult female **bores into green coffee berries** to lay her eggs. Several holes are found when berries are scarce as several females try to enter.

The tissues of young berries can be pierced but they are not favourable for egg-laying, so they can wait a few weeks or leave. Some of the berries will rot because of bacteria and fungi that contaminate the berry through the entrance hole.

Picture 1 - Side view of adult coffee berry borer

Mature damaged berries develop a distinctive blue-green colouration and may contain many small white, legless larvae with brown heads. *Picture 2*

As egg-laying takes place over several weeks, the larvae in the same berry are at different stages of development.

Picture 2 - Larvae of the coffee berry borer, H. hampei, and damaged coffee bean

Symptom :

Small round entrance holes about 1 mm in diameter, almost always near the apex (tip) of large green or ripe berries. Berries on lower branches and those that have fallen to the ground are more likely to be infested.

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Berry Borer

How does it spread?

The female pierces the hardened and ripening coffee bean where she lays about 30 whitish eggs per berry for 20 days. After 6 to 8 days, the eggs hatch and the larvae bore into the beans to feed.

25 and 35 days separate the time of egg laying and reaching adulthood. The males remain in the bay where they fertilise some of the females to start the new generation. As food resources diminish, the other part leaves the bay and flies from tree to tree to lay eggs.

The conditions that trigger their departure are :

- Rain: when the bay is moistened by rain, many females leave the bay the next day, in the late morning and afternoon
- High temperatures

Females live for 9 months and males for 3 months. The beetle then survives between harvests because it remains in the initial berry: overripe infected berries left in the tree or fallen to the ground favour its infestation.

How to fight?

Low temperatures and low humidity limit its survival and reproductive capacity.

None of these means of control is effective alone, it is best to combine these means of control:

- Cultural control:
  - Remove and destroy old dry berries from the tree and the ground before the main flowering and the beginning of the rainy season as there can be up to 100 females per berry waiting for rain to trigger their dispersal
  - Harvest ripe berries frequently: every 2 weeks during peak fruiting and once a month at other times
  - Place a large piece of cloth or mat to collect berries that fall off during harvest
  - Regularly check the berries and open those with small holes: see if the bean has been damaged or is discoloured, a sign of the pest
  - Compost old coffee pulps well, before using as fertilizer

- Biological control :

Natural enemies :

- Wasps: natural enemies that attack eggs, larvae or adult stages. Some examples : *Picture 3 & 4 & 5*
  - *Heterospilus coffeicola*
  - *Phymastichus coffea*
  - *Prorops nasuta, P. nasuta*

Picture 3 - Heterospilus coffeicola

Picture 4 - Adult of Phymastichus coffea, parasitizing adult of coffee berry borer, when is trying to penetrate the coffee fruit.

Picture 5 - Prorops nasuta, P. nasuta

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Berry Borer

- Beauveria bassiana fungus: naturally present in most soil. During its reproduction process, it sends out spores* which, when in contact with the insect, germinate and develop on it, killing it - Picture 6

*Spore: The spore is the base of the fungus, it can be considered as the equivalent of a plant seed

Picture 6 - Effectiveness of Beauveria bassiana sprays against the coffee berry borer

- Insect trap:

Mixture of alcohol and turpene

- Chemical control:

Beware, the use of insecticides has harmful effects on the environment and on natural enemies (wasps), so care must be taken in their use. Products such as chlorpyrifos, fenitrothion and fenthion are effective. To be effective, they must be applied before the insect pierces the berry and sprayed no later than 100 days after flowering.

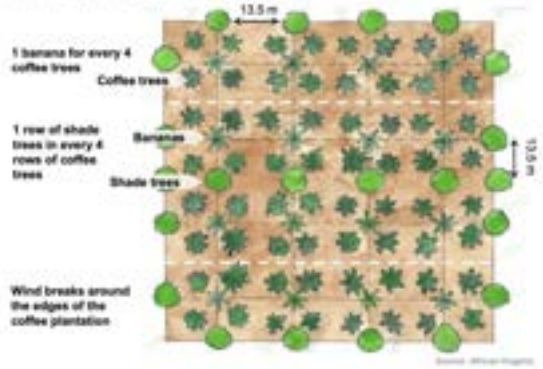
Tree density

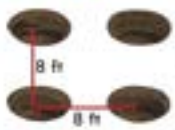
Tree density should be managed to optimise the use of land and/or labour for maximum income.

When a coffee tree has more space, the trees can grow taller and wider or possibly with more stems and each coffee tree will produce more cherries. *Picture 1*

Reminder: it is recommended to put a distance of 8x8 feet between each coffee tree. *Picture 2*

Picture 1 - How to arrange coffee trees and intercrops





Picture 2 - Plant Arabica coffee in lines at a spacing of 8ft x 8ft (680 trees per acre)

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Weeding

Weeding

Weeds take up nutrients and moisture that would otherwise be available to the coffee plants. All these elements lead to a decrease in yield. They can harbour pests and diseases. Weeding helps to :

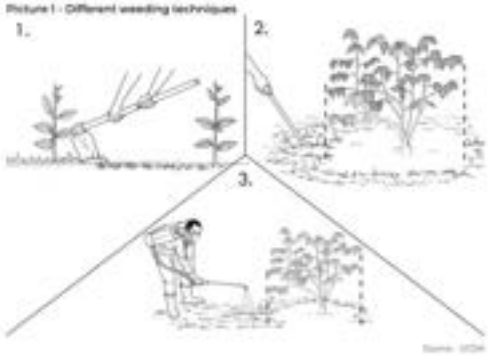
- Reduce habitats for pests and diseases
- Avoid competition for water and nutrients
- Facilitate access to the coffee trees

There is a wide variety of weeds that affect the growth or productivity of coffee to varying degrees.

How to remove weeds? - *Picture I*

- By hand with a hoe: this is the best way. Be careful not to use the hoe beyond the first few centimetres of soil as this can damage the roots of the coffee, disrupt soil life and contribute to its drying out
- Herbicides: can be effective, but misuse can damage coffee trees and lead to environmental pollution

Picture I - Different weeding techniques



	• More than half of areas has no weeds AND • weeds less than 20 cm high AND • weeds not flowering AND • No evidence of disturbing of superficial coffee roots or soil disturbance under the canopy
	• More than 50% of areas has weeds OR • weeds more than 20 cm high OR • weeds flowering OR • Evidence of disturbing of superficial coffee roots or soil disturbance under the canopy

Shade

Shade trees with dense canopies can be pruned regularly to reduce canopy density.

All the coffee trees needs some shade 50% but if its too shade, its can encourage pest and Desease. How to choose the trees for the canopy ?

Picture 1 - Growing coffee in an agroforestry system
Shade trees protect the coffee plants against strong sunlight, contribute to prevention of soil erosion and reduce moisture loss in the coffee garden.

Cover crops protect the soil and provide organic food for the soil.