Feasibility study of a mulching sector using recycled organic matter in vegetable production – Galion watershed, Martinique

MSc Thesis Plant Production Systems

Sixtine MICHEL
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Name Student:	Sixtine MICHEL
Registration Number:	981015570080
Study:	*MSc Organic Agriculture – Specialization Agroecology Double degree*
Chair group:	*Plant Production Systems (PPS)*
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Date	*August, 2022*
Supervisors:	*Marloes Van LOON (WUR)* *Joséphine PEIGNE (ISARA)* *Laurent PARROT (EXTERNAL)* *Laurent THURIES (EXTERNAL)*
Examiners:	*Katrien DESCHEEMAEKER*

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Contact office.pp@wur.nl for access to data, models and scripts used for the analysis

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List of abbreviations

CLD: Chlordecone

RCW: Ramial chipped wood

MAA: Multi-actor approach

CRM: crop residue mulching

GW: Galion river watershed

OVC: Organic valorization center

SGO: standard gross output

DAAF: Food, agriculture, and forest regional direction

ha : hectares

ADEME: Environment and Energy Management Agency

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Abstract

Natural mulch has proven to be efficient to limit weed presence whilst providing additional advantages such as fertilization. In Martinique, an island located in the French West Indies, due to tropical climate, crop growth, and weed growth is accelerated. The topography of the land makes it difficultly mechanizable, hence finding weeding solutions is important. This thesis analyses whether a mulching sector for vegetable producers thanks to organic matter in the Galion watershed is possible, and what the brakes and levers are.
The Galion watershed is an interesting case study because it has been monitored for its pollution since 2016 and because of the potential use of organic resources as mulch on its territory.
The steps of a socio-technical analysis were used as guidelines throughout this feasibility study, combined with the inspiration of similar projects and studies conducted on other islands. Combining interviews with actors involved, quantification of the organic matter and accessibility assessment

helped determine which biomass could be included in this sector, and the brakes and levers linked to the creation of this sector.

Findings show that sugarcane, banana, and vegetable crop residues are used directly on the field they are produced on, bagasse is a competitive biomass as it has multiple uses making it hard to access. Grass cutting is interesting but cannot be used as the main source of organic mulch. Therefore, the most promising sources of organic material to use as mulch are coconut crop residues and mulch from wood. These sources still have to be studied for their quality, quantity and effect they have on the land they are applied on. Sociological aspects linked to the creation of a sector, such as the difficulty of working together, can also influence the feasibility of this mulching sector.

First Part: Introduction

I. Context of the study

1. The Ecophyto Interlude project

The Ecophyto project is a governmental action, created in 2009, which aims to reduce the use of chemical products in agriculture whilst maintaining a satisfying economic performance. The initial objectives were to reduce by half the use of these phytopharmaceutical products by 2018. The Ecophyto II+ plan is the newest version of the Ecophyto plan which aims to consolidate the previous plans and actions put in place (Ministère de l'Agriculture et de l'Alimentation 2022), its aim is also to limit the use, impact and risks linked to the use of phytopharmaceuticals.

The Interlude project, which is an Ecophyto project, stands for "territorial innovations to reduce the use of phytopharmaceutical products in vegetable production". Its objective is to reduce the use of chemicals thanks to a (re-)organization of the different actors in order to put in place agro ecological levers for change (Ecophytopic 2022). Interlude project focuses on the different actors of the vegetable sector, their relations and how they impact the adoption of new practices in vegetable production.

The Interlude project includes 4 different case studies, two of the case studies are situated in metropolitan France, and two are situated in the French West Indies.

-Agro-ecological management of soil health in **Provence**

-Rotation diversification in **Roussillon**

-Weed pressure management in **Martinique**

-Biocontrol and bio stimulation in Guadeloupe **and Martinique**

The first step of the case study in Martinique was to create an agronomic diagnosis of the situation in the watershed, this diagnosis was done by Signarbieux (2021) in the Galion watershed (GW). Her work allowed to depict a better image of the vegetable farms in the watershed and she came to the conclusion that weed pressure was a real problem for these farmers. Often they do not have access to pesticides or do not wish to use them in which case manual weeding is often used (Signarbieux 2021). This task is tiring and time consuming for farmers, a different solution allowing farmers to be more efficient could be imagined.

By combining the studies of the GW, the research carried out by Signarbieux (2021) and the Ecophyto Interlude project, CIRAD researchers came up with the idea to use mulch composed of organic matter in order to prevent weeding in vegetable production in the watershed. The Interlude project aims to have a multi-actor perspective, therefore the imagined innovation respects this criterion, as it will necessitate the inclusion of different actors, such as those using biomass, and those detaining it.

2. The research question and main hypothesis

The main thesis objective is to complete an explanatory study in order to determine whether a mulching sector thanks to existing organic matter in the GW is possible.

In order to correctly define the research question and objectives of the study, getting a hold of the project was an essential step. Reading the past studies and talking to the different people currently involved in the project helped define the research question. In order to define the research objectives, the main questions that came to mind were listed, and confronted to the existing information. The remaining questions will be the focus of this study.

The research question is: What are the brakes and levers to creating a mulching sector for vegetable producers thanks to available organic matter in the Galion watershed?

My first assumption is that farmers are interested in using natural mulch in their systems. This assumption is based on the research carried out by Signarbieux (2021), where she states that weeding is major problem for vegetable farmers in Martinique. As mulch could help limit the time spent weeding, therefore reduce difficulties and labour costs, it is fair to believe that farmers will be keen on trying new practices that may facilitate their work on a daily basis.

My second assumption is that there is competition between the different actors for the use of organic matter, leading to a lack of availability for farmers. Indeed, on any given territory, several sectors make use of organic material such as the energy sector, companies producing fertilizer or compost, farmers … Perhaps that the competition in the GW is too strong, leaving no room for the mulching sector to be put in place. This assumption can be checked thanks to interviews with different actors of the sector, to understand the different sources of organic matter and their destination.

The last hypothesis concerning the creation of this sector is the quality of the organic matter exchanged between the different actors cannot be guaranteed. However, it is important for farmers to know what they are applying on their land, as each type of organic matter can have a different effect on the soil (Chopra, Koul 2020), both positive or negative. Organic mulches tend to acidify the soil affecting crop productivity (Chopra, Koul 2020). Mulches can also bring pathogens to the field (Jacobs 2005). This hypothesis can be tested both through farmer interviews, where they can share their need concerning the quality of the natural mulch, but also through interviews with other actors to know whether they can certify the origin of the organic matter, or if any analyses are done on it.

II. The social-technical diagnosis

1. Description of the diagnosis

Creating a project with multiple actors can be a challenging task as it demands a lot of communication and structure in its organisation. In order to better understand how such projects could be put in place and function properly, past studies were used to inspire the working methods and methodology for this explanatory study (Casagrande et al. 2021) (Parrot et al. 2022) (Conrozier 2019). These types of projects are also known as the Multi-Actor Approach (MAA) and consist of co-creating knowledge with different types of actors (Feo et al. 2022).

The socio-technical diagnosis aims to find solutions to complex problems including multiple actors, scales and perspectives. Actors are solicited, as individuals or as a collective, in order to come up with innovative solutions for the specific problem (Casagrande et al. 2021). The socio-technical diagnosis often includes all the potential innovative solutions, but during this exploratory study we will be focusing on one specific solution.

In MAA projects, actors often have different objectives: economical, environmental, social … depending on their position in the sector. During these types of projects, it is important to hear out the different actors and their different goals to deal with different or conflicting points of views. The actors should not perceive the research as a top-down approach and must feel included and involved in the project: the presentation of the project to the different actors is a key in getting them to part take. Farmers have a key role in this study as their knowledge and feedback is crucial in order to conduct transformation (Feo et al. 2022). This will also help link the different actors of the territory together and study the connection between these actors (Casagrande et al. 2021). During this step, the actors may be interviewed or surveyed to grasp their views and experiences on the subject.

Sharing the diagnosis with the different partners is a vital part of the project, as it allows feedback and advice to be given. Facilitators may be useful in helping mutual understanding between different actors (Feo et al. 2022), indeed, a communication gap can often be observed between researchers and farmers (FAO 2018). This part is a conclusion of the diagnosis, where the actors should be aware of the main conclusions of the project. The conclusion of the diagnosis, or in our case the feasibility study, should either be that it is possible, or not, to take action. When the feasibility study turns out positive, the next project would be to implement the proposed solutions with the different actors. Collaboration between the different partners allows to turn existing knowledge into innovations that can be put in place (Feo et al. 2022). To keep the progress in action, partners should have individual or group actions that they should conduct and indicators should be put in place to analyse the progression of their actions.

2. Description of the different steps

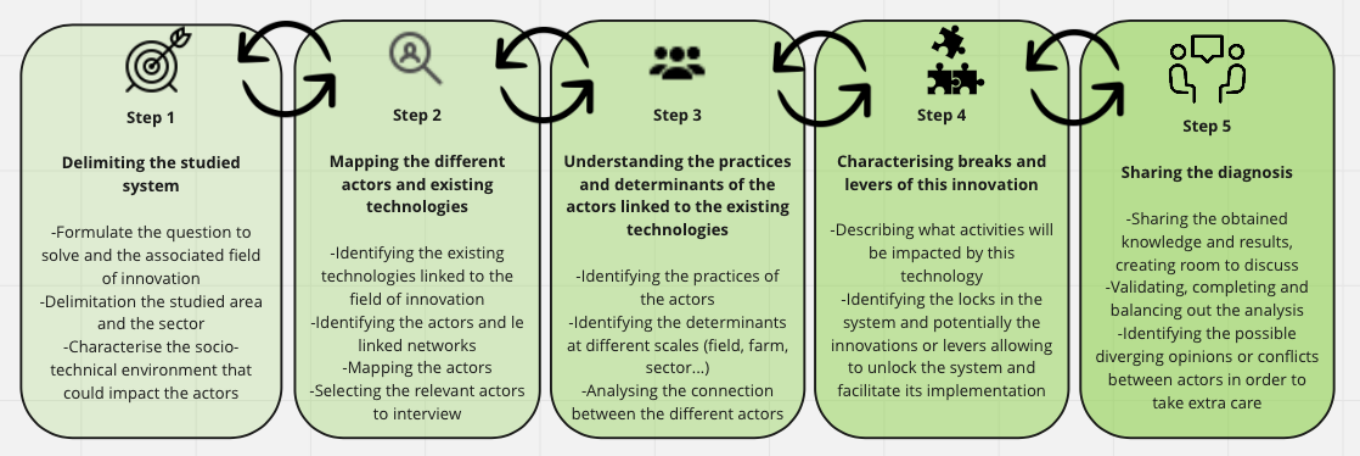

Figure 1: 5-step socio-technical diagnosis (translated) (Casagrande et al. 2021)

This diagnosis model that we will be using as a guideline during this explanatory study (Figure 1) includes 5 steps that have a specific goal, but different ways to achieve it.

1. Delimiting the studied system: the step is key as it determines what will be studied and how. This step comes from actors that express a problem or something that could be improved, an idea that is shared with researchers. The actors share a common vision for the future (e.g. switching to more agroecological practices) (Casagrande et al. 2021). Determining together the problem we wish to resolve as well as the innovations linked to this change and delimiting the studied area are key aspects of this step.
2. Mapping the different actors and existing technologies : this step aims to identify the actors involved by this change or by this innovation that are included in the studied zone (Casagrande et al. 2021). This first step helps to have a clear vision of the actors involved and creates a list of actors who will need to be interviewed. The actors can be situated in the delimited study zone, but also outside of it if they play an important role in this innovation.
3. Understanding the practices and determinants of the actors linked to the existing technologies: in this step, the important actors identified are surveyed or interviewed. The goal is to identify what encourages innovative practices and what limits their implementation (Casagrande et al. 2021). By questioning the actors about the technologies or practices used, a link between the different actors can be visible.
4. Characterizing brakes and levers of this innovation: this step consists of analyzing the previous steps and collecting the information. This step is important as it will help lead to the conception of solutions. This step allows to select the most relevant actors and to guide the decision process to a/or a few specific innovations (Casagrande et al. 2021).
5. Sharing the diagnosis: this step consists of sharing the diagnosis with the actors of the system, that may have been interviewed or not. Allowing room for debate and discussion is important

to complete the analysis. This step can help understand new conflicts between actors, that need to be solved to continue the project (Casagrande et al. 2021).

