Climate Resilience for Bay Oil

– An analysis of the bay oil industry in the Commonwealth of Dominica

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Environmental and Energy systems studies
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Sammandrag

Samväldet Dominica är en liten önation i de Små Antillerna i Västindien. Denna studie analyserar och sammanställer konsekvenser som de senaste stormarna och orkanerna haft på den lokalt traditionella industrin för lagerbladsolja. Syftet med rapporten var att identifiera Dominicas historiska och nuvarande position på marknaden, att identifiera faktorer som fortfarande påverkar produktionen i Dominica och att utvärdera vilken påverkan det har.

Studien genomfördes som en Minor Field Study, ett stipendium som finansieras av Sida. Data samlades in under en tio veckor lång fältstudie på plats i Dominica, i samarbete med Climate Resilience Execution Agency for Dominica, CREAD. Information hämtades även genom artiklar i vetenskapliga rapporter, sökningar på internet, lokala rapporter och dokument inom jordbrukssektorn, intervjuer med nyckelpersoner och studiebesök.

Enligt resultatet från studien har stormar och orkaner under de senaste åren haft en stor inverkan på industrin genom att störa och avbryta flera viktiga steg och komponenter i sektorn. Just nu återhämtar sig sektorn, men en av de största utmaningarna är att öka andelen av produktens värde som når producenterna och att återskapa en stabilitet på global marknad för att säkerställa framtida efterfrågan.

Nyckelord

Lagerblad, Lagerbladsolja, Bay Rum, Pimenta racemosa, Eterisk olja, Dominica, Samväldet Dominica, Karibien, Västindien, Små Antillera, Klimatförändringar, Extremt Väder, Orkan, Orkanen Maria, Tropiska Stormen Erika, Hantverksmässiga Destillerier, Ångdestillering.

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Abstract

The Commonwealth of Dominica is a small island nation, located in the Lesser Antilles of the West Indies. This study analyses the effects from recent storms and hurricanes on the traditional industry of bay oil production in the country. The aim is to find Dominica's historic and current position on the market, find factors currently affecting the production in Dominica and evaluate these effects on the production capacity.

The study is done as a Minor Field Study which is a scholarship funded by the Swedish International Development Agency, Sida. Data was collected during 10 weeks in Dominica, in collaboration with the Climate Resilience Execution Agency for Dominica, CREAD. Information was gathered through scientific articles, internet research, research in local reports on agricultural production, interviews with key stakeholders and field trips.

It was found that the recent storms have had a major impact on the industry, damaging several steps in the supply chain. However, the industry is starting to recover. One of the major challenges is to increase the value of the product to reach the producers, and to regain a stability on the market to ensure future demand.

Keywords

Bay, Bay Oil, Bay Rum, Pimenta racemosa, Essential Oil, Dominica, Commonwealth of Dominica, Caribbean, Climate Change, Extreme Weather, Hurricane, Hurricane Maria, Tropical Storm Erika, Artisanal Distilleries, Steam Distillation

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Preface

This study is a Master Thesis written at Lund University, at the Department of Technology and Society the division of Environmental and Energy Systems Studies. It is a Minor Field Study, funded through a scholarship from the Swedish International Development Agency. The study was conducted between September in 2019 and in January 2020, of which 10 weeks were spent in the Commonwealth of Dominica.

The content of this report is focusing on mainly two perspectives. Firstly, it is a story and analysis of what is likely the impacts of climate change on a productive industry and how it completely can change the conditions within this industry operates. Secondly, it is an original research of an industry that has existed for almost a century and yet very little is publicly known or previously documented. The result of the report gives an overview of the current status of the industry, as well as evaluating future opportunities.

I would like to thank my mentor Lars J. Nilsson, for giving me great advices from across the Atlantic or even further away. Thank you for providing quick and concise feedback in your busy schedule. I would also like to thank the staff at the Climate Resilience Execution Agency, especially Pepukaye Bardouille, Belinda Charles, Brent Barnette, Nadia Pacquette-Anselm and Elijah Leblanc. Thank you for your warm welcoming to Dominica and your office, for teaching me about Dominica and taking your time to help me with this study, without you the study would not have been possible. I hope this report will be useful in your work. I am also thankful for the opportunity to go to Dominica, it has given me new knowledge, humbleness and perspective on the world to bring with me.

Table of Content

1. Introduction

The Commonwealth of Dominica is a small island nation located in the Lesser Antilles of the Caribbean. The country has a challenging topography for building and construction and it is one of the most exposed areas in the world to natural disasters including volcanic activity, frequent earthquakes, unstable soils prone to landslides, flash floods and hurricanes.