3. Previous work of the Ecophyto project

The study conducted by Signarbieux (2021) aimed to characterize agriculture in the GW, with a focus on vegetable production. This can be considered the first step in the socio-technical diagnosis (Figure 1), as it allowed us to determine the problems present in the GW. This research led to several conclusions concerning vegetable production in the watershed :

- the main production systems aren't very profitable, dissuading younger people to settle on a farm. This will lead to a reduction in the number of farms
- diversifying the agricultural production and diversifying outcomes could be a solution for farmers to receive a higher income
- access to land is complicated: in the best case, family arrangements are made for the farmer to be able to cultivate a bit of land, in the worst, potential farmers cannot find an adequate land to build their farm on
- the arduousness of the work is often identified by farmers as a major brake to vegetable farming
- weeding demands a lot of work, as due to the tropical climate, plant growth is very rapid

The next steps of the project will be focused on the two last conclusions: the arduousness and the time spent weeding, which are major constraints for farmers. Indeed, as mentioned by Signarbieux (2021), weeding is an important pressure for vegetable farmers, and there is potential to identify and put in place alternative weeding practices to help farmers.

Steps 2,3 and 4 of the socio-technical diagnosis (Casagrande et al. 2021) will be completed in this study, following Signarbieux's (2021) work. The last step will not be included in this study, as this year marks the end of the financial support for the study. The last step will be interesting to complete if partners are interested in the project and are willing to take part.

III. Delimiting studied area

1. Agriculture in Martinique

The French west indies are situated in the Lesser Antilles, an archipelago of islands formed due to volcanic activity. Martinique is an island situated in this archipelago, in between the islands of Santa Lucia and Dominica, surrounded in the east by the Atlantic Ocean and by the Caribbean Sea in the west.

The Pelée mountain, the active volcano present in the north of the island, culminates at 1 395 m. Due to its volcanic origin and activity, the island has many different types of landforms, creating the diverse landscapes we observe today. The pedology is diverse on the island due to the different volcanic activities: allophane soils are present in the north around the Pelée mountain, vertic soils in the south, and ferrisols in the center of the island.
Martinique has a tropical climate, remaining hot and humid throughout the year. The average temperature throughout the year is 26,5°C and the average rainfall is 1 950 mm (Météo-France 2022). Two seasons can be observed: a dry season, called 'Carême', from December until mid-June, and a wet season called 'Hivernage' the rest of the year.

The agricultural sector in Martinique represented 21 863 hectares (ha) in 2020, split into 2 606 agricultural farms (Agreste 2021). This is 20% fewer farms than 10 years ago, with the less agricultural area available (-12,5%) (Agreste 2021). The island is historically dominated by large monocultures:

- *Musa*, commonly called banana tree, production (5000 ha): In 2018, 359 banana producers produced 140 435 tons of bananas. 97,6% of the total production was exported (Agreste 2021).
- *Saccharum officinarum*, also known as sugarcane, production (4000 ha): In 2018, 168 sugarcane producers produced 208 249 tons of sugarcane. 81,2% of the sold production was bought by distilleries (Agreste 2021).

On the island, 127 farms own 44,6% of the total agricultural area (Agreste 2021), these farms cultivate either bananas or sugarcane. The average agricultural area of a farm is 8 hectares, slightly more than in 2010 (Agreste 2021). Organic production is developing on the island, however, it still only represents 3% of the farms (Agreste 2021).
In 2020, 64% of the farms were engaged in short supply markets, and 50% sold their produce directly to the consumer (Agreste 2021).

The vegetable sector, in which we consider fresh vegetable production, vegetable plants, melons, strawberries, and potato production represent 7.16% of the total agricultural area (Agreste 2021). On the island, every crop apart from banana and sugarcane, are considered as "diversification culture", but under this name, all different productions can be found.
In this study, we will consider vegetable production as the production of vegetables but also tubers such as *Ipomea batatas* (sweet potatoes) and *Colocasia esculenta* (dasheen): these productions are difficult to isolate as they are often produced simultaneously or alternatively, on the same land as the vegetables, by the same farmers. Additionally, it makes sense to include them in the vegetable production, as they are a part of the daily diets just like vegetables.

In tropical climates, such as the one in Martinique, plants have ideal conditions to develop and grow, therefore weeding is an important challenge for farmers, and one of their main tasks daily (Wintz, Pak 2021). To control pests and weeds, different phytopharmaceutical products are used in vegetable production in Martinique. The most used are insecticides with active substances such as *spinosad* and *thiaclopride* as well as fungicides (Préfet de la Martinique 2019). These are used to limit the loss of yield caused by the presence of pests and weeds during the production cycle.

As shown in figure 2, 11% of the sold active substance goes directly into vegetable production (Préfet de la Martinique 2019), however, it is hard to know the total amount of chemical products used during the whole vegetable production process. Indeed, 49% of the active substances go into general treatments, which is mainly the use of glyphosate (around fields or between crop rows), which can also be used in vegetable production.

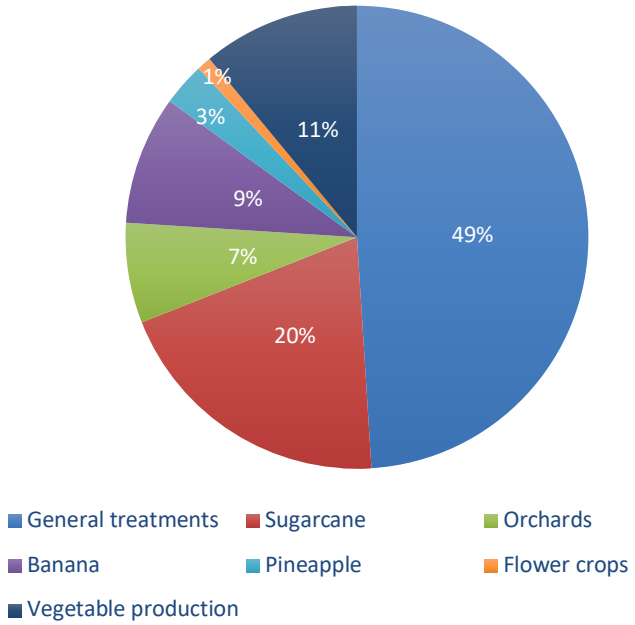

Figure 2: Distribution of quantity of active substance sold per sector in 2019. (Préfet de la Martinique 2019).

These active substances contained in chemical products often persist in the environment and can be found as pollutants in the environment such as in soil and water bodies. With the development of global awareness of pollution and the use of chemical products in agriculture comes the development of new solutions. These solutions can be programs to find alternatives for the use of these chemicals, that have less impact on the environment (Ranjan, Prem et al. 2017), such as the Ecophyto programs.

The French West Indies are known for their chlordecone (CLD) contamination, a pesticide largely used between 1972 to 1993 against weevils in banana production (Voltz et al. 2013). CLD is dangerous to human health and causes different symptoms depending on the time and frequency of

exposure to the product. This product was discovered to be highly persistent in the environment: studies have shown its presence in water bodies, soils, and human blood in the islands of Guadeloupe and Martinique (Voltz et al. 2013). For this reason, the product was banned from use but remains a severe complication today.

Although CLD was mostly used in banana production, its persistence in the soils and waterbodies (Voltz et al. 2013) made it a risk to all the agricultural land on the island. Depending on the level of contamination of the soil, certain productions shouldn't be produced. For vegetable and tuber production, the level of contamination should be relatively low. The CLD crisis in the French West Indies and a raise in global awareness of the negative impacts of phytopharmaceutical products have led, to a strong social demand to limit the use of chemicals in cropping systems, from the consumers but also the farmers (Deffontaines et al. 2019).

2. The Galion Watershed

The Galion watershed is one of the seven watersheds present on the island. The largest is the Lézarde watershed (116 km^2), followed by the Capot watershed (57 km^2) followed by the one we will be studying: the Galion watershed (Observatoire de l'Eau, Martinique 2010).

The GW is situated in the northeast of Martinique and covers an area of 45 km^2 (Observatoire de l'Eau, Martinique 2010). Its main river, the Galion river is 23km long, however, the total watercourse is 245 km long (Observatoire de l'Eau, Martinique 2010). This watershed was chosen as a case study because previous studies were able to identify the main characteristics of this watershed and follow the pollution rates, showing significant pollution in the water bodies. Therefore, it makes sense to continue working in this watershed to limit the use of pollutants to help preserve waterbodies, fauna, and flora.

This watershed covers 4 municipalities: 'La Trinité' in the north-east, 'Le Robert' in the south-east, 'Gros-Morne' in the south-west, and 'Sainte-Marie' in the north-west of the GW.

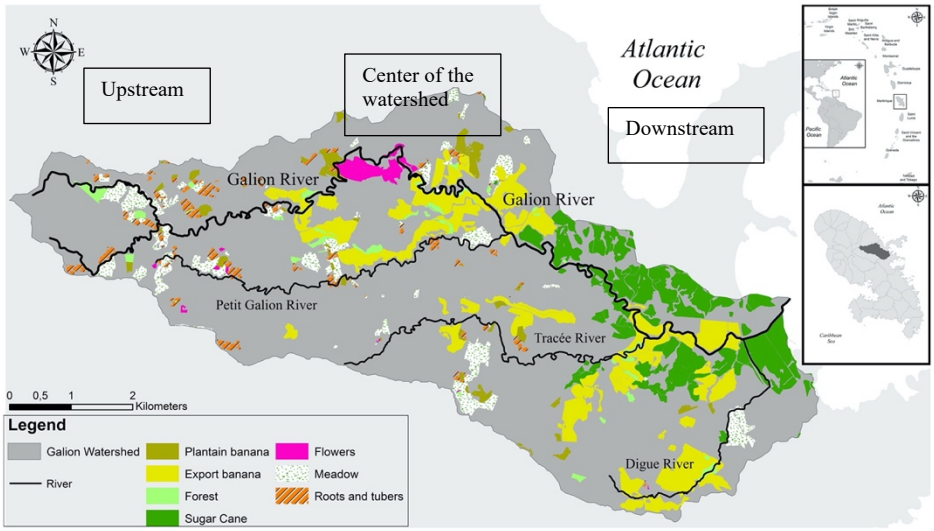

Figure 3: Location, hydrography and agricultural land in the Galion watershed: the Galion river and its main tributaries (The Petit Galion, Tracée and Digue) are in black, agricultural land is in color. Della Rossa et al. 2017)

The watershed is divided into 3 agroecological zones, with different types of agricultural productions (Della Rossa et al. 2017; Deffontaines et al. 2019) which are indicated in figure 3:

-Upstream: this mountainous zone is composed of tropical forest and agricultural land used for mixed farms, livestock as well as traditional food production. It is also characterized by steep slopes (>40°) and volcanic ash soils (andosol) leading to high infiltration rates and high organic matter content (Della Rossa et al. 2017). It benefits from abundant annual rainfall (3500 to 4000 $mm.y^{-1}$) (Deffontaines et al. 2019).

-Center of the watershed: the zone is less steep than the upstream zone with slopes of 20°. The soil has the properties of both andosol and compact ferralsol, this zone was used for banana production in the past (Della Rossa et al. 2017). The annual rainfall is 2500 $mm.y^{-1}$ (Deffontaines et al. 2019).

-Downstream: this zone is a floodplain with industrial crop production such as banana and sugarcane production (Della Rossa et al. 2017).

The total cultivated area is composed of 1090 ha (2015), ¼ of the watershed area, but it is not equally distributed between the different crop productions: 82% of the cultivated surface is dedicated to the production of exported crops (banana and sugarcane) (Deffontaines et al. 2019).

The observatory of agricultural pollution in the French West Indies has been studying the Galion river watershed since 2016 with 3 sampling spots aiming to measure and identify pollution caused by agricultural chemical products (Wintz, Pak 2021). This research confirmed the presence of Chlordecone in the soil, as shown in figure 4, Chlordecone is responsible for 88% of pollution in the Galion watershed (Wintz, Pak 2021).

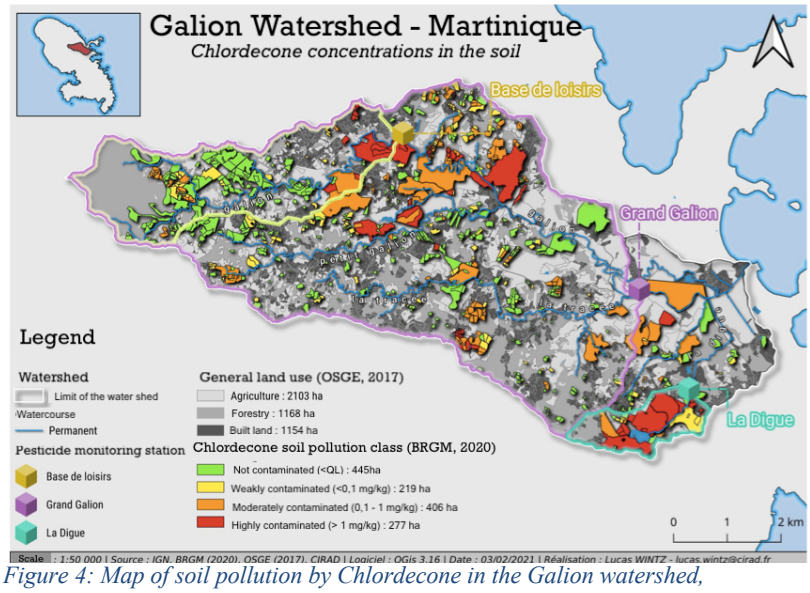

Figure 4: Map of soil pollution by Chlordecone in the Galion watershed, Martinique. (Wintz, Pak 2021).

The presence of other pollutants were also found, such as glyphosate, with a general reduction of the presence of glyphosate in the water (Wintz, Pak 2021). Other pollutants such as fungicides applied to banana production were found, corresponding to the treatment periods (Wintz, Pak 2021). The presence of herbicides, is mainly linked to sugarcane production and the high weed pressure in the production (Wintz, Pak 2021). The watershed is not equal in terms of pollution, the 'La Digue' pesticide monitoring station, south-east of the watershed, is responsible for 87% of the pollution of the Galion watershed (Wintz, Pak 2021).

Although Chlordecone is present in this watershed and is not used anymore, farmers are still applying phytopharmaceutical chemicals for certain agricultural issues they face. To help limit the presence of pollutants in the water, solutions are being researched by imagining different agro-ecological practices to reduce pest and weed pressure on vegetable production, to limit pollution in the water bodies.

3. Mulching as a solution

Mulching is an agricultural practice aiming to cover the soil, with organic or inorganic materials, in order to create a physical barrier between the soil and the air to limit weeding (Kasirajan, Ngouajio 2012). This practice has additional benefits such as limiting soil evaporation (Kasirajan, Ngouajio 2012), buffering the effect on soil temperature and moisture and controlling erosion (Kyulavski et al. 2019). In tropical environments, where weeds are very present and where there is a lack of available phytopharmaceutical products for smallholder farmers, there is a need to control weeding through manual or mechanical weeding methods, requiring a lot of labour. Mulching can be an interesting option to control excessive weeding (Tournebize, Kelemen, Sierra 2020) and reduce the time spent on this task. Different types of mulches exist, each having different advantages and disadvantages, a table summarizing the positive and negative impacts of different types of mulching can be found in appendix 1.

The focus during this study will be on natural mulches, or organic mulches, that are derived from animal or plant material (Kasirajan, Ngouajio 2012) which have proven to have additional benefits than the above-mentioned. There are different types of natural mulches, depending on the matter used, the state of the matter and how it is applied. Hereunder several natural mulches are presented.

- **Crop residue mulching** (CRM) , also named conservation tillage, consists of retaining the crop residues after the crop establishment to ensure an adequate soil cover (Erenstein 2002). At the time of crop emergence, at least 30% of the soil surface is covered by organic residue of the previous crop (Erenstein 2002). The fact that the mulch is composed of the previous crop distinguished CRM from other mulching techniques (Erenstein 2002). For many years, agricultural practices emphasized on keeping agricultural land clean without any crop residues

(Erenstein 2002), CRM is slowly making its way back into agricultural systems thanks to the emphasis on agroecological practices.

Crop residues from one type of production can also be applied on another type of production that requires mulching.

- **Straw mulching** is used because it limits the weeding by covering the soil and limiting the access of the seeds to sun; straw mulch also helps reduce soil erosion (Gholami, Sadeghi, Homaee 2013). Different types of straws can be used to create this mulch such as rice, wheat, oat or maize (Gholami, Sadeghi, Homaee 2013).
- **Grass mulch** was often used in traditional farming methods, however today the main users are organic farmers (Matsuura et al. 2015) and smallholder farmers.
- **Ramial chipped wood** (RCW) is an agricultural practice mimicking what can be seen in natural ecosystems with trees and consists of crushing small to medium sized branches, creating woodchips that are later applied on the soil. Indeed, the forest is the best production system concerning biomass production and environmental protection (Roose 2015). Its structure is naturally protected by leaves, twigs, branches, insects… This cover protects the soil surface (weeds, heat, rain …), but also releases nutrients during its decomposition (Roose 2015). This material was first used as a fertilizer, to enrich the soils with nutrients and organic matter. During the decomposition, the micro-organisms stock nitrogen in order to degrade the wood. If the C:N ratio is too high, micro-organisms will have to use the nitrogen available in the soil for the decomposition process (Tissaux 1996). This can lead to nitrogen hunger for the next crop and result in lower yields. When the micro-organisms die, they release the trapped nitrogen that then becomes available once more. The rapidity of decomposition of the RCW is dependent on the nitrogen quantity present in the soil as this element is essential for micro-organism and mushroom growth (Tissaux 1996). However, when using RCW as mulch, there is less contact with the soil than when it is buried, this enables a slower decomposition of the RCW and less risk of mobilizing the nitrogen in the soil.

  Sawdust does not have the exact same properties as RCW as it is shredded more thinly and there are no requirement concerning the branch sizes. It is very opaque when applied to the soil giving it a high inhibiting impact on weeds, which can also cause excess humidity (Zangoueinejad, Alebrahim 2021). Sawdust is commonly mixed with other mulches to limit the problems that can occur.

Second Part: Methodology

I. Mapping of the different actors

1. Sector identification

Understanding and qualifying the different sources of biomass (A biomass is considered as a matter that comes from a living organism (Conrozier 2019)) in Martinique and in the GW is a key step to start this study, to identify the main actors detaining, using or dealing with this biomass. To determine the sector list, different reports identifying the different sources of biomass on the island were identified such as the report of the Collectivité Territoriale de Martinique (2019). The information found was crossed with the different sources of matter that could be used as mulch in vegetable production. Thanks to these reports, 5 specific sectors were identified, and one "Other" sector was created for actors that couldn't be defined by one of the five sectors, which can be found in figure 5.

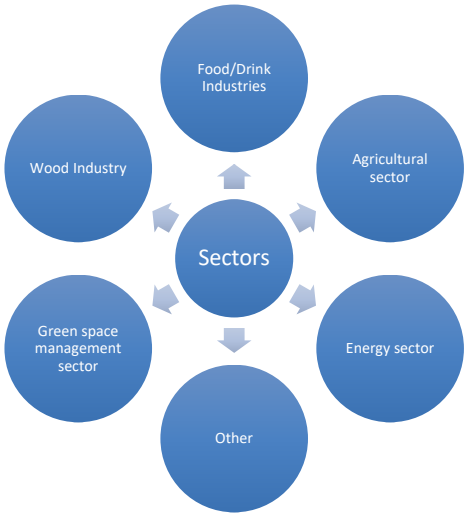

Figure 5: Different sectors studied, personal source

Considering the aim of the Interlude project: to limit the use of chemicals and promote agro-ecological practices, we only considered local biomasses and local actors, situated on the island: imported biomass will not be taken into account during the study. Our priority will be on the GW; however, since the borders of the GW may not be limiting when imagining biomass exchanges, important actors may be situated outside the watershed.

Hereunder is a short description of the sectors identified, and how they can be related to a mulching sector, which can also be seen in figure 5:

- Agricultural sector: this sector deals with biomass daily by producing it but also by using it on the land.

- Food/Drink industry: these sectors are important as they use agricultural produce to create their final production. During the production, some organic waste may be produced that could potentially be used by the mulching sector.
- Wood industry: This industry, like the agricultural sector, deals with biomass directly. Depending on the biomass, it can either be sold or disposed of.
- Green space management: whilst this sector may not seem to deal with biomass, urban actors are often in charge of dealing with public green spaces that generate biomass.
- Energy sector: this sector consumes biomass to produce energy. This sector is important as it can be a competitor for biomass.
- Other: This entity was created to include other sectors that could exist and have a limited number of actors. This sector could include individuals, or private companies dealing with biomass in one way or another.

2. Biomass identification

Thanks to the 6 sectors identified above, it is possible to create a list of the different types of biomasses available that could potentially be used as mulch. In this study, the aim will be to explore the mulching options, their quantity, and availability, therefore we focused on biomass that is already used as mulch by certain farmers, or biomass that could cover the soil in an adequate way to limit weeding. Additionally, the biomass considered must be produced and available on a local scale, at best in the GW, but at least on the island.

- Agricultural sector: the focus will be on crop residues coming from different productions present in Martinique. The two most important crop productions are banana and sugarcane. Coconut production will also be considered. We will not consider vegetable crop residues, as the vegetable production is very low therefore the vegetable crop residues are mostly used directly in the field.
- Food/Drink industries: Martinique is very dependent on imports for its food industry, indeed between 2013 and 2019, the island covered 44% of its raw fruit consumption, 26% of its raw vegetable production, less than 25% of its meat consumption, and nearly none of its milk production (ODEADOM 2021). However, the main food industry linked to agricultural production is linked to sugarcane transformation into rum or sugar. Therefore we will include rum and sugar production in this study.
- Wood Industry: in this sector, we consider all wood that can potentially be mulched.
- Green space management sector: the biomass from this sector will include grass cuttings, hedge cuttings, and branches of different sizes.

- Energy sector: knowing what biomass the energy sector uses will be helpful to determine the availability and quantity of certain biomasses.
- Other: seeing how different organizations are involved in dealing with biomass will be important in determining the availability.

3. Actor identification

After having listed the different sectors to study and having noted the biomass of interest for this study, identifying the actors linked to the sector and the biomass was essential to collect the information wanted, and to understand the possibilities of this future sector.

The categories of actors were found based on existing literature, either through past studies in the GW or in Martinique that identified important actors, or thanks to research linked to the biomass identified. The CIRAD in Martinique also had knowledge of important actors on the territory, some actors were also found thanks to discussions with colleagues. This step was time consuming, as it can be difficult to find the correct actors, and their correct contact and to reach them. Table 1 hereunder synthesizes the sector, biomass and actor identified. The focus once again was on actors inside the GW, however some actors work on the whole island are also included.