Dominica is a developing country, and industrial activity has been limited while agricultural products historically has been the most important part of the country's economy. One of these products is bay oil, an essential oil with a long history and cultural value in Dominica. Bay oil is produced through steam distillation of the leaves and the twigs from the tree *Pimenta racemosa*. Like other essential oils, bay oil has a strong fragrance and supposed medical properties. It is used for a variety of purposes such as cosmetics, perfumes, food additive, medicine and aromatherapy. The production of bay oil has a strong connection to farming traditions, as well as being the main ingredient in bay rum, an appreciated local all-purpose ointment and aftershave product. It is also said to be bug repellent which makes it applicable in mosquito repellent products.

As will be described later in the report, hurricane Maria completely destroyed the country during the hurricane season of 2017. In the aftermath of the devastation, people lost jobs and livelihoods and restoration of homes, water and electricity supply is still ongoing projects. The increase of intensity and frequency of the hurricanes is likely to be due to climate change, and after Maria the honourable Prime Minister of the Commonwealth initiated the founding of the Climate Resilience Execution Agency for Dominica, CREAD, to lead and coordinate the reconstruction of the island. This project was executed in collaboration with CREAD. Hurricane Maria had a severe impact on the bay industry and the production in 2018 is believed to have been negligibly small. However, the production has dwindled continuously during the last decade, mainly due to tropical storm Erika in 2015 destroying the industrial as well as several artisanal distilleries and the fungal infestation of Guava Rust on trees in 2008.

Due to the scarcity of bay oil on the global market the price of bay oil has escalated to increase at least four times in four years. Many buyers claim that the insecure market during the last decade have made them either change their recipes or replace the product. Meanwhile in Dominica, production has slowly restarted in a few reconstructed artisanal distilleries but farmers are still being paid minimum wage for their oil.

1.1. Aim and objective

The aim of this report is to conduct an assessment of Dominica's capacity of restoring the bay oil production at an economically feasible level, and provide suggestions on how to achieve that capacity. To do this, it is vital to understand what has happened in the bay oil industry in the country and on a global level, as well as to assess Dominica's position on this market. This includes to answer the following research questions:

- Analyse and map Dominica's historic and current bay oil market position
- Identify factors and limitation currently affecting the bay oil production in Dominica.
- Conduct an estimation for future production capacity based on an assessment of the effect of factors and limitations, such as acreages, distillery capacity and labour.

This report is limited to only manage essential oil from the species *Pimenta racemosa* var. *racemosa* P. Miller (J.W. Moore), although acknowledging that other essential oils may be, or could be produced in Dominica. Further acknowledging that "bay" can refer to a variety of species, the word "bay" in this report solely refers to *P. racemosa*, unless otherwise specified, see appendix 9.1.

2. Method

2.1. The plan

This thesis was conducted as a minor field study in Dominica. A so-called mixed method approach was used, consisting mainly of two parts: a quantitative and a qualitative research. Gathering of information constituted the qualitative research and includes studying written sources, making field visits and interviews. The information gathered through these activities has been analysed and compiled in a quantitative part of the study using the Michael Porter value chain model and making an assessment of production capacity.

The information is presented in a way that is meant to be adapted to Dominican, Swedish and other international readers, hence units are presented in both the metric and the imperial unit systems. Some information that may be trivial to some readers, can be important to others.

2.2. Gathering of information

Gathering of information can be divided into further categories: finding and studying scientific articles and reports made by stakeholders in Dominica, internet research, semi structured interviews with different stakeholders in the sector and field visits.

2.2.1 Written sources

There are few scientific articles on bay oil publicly available, and information in reports and other sources usually deviates or incomplete. Because of this, a variety of less credible internet sources has been used to try and fill in these gaps, and a considerable amount of time was spent on evaluating the reliability of information. This was made in an effort to illustrate the lack of scientific records and statistics.

Search on essential oils, bay oil, *Pimenta racemosa* and climate change in the Caribbean on LUB-search: generated 10 articles about *P. racemosa*, one about essential oils market, one on essential oils production.

Information was also found on the Dominica Government webpage and some documents were provided straight by key stakeholders, this is accounted for in the Reference chapter and in the Appendix.

The credibility was valued gradually as more information was gathered, the content was evaluated based on how well it coincided with other sources, e.g., sources with highly deviating information was either neglected or presented as an alternative explanation.

2.2.2. Semi structured interviews

Interviews were conducted with various key stakeholders in the sector, this part of information gathering constitutes the most important information, as well as giving the major share of information. There were a number of challenges in this step, such as booking meetings with the right people, language and cultural barriers, and the fact that the bay oil industry and essential oils overall is a secretive and sensitive area. Recording of the interviews was mostly rejected, hence they were documented with a notebook and pen. Further complications were a reluctance from both producers and buyers to provide certain information, such as how bay oil leaves Dominica and the path to reach final customers. To

respect and protect the integrity of the people interviewed, anonymous sources are used. The total number of people interviewed is 25.

In the research, seven farmers were interviewed, they were selected randomly based on who were present during the field visits.

They were asked questions such as:

- Why they became farmers and what it is like?
- What they experience as opportunities and challenges?
- How much and how often they produce bay oil, as well as how they operate the process and maintain their fields?

From the local key stakeholders or other knowledgeable sources, 10 people were interviewed, some were interviewed several times. Representatives from the following organisations were interviewed:

DEOSC - Dominica Essential Oil and Spices Cooperative: 1
DEXIA - Dominica Export and Import Agency: 1
Cooperative Division: 1
Ministry of Agriculture: 3
Ministry of Commerse: 1
United Nations Development Program: 1
Shillingford Estate LTD: 1
Wild Dominique: 1

They were asked questions such as:

- What is their perspective on challenges and opportunities for the bay oil sector?
- What is the history of the sector?
- What has been done and what is currently done within their organization to develop the sector?
- What is their vision for the future?

By the end of the minor field study, the same representatives from the mentioned organisations were invited for a discussion workshop. The following representatives were present:

- Ministry of Agriculture (1)
- Ministry of Commerce (1)
- The Dominican Essential Oils and Spices Cooperative, DEOSC (4)
- The Dominica Export and Import Agency, Dexia (1)

Three people of the CREAD staff were also present, and the author of this report.

From the global market 21 companies were found to have bay oil on their list of products, they were contacted.

The companies contacted were:
Anhui Haibei
Augustus oil LTD
Berjé

Citrus & Allied
Coal Pot
De Monchy Aromatics
Excellentia
Firmenich
Fleurchem
Floral Concept
The George Uhe Company
Heaven Scent
Hermitage Oils
Jollys Pharmacy
Mountain Crafted
Robertet
Ultra International
Ventos
Venus Enterprises
Lush
CPL Aromas.

Of these companies, eight representatives volunteered to answer questions such as:

- How does your company/organisation perceive the current and future demand for bay oil?
- What do you see as the most important factors when evaluating e.g. quality, origin, shipping of bay oil?
- What and how would you like to improve on the market?

Further information on the bay oil industry was provided by experts in agriculture and economy at the CREAD. Other expert sources were a phone conversation with an assistant professor at the University of Virginia, and an email conversation with a PhD graduate at the University of Los Andes.

2.2.3. Field Visits

Three field visits to bay tree fields, artisanal distilleries and other key locations were made. The field visits were documented through photography, videos, notebook and Google Maps. The result of field visits is shown in appendix 9.4. A majority of interviews with farmers and some key stakeholders were made during the field visits.

2.3. Approach

2.3.1. Michael Porter value chain

To identify the different steps and activities of the industry, a Michael Porter value chain was applied in the beginning of the studies. A value chain is a tool normally used to analyse a company or organisation's production system. More specifically, Michael Porter value chain analyses the activities of a company or organization, where the primary activities analysed are inbound logistics, operations, outbound logistics, marketing, sales and service. The second segment is constituted by so called support activities. Infrastructure, Human Resources, Technology Development and Procurement, are analysed to further improve the primary activities (Harvard Business School). The bay oil industry is however not a company or an

organisation, it is a sector, hence the layout of the traditional Michael Porter value chain needed some adaptation (Barnette, 2019), see Figure 1.