Table 1: Sector-Biomass-Actor table

Sector	Biomass	Actors in the GW
Agricultural sector	Vegetable crop residues	Vegetable farmers
	Banana crop residues	Banana farmers
	Sugarcane crop residues	Sugarcane farmers
	Coconut crop residues	Coconut farmers and coconut processors
Food/Drink Industry	Bagasse	Distillery
		Sugar factory
	Coconuts	Coconut transformers
Wood Industry	Excess cut wood	ONF
		French Association for Agroforestry
Green space management	Grass cuttings	Municipalities/communities
	Tree/branch cuttings	Municipalities/communities
		Pruning companies
Energy sector	Bagasse	Distillery
		Albioma
	Tree cuttings	OVC
		Albioma
	Organic waste	OVC

Once the category of actor has been identified, individuals or organizations had to be found in order to collect the information and complete interviews if needed.
Concerning the farmers contacted, a data base was created by the CIRAD, thanks to the previous work and studies, with the contact information of vegetable producers and their location on the island.
Concerning the food and drink industries, research was conducted on the internet where most of the required information was available. If not, their contact could often be found on their website.
Concerning the wood industry, the main actors, which are the ONF (National Forest Office) and the AFAF (French association of agroforestry) were found online and through word of mouth.
Concerning the green space management sector, we included public actors dealing with green waste management, such as municipalities, but we also include private companies dealing with pruning, as a service for public or private actors. Additionally, we included the study of the landfills in the GW, as they deal with green waste brought by different actors.
For the energy sector, information concerning Albioma was collected, as it is in competition for organic matter that could be used for mulching. Albioma was implanted in Martinique in 2007, it produces photovoltaic and thermic biomass to participate to the energetic autonomy of the island (Albioma 2022). The organic valorization center (OVC) is a structure that produces electricity thanks to a methanizer. The OVC produces compost as a result that is stocked and commercialized (SMTVD 2022). The bio-waste it uses comes from professionals that deliver the waste directly on site. The OVC therefore can also be a competitor for biomass.

II. Conducting interviews

1. Defining interview type

The information collected is mostly qualitative, therefore in person interviews were done face to face. These are useful and more complete than virtual interviews as they include social cues (voice, body language, intonation…) (Opdenakker 2006) which is information that can be analyzed in addition to the answers of the interviewee. Additionally, the person is more likely to open up and share more personal views on a subject when conducted face to face. However, this can also be problematic as the interviewer can also influence the interviewees answers (Imbert 2010) by the formation of the questions or by his/her nonverbal actions/mimics. For this study, we chose to conduct face-to-face semi-structured interviews, as it was important to grasp the points of views of the different actors. A semi-structured meeting allowed us to obtain required data without the interview being too vague or too directive (Imbert 2010), letting him/her express his or her opinion on the subject.

In order to conduct these interviews, we created different interview guides allowing us to direct the interview and to follow a logical structure during the meeting. For each type of actor there was a different guide, adapted to what information we wanted to collect. For some categories of actors, interviews weren't necessary as the information needed was found in literature.

2. Interview description per sector

In order to define how the data was going to be collected, a key step was determining what type of information was needed. During the interviews, most of the information was qualitative, with some quantitative data when possible. As this was an explanatory study, the qualitative information collected helped determine whether the creation of this sector is feasible according to the different actors. More detailed data may be needed later on when implementing the project, depending on the conclusions of this study, in order to create different partnerships.

For each sector, the main information we wanted to collect was:

- Agricultural sector: type of farms, current weed management, how problematic weed is, brakes and levers to adopting mulch, past experiences with mulch, what kind of biomass they possess and how they use it. The interview guide for vegetable farmers this sector can be found in appendix 2. These interviews should last more or less an hour: a little less if the interviewee does not use mulching, and a little more they do.
- Food/Drink industries: type of biomass they possess, conditions to sharing their biomass, quantities of biomass, what is done with the biomass
- Wood industry: type of biomass they possess, conditions to sharing their biomass, quantities of biomass, what is done with the biomass
- Green space management sector: type of biomass they possess, conditions to sharing their biomass, quantities of biomass, what is done with the biomass
- Energy sector: quantities of biomass consumed, type of biomass consumed
- Other: type of biomass they possess, conditions to sharing their biomass, quantities of biomass, what is done with the biomass

The interviewees were first contacted by phone or email in order to explain the project and chose a date when they were available to conduct the interview. Phone calls were often the most efficient way to contact the actors, as many more interviews were set using this technique. The actors were selected through a non-probability sampling method, meaning that they were selected following a certain criterion. The available database given by the CIRAD allowed us to sort the vegetable farmers according to the municipality they belong to: therefore, the farmers contacted were situated in the 4 municipalities of the watershed.

For the other actors, the interviewees and data obtained were collected through contacts and through targeted company websites.

3. Description of interviewees

Actors for whom the required information could be found through either literature or websites were not contacted. However if the information could not be found or if having the actors' thoughts was important, they were interviewed when possible.

Hereunder, in table 2 the different types of actors interviewed can be found, with the numbers of interviews conducted. The interviews conducted helped confirm or confront the information read in literature and add opinions and advice to the construction of this sector.

Table 2: Table showing the conducted interviews

Actors	Number of interviews conducted
Vegetable farmers (Municipalities inside GW)	11
Vegetable farmers (Municipalities outside GW)	3
Urban sectors of the towns inside GW	4
Sugarcane producers	2
ADEME[1]	2
Chamber of Agriculture	1
Espace sud[2]	1
Pruning companies	1
French association for agroforestry (AFAF)	1

The farmer interviews were the most numerous as their aim was to gain more knowledge on the current weeding practices used by vegetable farmers in the GW, but also to discover what innovative practices are already but in place, what farmers are looking for and what they would be interested in.

Table 3 shows us some characteristics of the interviewed farms, allowing us to visualize the types of farms present in the watershed, their main productions and their surface. The map on figure 6 shows the location of the different interviewed farms.

[1] ADEME : Environment and Energy Management Agency

[2] Espace sud: urban community of municipalities situated in the south of the island

Table 3: Description of interviewed farms

Farmer number	Installation year	Main production[3]	Secondary production	Agricultural area (ha)	Type of agriculture
1	2003	Vegetable	Fruit trees	1.5	Conventional
2	2010	Vegetable	Fruit trees	1.5	Organic
3	2019	Vanilla	Vegetable + Fruit trees	1.5	Conventional
4	2005	Vegetable	Fruit trees	2.5	Conventional
5	/	Vegetable	Fruit trees	6	Conventional
6	2016	Vegetable	Fruit trees + sheep	5	Organic
7	2014	Vegetable	/	4	Conventional
8	1992	Fruit trees	Vegetable + Fruit trees + sheep	2	Conventional
9	2018	Vegetable	Fruit trees	2	Conventional
10	2008	Vegetable	Fruit trees	7.5	Conventional
11	2010	Vegetable	Medicinal plants	2	Conventional

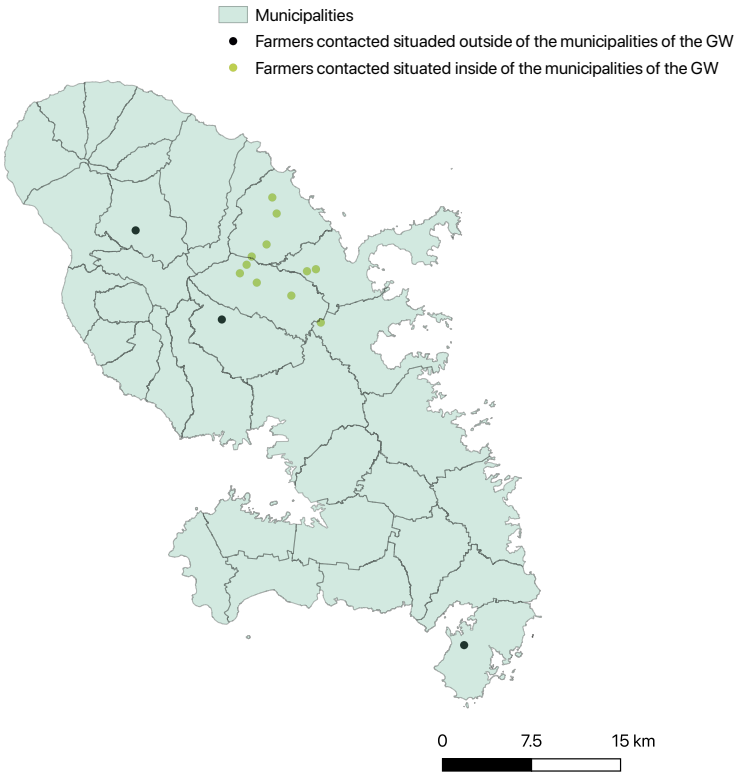

Figure 6: Map of interviewed farmers

[3] The main production is considered as the production the farmer talks about first, it can be linked to the income it generates or the area of cultivated land.

In 2019, according to the graphical parcel register, and to (Wintz, Pak 2021) the agricultural area was 1334 ha for the GW. 5% of this agricultural area (66,7 ha) is dedicated to horticulture production, including vegetable production, flower production, ornamentals, perfume plants, medicinal plants and non-perennial fruit trees. Our vegetable farm sample inside the GW includes a total of 35,5 ha, situated in the municipalities of the GW, so 53% of the total horticultural area of the GW, just for vegetable production.

Other interviews conducted were with green space management actors (Table 4), those situated in the municipalities of the GW. Indeed, on their websites it is hard to find and understand which green waste they deal with and how they dispose of it. These interviews aim to clarify these points.

Table 4: Municipalities interviewed on their green waste management (INSEE 2022)

Role of interviewee	**Town**	**Municipality area**	**Population (2018)**
Responsible of green spaces	Le Robert	47,3 km^2	22 429
Assistant head of department – Green spaces	Sainte Marie	44,55 km^2	15 571
Head of green spaces	La Trinité	45,77 km^2	12 232
Head of green spaces	Gros-Morne	54,25 km^2	9 755

III. Characterizing brakes and levers

1. Analysis of interviews

During the interviews notes were taken according to the interview guides, and when possible the interviews were recorded in order for the reported speech to be more precise. After the interviews, the notes were completed using the recordings in order to improve the details and quality of the notes taken. The information given by the actors will help determining the brakes and levers concerning this sector on the territory.

As qualitative information was collected during interviews, the analysis will consist of reporting the speech, characterizing what the interviewees say into different categories.

For farmer interviews, the first step was to use the descriptive information of the farm to describe the types of farms interviewed in the GW. Information used was the agricultural land, presence of employees on the land, main production … The questions linked to their current weeding practices and how they perceive the weeding on their farm was also used in order to add description to the farms.

The rest of the information, linked to the different organic materials that could be used as mulch that they know of or that they have used, was studied using two criteria: first of all what type of mulch the farmer is talking about, and then whether the farmer is describing a phenomenon on a field, farm or sector level. The opinions and speech collected by the farmer were categorized into two columns: advantages and disadvantages. The synthetic table obtained through this cross-analysis will help us get an overview of the main advantages and disadvantages reported by farmers for the different mulching options. This method helped us discover, from the farmer's point of view, the main brakes and levers to the different mulching options, and see if the brakes are justified or if they are linked to general apprehension.

Questions linked to the organization around the mulching sector helped us perceive whether farmers are willing or not to take part in this sector if certain exchanges already take place, and how.

For the other interviews, the aim of the analysis was to get an overview of the system: what biomass is dealt with, where, and how it is disposed of. These interviews were analyzed separately as they often deal with different types of actors. An aim of these interviews was also to describe the project to the different actors and to capture their reactions, their thoughts, and opinions linked to the creation of a mulching sector. Understanding if they are reluctant to it, or if on the contrary, they find it interesting, was important as it will determine how the next steps of the project will be handled.

2. Biomass quantification

Quantification was necessary for each biomass identified, as the aim is to have sufficient quantity in the GW or in Martinique (Wilt 2012). If interesting biomass is identified but is inexistant or present in a very low quantity on the territory, it will not remain a possible solution.

For each matter, the estimated quantity was determined through different articles, but also through information collected during interviews. The aim of the quantification was not to have a precise quantity, but to have an estimation of what quantity of matter is available, and when throughout the year they are available, if applicable. Concerning the literature, the most recent documents found were used, however as biomass quantities vary from one year to another the numbers obtained depend on the year.

3. Biomass availability

In addition to the quantification, verifying the availability of the identified matter was essential in order to see if it could potentially be used as mulch. To do so, we studied and analyzed what the biomass is currently used for, and if a certain quantity could be spared to be used as mulch. The aim was to confront the identified brakes to the actual situation to see whether these brakes were actually existent, mental brakes, or linked to a lack of knowledge of certain biomasses. This section helped us identify which organic matter could be used, not only including the brakes mentioned by the farmers,

but also thanks to the information collected for each sector. Conducting interviews and the research was used to determine the availability of biomass.

Third Part: Results

I. Understanding practices and determinants of natural mulch adoption

1. Farmers interviews

To understand the types of farms interviewed, a description is available in appendix 3. More than half of the farms interviewed have less than 2 hectares of agricultural land (6 out of 11). Nine farms have vegetable cultivation as their main agricultural production on the farm.

Farms only have one main production but can have several secondary productions. On appendix 3, we can clearly observe that fruit trees are the most mentioned secondary type of production. This is linked to the farms in Martinique being very diversified, with a lot of self-consumption on farms. This leads to farmers wanting to have many different productions on their farms.

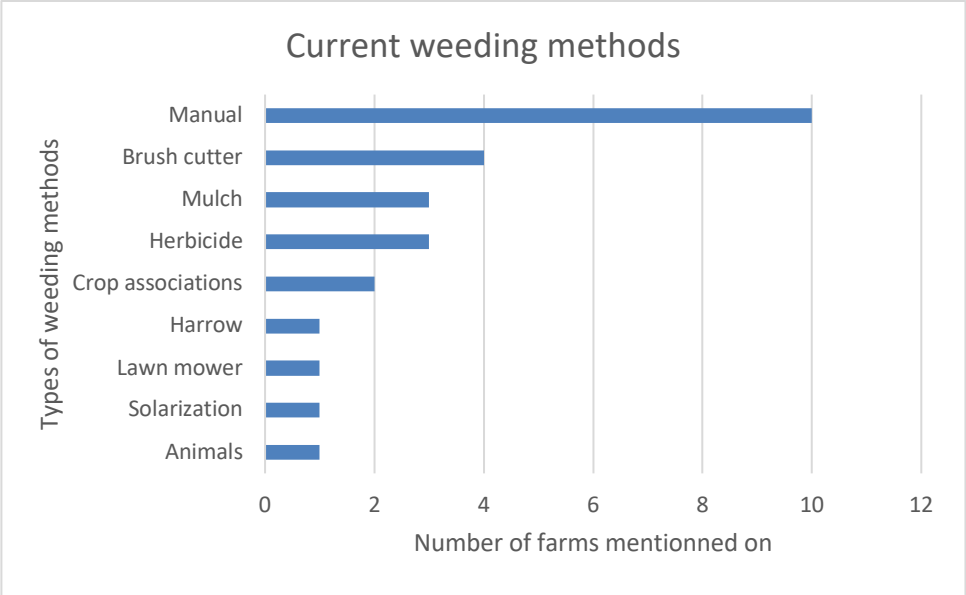

Figure 7: Current weeding methods on the interviewed farms

Figure 7 shows that the main weeding method observed on the interviewed farms is manual, as it is present on 10 of the 11 farms. The brush cutter is also a common tool used in Martinique, not only on farms but also in different green spaces, an advantage being that it can be used in relatively steep fields. The farmers that mentioned mulch as one of their weeding practices used organic material coming from their farm as mulch.

The thoughts of the interviewees on the different natural mulch they use, or that they could potentially use, are reported in table 5. In order to differentiate the thoughts shared by the farmers, the information was analyzed as either an advantage or disadvantage, and categorized into field (green), farm (blue) or sector (purple), depending on what scale the farmer was talking about.

Table 5: Advantages and disadvantages of the different natural mulches collected from farmer interviews. The different scales can be seen in color : field in green, farm in blue and sector in purple.

	Advantages	Disadvantages
Sugarcane leaves	-Often present on the farm (Farmer 4 & 6)	-The leaf residues often contain seeds, that increase weed presence (Farmer 1) -Potential presence of beetles (Farmer 4) -Generally, this matter is used directly by the sugarcane producers as organic matter (Farmer 2) -Transporting the matter can be a challenge (Farmer 3)
Bagasse	-Interesting as it limits weeding but additionally fertilizes the soil (Farmer 2) -Bagasse can be collected for free in certain distilleries (Farmer 4)	-Very acid and sugary, when it was applied it burnt the production (Farmer 10) -Necessity to analyze the presence of CLD in bagasse (Farmer 3) -Competition for the matter with the energy sector and animal production (Farmer 4) -Farmers are skeptical of the quality of bagasse (Farmer 4) -Transport can be costly (Farmer 4)
Grass cuttings	-Lawnmower directly applies grass cuttings on the rows (Farmer 10)	-Decomposes quickly, therefore doesn't provide sufficient soil coverage (Farmer 1) -Necessity to find thicker and more opaque matter (Farmer 1) -Attracts beetles and caterpillars (Farmer 9) -Complicated to transport as the land is relatively steep (Farmer 3)
Banana leaves	-Used between the rows of culture to limit weeding, additionally, it brings potassium and nitrogen to the soil (Farmer 9) -Keeps the soil fresh (Farmer 9)	-Leaves are decomposed very rapidly (Farmer 1) -Banana producers use them directly on their land (Farmer 1)
RCW/mulch	-Enriches the soil in nitrogen (Farmer 9) -Bought a mulcher in order to use the crops/trees present on the farm as mulch (Farmer 1 & 10) -Sufficient organic matter on farm that could be used (Farmer 2) -Some plants present on the farm have a good coverage and are able to limit weeding (Farmer 9) -Can additionally be used to fertilize the soil (Farmer 5)	-Makes the soil acid (Farmer 9) -Necessity to have access to a mulcher or to a service that could mulch the organic matter (Farmer 2 & 7) -Can't be used for short production cycles as it demands some work (Farmer 11) -Transport difficult to organize and costly (Farmer 3) -Access to resource (Farmer 4)
Coconut	-Coconut leaves do not contain any seeds which could lead to more weeding problems (Farmer 1) -Possibility to crush both leaves and fruit to create a mulch (Farmer	-Can attract centipedes that may attack the production (Farmer 2) -Necessity to have a good quality mulcher (Farmer 7)

	2 & 10) -In the past, coconuts where cut in half and put around the tree to limit weed pressure and fertilize the soil (Farmer 6) -Allows a good water retention (Farmer 8) -Coconut fiber is used as substrate for tomato production, then applied on fields at the end of production cycle (Farmer 4) -A good idea, as a lot of coconut water is consumed on the island (Farmer 5) -Interesting source, as people who transform it often throw the leftovers away (Farmer 7)	
Crop residues	-Can be used directly on the field, no need to transport it (Farmer 6) -All organic matter can directly be reused on a farm scale (Farmer 1) -Crop residues could be crushed and applied in the field (Farmer 4)	-Not enough matter on the field to use as mulch (Farmer 5) -Not enough crop residues to sufficiently cover the soil (Farmer 1) -Crop residues can be too voluminous to be applied directly on the field, and therefore need to be mulched (Farmer 4)

Thanks to these interviews, the key advantages, and disadvantages according to farmers, for each type of organic matter were determined, allowing the establishment of a list of brakes for the creation of this sector. The brakes identified are the quality of the organic matter, the quantity of biomass available, the transportation of the biomass, the competition of the biomass with other sectors, and the lack of available material. An additional constraint identified is linked to the trouble of working with others, this was mentioned by several farmers. Farmers prefer working on their own and having their own tools than having to rely on others; this brake could potentially become significantly problematic if farmers refuse to work with other actors.

The interviews were able to show the farmers' perception of mulch, thanks to their experience or their knowledge, however, the information collected remains a perception and not necessarily the reality. Indeed, sometimes farmers have strong thoughts on a subject that aren't necessarily justified.

2. Urban sector

The aim of the interviews with the different municipalities was to understand what organic matter they deal with, and what they do with it.

The municipalities have access to different types of biomass :

-grass cuttings: from sporting areas, parks, urban green spaces …

-plant cuttings: these are the results of the different pruning operations that can take place: on the side of roads, around schools, in the parks …

None of the 4 interviewed municipalities possess a mulcher, most of their green waste is brought to the OVC, organic valorization center, which mulches the matter and uses it for its mechanizer. As a public actor, they have a contract with the OVC and can bring up to a certain amount per year of biomass for free, if they exceed this quantity they have an additional fee to pay.
Other ways of disposing of the organic matter is to allow individuals to take a part of the cuttings free of charge, they generally use it as fertilizer or mulch for their private gardens. The municipalities also admitted to leaving a certain part of the organic matter on the pruning sites, or in ditches near by the site. This practice depends on the location of the pruning site.
For the pruning operations, municipalities have a pruning team, but if the operations are too large or technical they can also hire pruning companies which are more specialized. These companies then dispose of the organic matter in their own way.

3. Organizational level

Interviews with actors such as the ADEME (Environment and Energy Management Agency) or the Chambre of Agriculture are useful because these organizations are well implemented in the territory. They have a good view of the different ongoing projects, how the different agricultural productions function, and how the producers and other actors take part in the different projects. In this case, interviews with these actors allowed us to identify the problems linked to access to mulchers on the territory: there is a lack of this tool in Martinique, and the few mulchers that are efficient and have a good capacity often have important mechanical problems or brake very often. Another difficulty mentioned by these two institutions was the organization of actors into a sector: actors are very independent and are not very cooperative, which makes it harder to complete projects together. They shared experiences that they had with certain projects that they conducted, where actors were not present throughout the project and rarely partook in the proposed activities.

The interviews helped us identify important biomasses the different biomasses the actors possess and how they deal with them. Important constraints were identified both for the use of the biomass (quality, quantity, transportation, competition, few mulchers) and for the organization of the sector (difficulty to work together).

II. Biomass quantification

1. Agricultural sector

For banana production, only the left-over crop residues will be considered as potential mulch material for vegetable producers as the whole fruit production is extracted from the field to be solf. In banana plants, the content of fresh/dry matter depends on what plant parts are being looked at.

Generally, a banana production after harvest leaves between 7 and 25 t/ha/year of dry matter. A good banana production leaves on average between 10 to 15 t/ha/year of dry matter in the field (Godefroy 1974), therefore we will use the average of dry matter left in the field of a good banana production: 12,5 t/ha/year.

$$Eq1 : Potential\ banana\ crop\ residues = cultivated\ banana\ surface\ (ha)\ x\ average\ of\ dry\ matter\ left\ in\ field\ (t/ha/year)$$

For the total surface in Martinique, we used information from 2021 (Agreste 2021), for the surface in the GW, numbers from 2019 by (Wintz, Pak 2021) were used. Table 6 shows the estimated banana crop residues available on the island and in the GW.

Table 6: Table of estimated banana crop residues (Agreste 2021) (Wintz, Pak 2021)

	Martinique	**Galion watershed**
Cultivated banana surface (ha)	5,000	545
Estimation of banana crop residues (tons/year)	62,500	6,812

Concerning sugarcane production, crop residues could be considered as a potential mulch that vegetable producers could use. According to Hassuai, Leal, Macedo (2005), the potential crop residues represents 14% of the stalk mass : for each ton of stalks, 140 kg of crop residues are left on the field. This estimation will be used in order to calculate the estimated sugarcane crop residue. The quantity of crop residues available is very dependent on the variety of sugarcane produced, on the climatic conditions and on the sugarcane yield (Kyulavski et al. 2019). The pressed sugarcane is the stalk mass.

$$Eq2: Potential\ sugarcane\ crop\ residues = pressed\ sugarcane\ (t)x\ \%\ of\ stalk\ mass$$

In this calculation we used the quantity of pressed bagasse found in (SAEM Le Galion 2021) for 2021. The estimation of pressed sugarcane in the GW was calculated using this calculation:

$$Eq3: Estimation\ of\ pressed\ sugarcane\ in\ GW = \frac{pressed\ sugarcane\ in\ Martinique\ (t)x\ cultivated\ sugarcane\ surface\ GW(ha)}{cultivated\ sugarcane\ surface\ in\ Martinique\ (ha)}$$

Table 7 shows the results of these calculations, with the estimations of sugarcane residues available.

Table 7: Table of estimated sugarcane residues (SAEM Le Galion 2021) (Hassuai, Leal, Macedo 2005) Wintz, Pak 2021)

	Martinique	**Galion watershed**
Cultivated sugarcane surface (ha)	4,000	302
Pressed sugarcane (2021) (tons)	206,553	15,596
Potential sugarcane crop residues (2021) (tons)	28,917	2,183

The coconut sector in Martinique remains very informal. According to exchanges with the DAAF (Direction of Food, Agriculture and Forestry), there is only one agricultural plot officially

registered as producing coconuts. Very little information on the yields linked to coconut production is available on the island. However, in the landscapes, it is possible to observe numerous coconut trees on the side of roads, in gardens…but these productions remain difficult to report as they are not considered as agricultural land.

2. Food/Drink industry

When sugarcane is transformed into either rum or sugar, it is pressed in order to extract the juice. During this process, an important part of biomass is left over, which is called bagasse. On average, when considering the quantity of pressed sugarcane, left-over bagasse represents 30% of the initial weight : for one ton of pressed sugarcane, 300 kg of bagasse remain (Archimède et al. 2011).
In table 8, the quantity of pressed sugarcane is from 2020, and collected from (SAEM Le Galion 2021), the corresponding bagasse obtained is estimated thanks to (Archimède et al. 2011).

Table 8: Table showing sugarcane and bagasse quantities (SAEM Le Galion 2021) (Archimède et al. 2011)

	Pressed sugarcane	**Estimated bagasse obtained**
Martinique	206 553 tons	61 966 tons
Sugar factory "Le Galion"	38 708 tons	11 612 tons
Distilleries	167 846 tons	50 354 tons

3. Wood industry

Bambusa vulgaris, commonly called bamboo, an invasive species in Martinique, was estimated to cover 2,000 ha of land in 2012 (Wilt 2012). This surface could potentially produce around 40,000 tons of biomass on the island per year (Wilt 2012). Dealing with biomass in Martinique could be both beneficial to limit the proliferation and to use the biomass as mulch.

During the interview with the representative of the French association of agroforestry in Martinique, the intention of the hedge project was shared. Hedges were used in Martinique before for agricultural purposes, and were a part of the landscape, however they were gradually destroyed because of the high maintenance they demand, and the lack of market for the produced wood. With the re-implementation of the hedges, the sharing of knowledge and the creation of a specific market for this wood, hopefully hedges will be more present in the landscape. AFAF's objective is to obtain around 10,000 tons of biomass each year, as the study they conducted estimated the grove wood in Martinique could reach between 10,000 and 20,000 tons per year. This project is conducted on the whole island, not particularly in the GW. The companies working with them could also be interested in doing service delivery for vegetable farmers on their land, either by selling them the service and leaving the mulch on the farm, or by maintaining the hedges for free and selling the mulch either to the farmers, or to other interested actors.

The ONF, which is the national forest office, takes care of 15,500 ha of public forest in Martinique, with 10% of this forest being used to produce wood. The rest of the forest, around 31,000 ha (65,7%) is privately owned, making it hard to quantify the available biomass.

4. Urban sector

In this category, we include public actors dealing with green waste management, such as municipalities. In 2019, green waste coming from the public spaces of the different communities represented 2 169 tons of green waste (Collectivité Territoriale de Martinique 2019). It is complicated to go more into detail concerning the green waste quantities, as each type of waste isn't quantified, only a general quantification is available. If this biomass was no longer considered as waste but as a resource, the quantification process would start and it would be possible to estimate the specific quantities for each municipality, and the different types of biomass they have.

The interviews with the municipalities of the GW showed that the quantity of biomass obtained is quite different depending on the type but also on the size of the municipality, however they all possess the same type of biomass (grass cuttings, wood…).

Table 9 shows the quantity of green waste collected in landfills in the different communities of municipalities, in 2016.

Table 9: Green waste collected in landfills per comminity of municipalities in 2016 (Collectivité Territoriale de Martinique 2019)

	Cap Nord Martinique	**CACEM**	**Espace Sud**	**Total**
Green Waste	2 249 tons	2 141 tons	9 069 tons	13 459 tons

Considering the size of Cap Nord Martinique (54,777 ha) and the size of the GW (45km^2), it is possible to estimate the quantity of green waste in the GW : **185 tons**. This would be considering that the green waste is equally distributed over the land, not concentrated in a specific area.

III. Biomass accessibility

1. Banana crop residues

Banana production, in 2019 corresponded to 41% of the agricultural area of the GW, 545 ha (Wintz, Pak 2021). The residues of this production could have therefore been a solution for organic mulch. However, when looking into technical itinerary of banana production, we found that crop residues are directly applied onto the field (Lassoudière 2007). According to Lassoudière (2007), the ideal way to deal with the crop residues is by leaving them in the field, to limit both weeding and erosion of the soils. By doing so, this adds organic matter to the soil and recycles fertilizing elements.

Pseudo-trunks and leaves can be used to cover the total surface, or only the cultivated rows depending on the meccanization possibilities (Lassoudière 2007).

Knowing this, banana crop residues will no longer be considered as a potential option for mulch in vegetable production as they are currently used as mulch and fertilizer in banana production.

2. Sugarcane crop residues

Figure 8: Photo of a sugarcane harvester, personal source, Feb 2022

On the island, there is an unequal distribution of agricultural land and land 'quality' linked to the historical background (Baron, Joet 1999) leading to several producers producing the majority of sugarcane : 5% of the sugarcane farms produce 80% of the production (Baron, Joet 1999) on farms from 50 ha or more. Harvest of the sugarcane starts in February and ends in June for the majority of the production in Martinique, as these are the dates were the labelled rum can be produced.

During the harvest, the crop residues are often left on the ground to serve as mulch and fertilizer for the following cycle, it also promotes a better water infiltration into the soil, stabilizes soil temperature and controls erosion in the field (de Aquino et al. 2017). However, calculations on the quantity of straw necessary to leave in the field show that 50% of straw mulching was sufficient to provide the advantages mentioned hereabove (de Aquino et al. 2017) and communications with a sugarcane specialist led to the same conclusions. Leaving additional straw does not lead to superior response, higher yield or any other additional benefits.

According to research on the sugarcane sector in Martinique, it is shown that the harvest of sugarcane is done mechanically for farms with more than 400 ha and for farms attached to a distillery (Baron, Joet 1999). Indeed, in 2019, 90% of the sugarcane was cut mechanically (Deniau et al. 2021). Manual harvest is only done by small producers, who do not have enough production, enough financial support to invest in harvesters or who have steep fields. Overall, an increase in mechanization has been observed in the sugarcane fields over the years.

Today, most of the mechanically-done harvest is done thanks to effective harvesters. The harvesters have many different roles: they first cut of the top of the leaves, then collect the sugarcane stalks, lift them up into the tractor that follows the harvesters, and lastly returns the un-harvested crop residues behind the harvester, on the soil. Therefore, the crop residues that we are interested in are directly

returned on the field, and evenly spread out. Considering what was mentioned above, that only 50% of crop residues needs to be left in the field, the rest could potentially be collected.

It seems complicated to go back into the field after the harvest to collect the shredded organic material that is already spread out evenly on the soil. This can be done in La Reunion, but the scenario is different as only 30% of the harvest is done mechanically (Deniau et al. 2021), therefore the crop residues are not directly shredded during the harvest. Additionally, when asking a sugarcane producer if it would be possible to transfer a part of the residues to other farmers she replied: "no no, we need the organic matter for our land, to fertilize it, and the machines return the residues directly on the field". This shows that crop residues can also be used directly on site as mulch but also as fertilizer for the following crop productions.

There seems to be reluctance towards the practice of taking sugarcane straw out of the field, however if this sector were to be put in place, the dynamics of the producers would certainly change. Undeniably, if sugarcane producers accepted that the same ecosystemic services (nutrient recycling and weed control) could be served with less residues, they would probably be onboard to selling a part of their crop residues to vegetable producers. In order to determine this, co-construction workshops could be useful to understand the point of view of each actor.

Therefore sugarcane residues could potentially be used as mulch, but sugarcane producers would probably only be willing to take part if the sector is well constructed and if they received financial compensation for the straw they would share. Therefore we will not consider sugarcane residues as a potential solution for the mulching sector in the first steps of the project, but they could take part later on.

3. Bagasse

Sugarcane bagasse, commonly called 'bagasse', is obtained from the cane stalks after their crushing and extraction of juice, it is a ligno-cellulosic residue of the sugar and rum industry (Pandey et al. 2000). Since it is directly linked to the sugarcane production, bagasse is therefore also available from February to June.

This material is often used directly by the factories producing it, as fuel for their boilers (Pandey et al. 2000). Indeed, at Rhum Saint James distillery, located in Saint Marie, their bagasse is used as fuel to create water vapor used in the distillation column (Rhum Saint James 2022). Saint James uses 75-80% of their bagasse production to fuel their ovens, but some distilleries valorize their bagasse less. Historically, people could come to collect bagasse directly at the factory, to use in their gardens, or for their animals. Today, they still have a few regulars that come to collect bagasse, but the rest is sold to Albioma, the biomass-fueled power-plant. In some cases, bagasse can also be used as additional organic matter, applied directly in the sugarcane fields. Distilleries therefore do not have large quantities of bagasse to spare, as they self-consume most of it. Farmer 1 shared however that he used to collect bagasse directly from the Rhum Saint James factory, where he said that the matter was

available for people who wanted to collect it. Farmer 4 also stated that he collects bagasse directly in the distilleries, for free; therefore, distilleries may have some excess matter available for farmers, however this depends on the sugarcane production which varies every year, but also depends on the self-consumption of the distillery.

The Galion sugar factory and distillery buys 40% of the cultivated sugarcane on the island (Le Galion 2022), therefore it processes 40% of the bagasse on the island. The factory was built in 1865, its main production is sugar and it is the only sugar factory left on the island (Le Galion 2022). In addition to the sugar production, the factory also produces two types of rums. The Galion sugar factory signed a contract with Albioma, located next to the factory, so that all the bagasse they produce is used to create electricity. Additionally to the 40% of the total bagasse of the island collected from the factory, Albioma also buy the un-used bagasse from the different distilleries. The use of biomass by the energy sector is likely to increase since solutions are being explored to create more renewable energy.

Concerning the risk of CLD in bagasse, it's presence is mostly found in the underground organs of sugarcane, as they are in contact with the contaminated soil. All the plant organs are necessarily less contaminated than the soil (Lesueur-Jannoyer et al. 2012), a gradient can be observed : the plant organs situated closer to the soil are more contaminated, and the ones further away are less contaminated (Lesueur-Jannoyer et al. 2012) (Marie, Chopart 2012). The CLD present in the leaves of the sugarcane and at the top of the stalk is low but not inexistent (Lesueur-Jannoyer et al. 2012). Several farmers mentioned that they were dubitative towards the quality of bagasse and the possibility of it being contaminated by CLD.

If we combine the availability of bagasse, which we estimate to be relatively low, the farmer's apprehension towards using this biomass and questions linked to the contamination of this biomass, we can conclude that this biomass is not the ideal solution for mulch for farmers.

4. Coconut crop residues

On the island it is possible to observe many coconut trees in the landscapes meaning they are present on the island. Additionally, several farmers mentioned that there is a high potential for this organic residue, as people on the island eat a lot of coconut derived products, in particular coconut water. Indeed, it is possible to buy coconut water on any of the large roads, these transformers collect the coconut either from private lands, but also public spaces, and sell coconut water. Once they have extracted the water, they often throw out the coconut residues in ditches or on this side of the road. On many farms visited, there were coconut trees, either for the farmers' personal use or to be sold as coconuts or coconut water to their clients. Several farmers mentioned that their parents and grand-parents used cut coconuts under trees in order to limit weeding and add organic matter to the soil. Therefore, it is possible to imagine mulching this matter to use in vegetable plots. This source of

organic matter is very interesting but as it is informal it is hard to organize. An in-depth study of the coconut sector would be interesting to determine the available quantities and their use.

Forth part: Discussion

I. Discussion of the results

When dealing with agricultural production, the quality of inputs applied on the field is of high importance, as they can directly impact the quality of the food produced. The interviewed farmers showed care concerning the inputs on their farms as aside from wishing to produce good quality food, many farmers self-consume their production. Several farmers mentioned that they needed to know the origin of the organic matter they would be applying on their land. General apprehension was shared by the farmers concerning the organic matter coming from other agricultural sectors, as their practices (often monocultures) are not always in adequacy with those of smaller farmers. Additionally, knowing the origin of the organic matter is essential, as one must know if the matter is contaminated, either by phytopharmaceuticals or by pests. If this is the case, applying contaminated matter on land could lead to negative impacts on the soils' health or directly on the crop yield. A farmer mentioned that the biomass he used to apply contained seeds which led to additional weed presence competing with the crop growth. The particularity of organic mulch is that it is left in the field to decompose, leading to advantages such as less work in the field and fertilization of the soil. However, this also highlights the importance of the quality as the matter will directly be degraded into the soil. Depending on the chosen biomass, some farmers shared that they had problems with excess humidity and the development of diseases in the plot. The actual content of the matter, defined by the C/N ratio, is also something that should be considered when choosing an organic material to use as mulch. If the C/N ratio of the mulch is higher than the ratio of the micro-organisms degrading it, there will be an immobilization of soil nitrogen (Sierra, Desfontaines 2018). When the soil nitrogen is immobilized, this creates a lack of nitrogen available for the growing crop (Sierra, Desfontaines 2018). This immobilization phenomenon is temporary, as once the mulch is degraded, the nitrogen is released into the soil and available for the growing crops (Sierra, Desfontaines 2018).

The quality being an important brake for farmers, the levers will be linked to learning more about the different biomasses available. This step would necessitate different analyses done on organic matter, in order to be able to certify the content and the quality. For example, the AFAF has started to list the different species present in the hedges they take care of; the aim is to be able to know precisely what their mulch will be made of. Traceability is necessary as it allows the farmer to limit the risks when applying an input on their plot. If extra work is done on organic matter, this will certainly lead to an increase in the demand and the price of organic matter.

Another mentioned brake concerning this sector is the access to mulchers. Indeed, in order to create a mulch that is easy to transport and apply on the plot, mulchers are a necessary tool. Mulchers can be of different capacities, strengths, and sizes, depending on the biomass needed to be crushed. According to the ADEME, there is a lack of mulchers on the island, leading to a limited quantity of

mulching possibilities. Additionally, discussing with people possessing a mulcher, such as 'Espace Sud' or farmers, helped understand the technical problems they often face with these machines. Regularly the mulchers break down, as they are often not adapted to the humidity and size of the tree species present on the island. Repairing these machines is costly, and takes a lot of time because transportation takes longer on an island. None of the interviewed farmers have active mulchers on their farms, two had bought mulchers but not yet started using them, and others plan on buying one to be able to mulch their own organic material. However, mulchers require an important financial investment, to acquire the machine but also to fix it if problems occur.

With this information, three scenarios can be imagined concerning mulchers on the island:

-Each farmer owns his own mulcher: this solution would require each farmer to receive financial support to acquire the machine. Mulching also takes time, both to collect the organic matter and to mulch it. Once it is mulched it also has to be transported to the field. This solution is far from optimal as vegetable farmers have very little resources and land, therefore the investment is too large.

-Common mulcher for several farmers: this solution would be less of a financial burden for farmers however it would necessitate organization between farmers or the creation of farmer groups. This could potentially allow farmers to group their mulching activities requiring less work time and more efficient results. Considering the farms are relatively small, this may be a plausible solution for farmers to have access to a mulcher.

-Mulching done by specialized companies: this solution seems to be the most adequate, considering the context in Martinique. These companies could either go on the farm to provide their services or sell mulch to farmers from their different working sites. The AFAF has already started working with companies that do so in order to take care of hedges. In this way, the companies mulching would be professional, more efficient in their work, and more available. This scenario would however represent a cost for the farmers, creating a public sector with fixed prices or financially helping farmers who wish to apply agroecological solutions against weeding could be solutions to accompany the transition towards the use of natural mulches.

An important subject to consider is the capacity of actors to work together, as it is necessary for the creation of a sector between several sectors. However, the actors showed reluctance towards cooperating together. Indeed, in Martinique, there are very few organizations allowing farmers or producers to collaborate. In the 1970s, an agricultural cooperative SOCOPMA was created for vegetable producers, the aim was to help farmers struggling to sell their products, and to create a safe space where they could help each other out. However this cooperative shut down in 2014, and since, no agricultural cooperative or organization has replaced it. Therefore, vegetable farmers are used to working individually, this has led to a lack of trust amongst these actors. Farmers expressed that they prefer to work by themselves, because they have trouble finding qualified employees and because they like their work done in a specific way. Farmers are used to working alone, several farmers mentioned

that they prefer working by themselves as at least they know what to expect. Several farmers have had disappointing experiences with employees, as they are not properly trained or because the farmer has high expectations. However, this does not seem to bother them as they have always worked in this manner. This is also linked to the lack of training, linked to agriculture, but also in general on the island. The few farmers who did not work alone got help from people from other islands, as they believe they work better than the local people from Martinique. When asked about the lack of trust in others, some farmers mentioned the history of the island, especially linked to slavery, when slaves were told to "mistrust" others.

Knowing this is important, as social brakes can be just as important as technical brakes. It has to be taken into consideration when imagining the creation of a new sector including diverse types of actors, as new challenges may be linked to this fact. Having an external actor, such as someone who takes care of the watershed dynamics could serve as a mediator between the different actors to help them find a common ground.

Concerning the quantity of organic matter available, estimations were made to have an idea of what is available in the GW. To this quantity, one must add the quantity available on the farms that were not quantified during this study (e.g. crop residues, wood cuttings coming from the farm…); however, this quantity is hard to numerate as it is not measured by farmers. It would be interesting to determine for each vegetable farmer, what mulch they would prefer using, on what crop, on what area… in order to determine the quantity of mulch necessary for each farm in the GW. Indeed, depending on the type of organic matter selected, the volumes needed are different as they are not applied in the same manner. However, this is a particularly difficult task as vegetable farming in Martinique is not formally recorded, farmers often have a visual representation of their needs, but do not know the exact quantities.

Transportation was also mentioned by some farmers as a potential constraint. Farmers who already collect organic matter from actors, for example, a distillery, need to collect it themselves. This could potentially become a problem if the source of the organic matter is too far from the farm, or if the quantity is important. This is a brake that will have to be studied once the most promising organic matter has been chosen. The potential levers could either be that farmers have to collect the biomass themselves or that transportation is organized by the actors detaining the biomass. Each solution has its advantages and disadvantages that will have to be studied.

II. Strengths, weaknesses, opportunities and threats of this sector

The creation of this SWOT analysis (figure 9) gives a general overview of the main strengths, weaknesses, opportunities, and threats identified during this study.

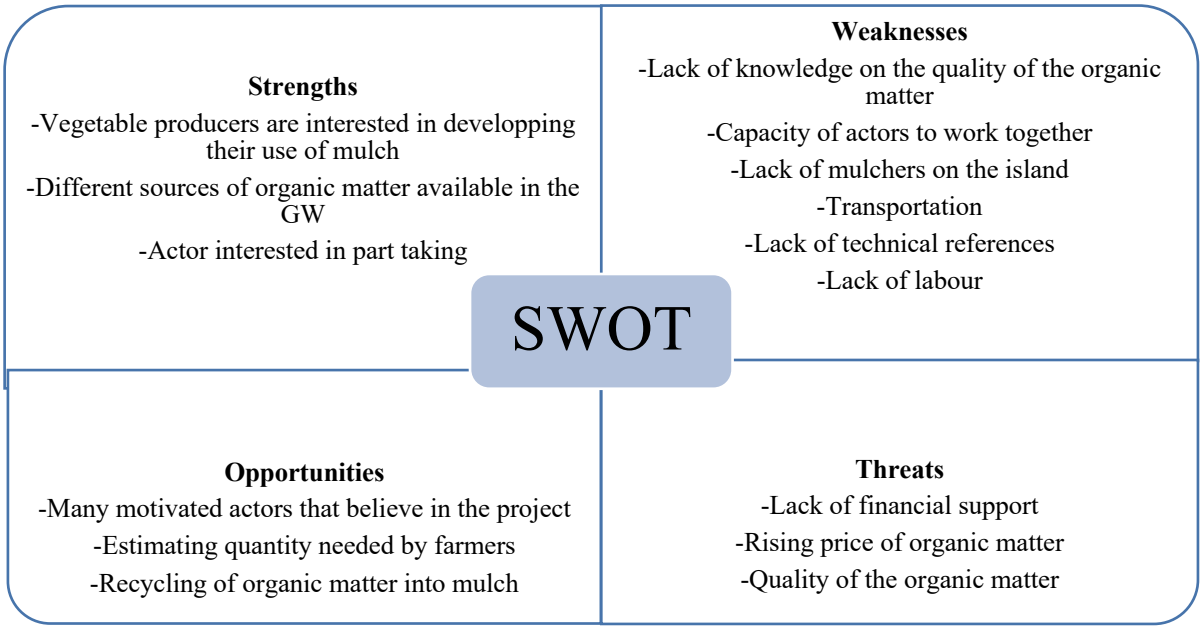

Figure 9: SWOT analysis of mulching sector

III. Reflection of study and methodology

1. Methodology limits

The choice concerning the methodology took some time at the beginning of the study, as this is an important decision leading the rest of the work. The steps of the socio-technical diagnosis were directly taken from Casagrande et al. (2021) written for the project. Other methodologies were previously used in La Reunion by Conrozier (2019) for the GABiR project and were used as inspiration for this study.

However, the difficulty linked to the recycling of organic matter is that this matter is often considered as waste by the actors who detain it, as it if often something they wish to get rid of. This does not lead to an accessibility problem, but mostly a problem when trying to quantify this matter. Indeed, the actors have a hard time quantifying the available matter. Therefore estimations were made to have an idea of the quantities, but in the next years it would be interesting to quantify in more detail the organic matter actually available for mulching. Additionally, estimations were made using information available in literature, but not necessarily in Martinique (e.g. for sugarcane crop residues), having more literature and studies on agriculture and agricultural practices in Martinique would be useful in order to have a more correct estimation.

2. Studied area limits

This study was focused on the Galion watershed, therefore we concentrated on the actors located inside the limits of the watershed, or slightly on the outskirts. Focusing on a relatively small part of the

island is interesting as it allows us to work on the local sources of organic matter and create a link between a restricted amount of actors. Local actions can emerge from reasoning on a small scale, which may not have been thought of on a larger scale.

However, as mentioned above, the GW is studied for different reasons, and the actors are often questioned on their practices and often solicited. During the interviews, the farmers mentioned that they were often questioned on their practices and on their thoughts but rarely received feedback and they do not benefit from the results of the studies. This is a shame as they invest time in the project and are not valorized in the end. A solution for this would be to organize project restitutions or meetings with the actors that were involved in order to share the outcomes of the studies and receive feedback.

Focusing on the GW also limits the possibilities for the sources of organic matter, indeed, some actors in possession of organic matter work in other parts of the island and could be a good source of organic mulch. Even if the borders of the watershed are not closed, there are limits to only considering a part on the island as it limits the territorial scale of a project.

An important challenge is to find an adapted scale for this mulching sector. Indeed, here we studied the sector in a watershed, but smaller scales such as farms or municipalities could have been done. Or larger scales such as the entire island. To choose the correct scale different factors must be taken into account such as economies of scale and environmental. The most agroecological way to function is to stay at farm level when possible, but if needed enlarge the sector to biomass situated around the farm.

3. Next steps for the project

Following this feasibility study, if there are funds to support this project, it would be interesting to create a space for the different actors to share their thoughts, advice and needs in a common space in order to create dialogue between the concerned actors. There are several known methods that help connect the diverse actors whilst helping them come to ideas or conclusions on certain projects. For example, serious games are growing rapidly in the field of academic research. These games allow users to experience situations that wouldn't happen in real life, in an entertaining yet productive way (Laamarti, Eid, Saddik 2014). This corresponds to the fifth step of the socio-technical diagnosis (Casagrande et al. 2021). The aim of this step is to share the obtained knowledge and results of the study and to identify the possible diverging ideas of the actors. This will help to identify conflicting views of the actors in order to know which problems or difficulties we may come across during the implementation of this mulching sector.

Parallelly, agronomists need to work on the selected sources of organic matter, in order to determine the quality and efficiency of the different types of biomass identified. An idea could be to set up experiments on farms to measure the different effects of using mulch, on the weed presence but also on the crop yield such as done in another project conducted by the CIRAD. Creating a table with

each organic matter, or each combination of mulches and their performance on the field (yield, weed inhibition capacity…) could be interesting to complete knowledge on the different mulches (Zangoueinejad, Alebrahim 2021).

Fifth part : Conclusion

The intent of this study was to identify the different sources of organic matter available in the GW, and to analyze if they were a plausible solution for the natural mulching sector. This was strongly linked to the research question which was to identify the brakes and levers to creating a mulching sector for vegetable producers thanks to available organic matter in the Galion watershed.

First, the vegetable farmers showed a real interest in mulching since weeding is an important and time-consuming task for them. They see mulch as a potential solution to improve their daily tasks. However, they have strong opinions on which organic matter they preferred or not use on their land. Their opinions are not always justified, however, some mental brakes can have an important impact on the farmers' decisions. Working with farmers on these brakes is essential to overcome some negative thoughts and accompany them in their change of practice.

For some organic matters, there is competition for use, as this is the case for bagasse, which has a variety of different functions (e.g. energy sector). The organic matter which is in competition with other uses may be harder to obtain and more costly than other types of biomass. On the contrary, some biomass is currently under-used, for example, wood mulch or sawdust, as it is still considered as waste by the companies who produce it. Therefore competition is present for some biomasses, but for other types, there is no competition as the biomass is not used. If the sector was to be developed, other competitions may emerge as the organic matter is more valorized.

The last assumption was about the quality of the organic matter and the fact that it couldn't be guaranteed. Indeed, the quality of the biomass is very important, as it can directly affect the crop and the soil it is applied on. It is hard to guarantee this biomass as it comes from different sectors, but efforts can be made to assure a certain traceability of the organic matter, therefore a certain quality. Efforts can include analysis of the organic matter, or having a better knowledge of the farm and farming practices from where the organic matter comes from. Experimenting with the mulches on the field and monitoring the different effects is produces will help assure the quality and that the desired effects are present on the field.

Mulches from other agricultural sectors seem complicated to be put in place, as all agricultural sectors need biomass in order to refuel their soil with organic matter and nutrients. Additionally, there is reluctance from vegetable farmers to work with other agricultural sectors, because of the types of production (monoculture vs diversified production) but also the types of practices (use of chemical products, contaminated land…).

The most promising type of biomass that could be used for mulch, in terms of quality and availability, is mulch coming from wood, sawdust, either from the private or public sector. Farmers have a lot of extra biomass on their land that could be mulched and used directly. There is no apprehension from farmers towards wood mulch coming from their own farm. The urban sector has a role to play in the development of this type of mulch, as it deals with an important quantity of trees

and wood, and could part take in the development of mulch for farmers. The quality of this matter still needs to be tested, as trees situated close by to roads could be polluted. The access to mulchers must also be taken into account if sawdust is chosen as mulch by farmers. Transportation of the matter will have to be organized to be efficient for farmers but also for those producing the sawdust.

Coconut crop residues could also be a source of biomass for mulch, however, this sector needs to be structured. When coconut production is more developed and less informal on the island, this source will likely become a plausible biomass to use as mulch, as it has interesting agronomic virtues, and was used by before in agriculture, so farmers are likely to want to adopt this practice.

The mulching sector needs to be structured and organized, but this can also be done by facilitating contact between vegetable farmers and municipalities or pruning companies with whom they can exchange directly. An external actor may be necessary to help create a dialogue between actors and part take in the organization of actors. Every farmer needs an adapted solution for his farm, his production, and his plot, considering the little number of vegetable farmers in the GW, it is possible to exchange with the farmers to find tailor-made solutions for them. Although this sector has potential, considering the size of the GW and how actors are used to working, individual or small-scale organizations will be the best solution today. However, if vegetable production was to develop in the coming years, a more structured sector may be needed to facilitate the exchanges of mulches.

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Appendices

Appendix 1: Table showing the key advantages and disadvantages of plastic, paper, and natural mulches

Type of mulch	Advantages	Disadvantages
Plastic	-higher yields -higher quality harvests -High efficiency against weeds (Tournebize, Kelemen, Sierra 2020) -Conservation of soil humidity and higher water-use efficiency (Bussière et al. 2011)	-Plastic often left in field after harvest leading to micro plastics accumulating in the soil (Qi et al. 2018) -Can cause excess humidity in the soil: this can slow root growth and encourages the development of diseases (Tournebize, Kelemen, Sierra 2020) -Heating on the surface leading to root necrosis (Tournebize, Kelemen, Sierra 2020; Bussière et al. 2011)
Paper	-Absence of pollutants in the paper used in Guadeloupe, so the paper can be buried in the field (Tournebize, Kelemen, Sierra 2020) -Paper has a complete and rapid degradation performance (Li et al. 2021; Tournebize et al. 2012) -Requires less labour than manual weeding (Tournebize, Kelemen, Sierra 2020) -Improved photosynthesis of the plant thanks to reflection on sun on paper (Tournebize, Kelemen, Sierra 2020) -Stays well in place even with high rainfalls (Tournebize, Kelemen, Sierra 2020)	-Development of nematodes in the soil harming production (Li et al. 2021) -Can get ripped, therefore may require more labour (Tournebize et al. 2012) -More expensive than plastic mulch (Tournebize et al. 2012) -Necessitates a change in agricultural practices for land preparation to apply the paper correctly (Bussière et al. 2011)
Natural	-Helps maintain soil organic matter because nutrients are released during its decomposition (Breton, Rey, Crosaz 2015) -Can be directly incorporated in the soil after use, saving on removal and disposal costs (Tournebize, Kelemen, Sierra 2020) -Improves crop growth and yield (Uwah 2011)	-Large quantities required (Tournebize, Kelemen, Sierra 2020) -Expensive transportation (Tournebize, Kelemen, Sierra 2020) -Rapid decomposition into the soil (Tournebize et al. 2012)

Appendix 2: Interview guide for farmers using mulch (Translated)

Interview guide for farmers using mulch

Name :
Location :
Date :

Context of the interview :
This interview is part of the project Ecophyto Interlude, financed by the French government, which aims to reduce the use of chemical products on the territory.
The aim of this analysis is to conduct a feasibility study on the mulching sector for vegetable produces, thanks to organic matter provided from elsewhere. The study will be conducted in Martinique, more specifically in the Galion watershed. To do so, we are questioning farmers on their usual use of mulch to understand their needs and experiences.

Description de l'exploitation :

Installation date	
Type of production (main and secondary) -vegetable production, fruit trees, sugarcane…	
Number of employees, help …	
Agricultural area	
Quality signs (organic, no chemicals…)	
Marketing methods (direct selling, markets…)	

On mulching :

What are your weeding methods ? (manual, herbivides…) How frequently do you use them ? How much time does it take ?	
Would you consider weeding as a problem on your farm ?	
How would you qualify weeding on your farm ? (Absent, weak, medium, high, very high)	
Do you use mulch ? Why?	
What type of mulch do you use ? (Plastic, crop residues, RCW…)	

What do you think of the effect of mulch on your crop production ? (On a scale of 1 to 5, 1 being none and 5 being the perfect effect) Why?	
What do you think of the effect of mulch on your crop yields ? (On a scale of 1 to 5, 1 being none and 5 being the perfect effect) Why?	
For how long have you been using mulch ? Why?	
Which crop productions do you use mulch on ? Why this choice ?	
How much mulch do you need?	
When in the year do you need it? When in the crop cycle do you use it? How frequently do you need mulch?	
How is the mulch applied on the field ?	
Has the use of mulch changed something in your agricultural practices ? (Time spent in the field, difficulty…) How and why ?	
Do you know of other types of mulches ?	
Have you tried other types of mulch?	
-if so : what did you think of them? Why did you choose your current mulch? What were the advantages or inconveniences of the other types of mulch?	
-if not : Why ? What were the main breaks to adopting new mulching practices ? (Access, transportation, habits…)	

Supply in mulch:

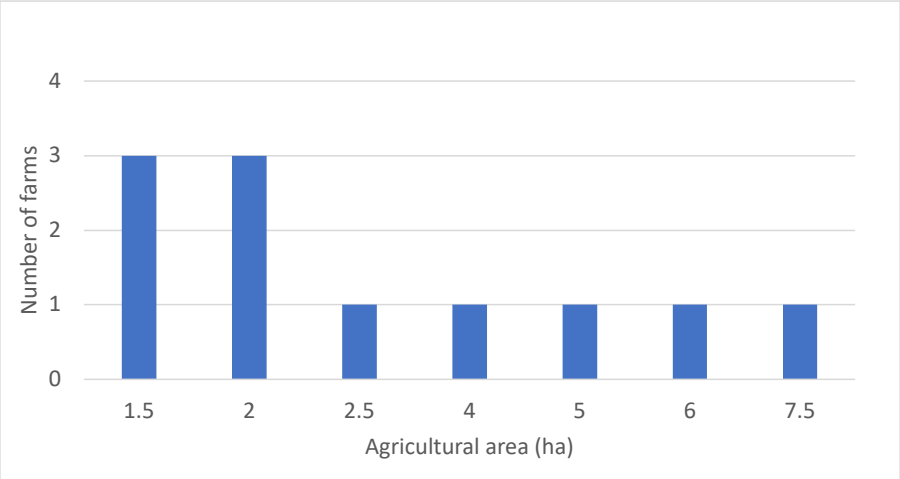
Where do you get the mulch from? How did you find this material ?	
Who do you get it from? How often ? What quantity do you receive?	
How is the material transported to you?	
Do you get this material for free ?	
Are you satisfied ? What could be improved?	
How did you create this partnership ?	

Interest in the project :

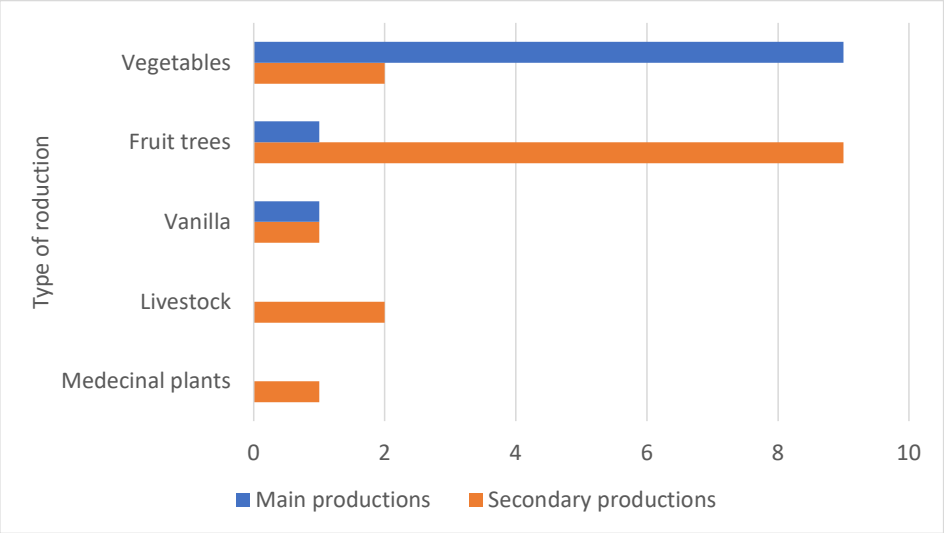
In this study, we are interested in knowing if a mulching sector could be put in place, and see if the sector is interesting from an agricultural and economical point of view. To do so, different organic matters will be studied to see what matter the farmers are interested in, and how this could be organized.

- Would you be interested to receive more organic matter? Do you have a need for this matter?
- Under what conditions can a partnership be imagined?
- Do you have any additional comments or ideas on the project?

Appendix 3: Description of the interviewed farms



Farm size of the interviewd farms



Main and secondary productions on the interviewed farms