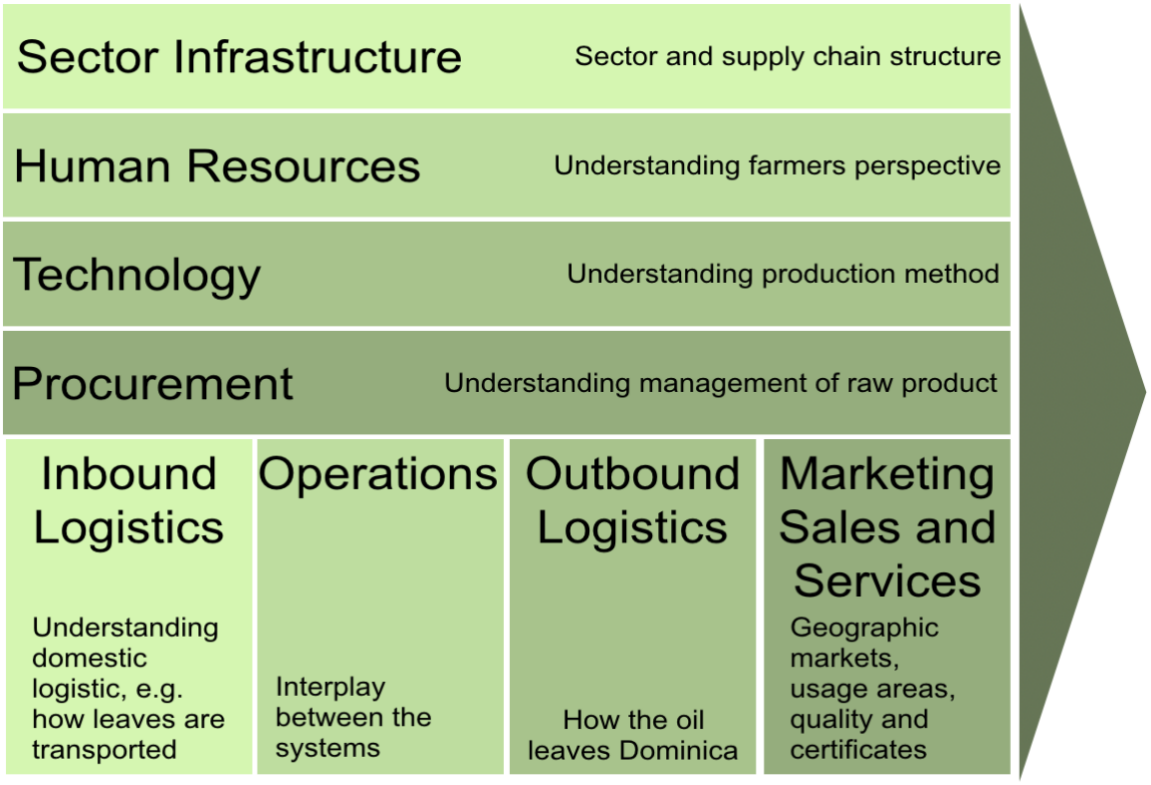

Figure 1: Michael Porter value chain adapted to analyse the bay oil sector in Dominica (Harvard Business School, Barnette 2019).

The firm infrastructure was exchanged to sector infrastructure, to understand the sector and supply chain structure. Human resource management focused on understanding the situation for bay oil farmers and what incitements there are to work with bay oil production. Technology was interpreted as the technique and method with which bay oil is produced in Dominica. Procurement was considered as to understand the raw product, in this case the leaves of the trees. For the secondary activities, inbound logistics was considered as how the domestic logistics works, such as transport of leaves from fields to distilleries. Operations was considered to understand the interplay between the different systems, while outbound logistics was interpreted as how the oil leaves Dominica. Marketing and sales were considered as identifying the market geographically, possible applications for the final product while service was used to understand what kind of certificates and qualities are necessary.

These features will all be discussed in the report in a historical and technical order to understand the main bottlenecks for the production. Three key factors were identified: amount of productive acreages on the island, the distillation capacity and human resources.

2.3.2. Assessment of production capacity

From the Michael Porter value chain, three main activities were identified as the most important bottlenecks for production capacity. These activities are *Procurement*, i.e. the availability of raw material, *Technology*, i.e. the capacity of the distilleries and *Human Resource management*, i.e. labour availability. In this chapter, equations on how to make estimations for these three capacities are derived.

The theoretical amount of oil that can be produced annually ($w_{tot\ oil}$) determined by available trees is given by the number of times a year that harvest can be done ($n_{harvest}$), the weight of leaves collected from one tree (w_{leaves}/tree), number of trees per area (n_{trees}) and total area (a_{tot}), and finally the weight to weight ratio of oil content in the leaves (w_{oil}/w_{leaves}).

$$number\ of\ harvest\ occasions\ per\ year \times weight\ of\ leaves\ per\ tree \times trees\ per\ area \times total\ area\ available \times w/w\ oil\ content = total\ oil\ production\ capacity\ per\ year$$

Or

1) $$n_{harvest} \times \frac{w_{leaves}}{tree} \times n_{trees} \times a_{total} \times \frac{w_{oil}}{w_{leaves}} = w_{tot\ oil\ t}$$

However, weight of leaves per tree is difficult to give a fair estimation, a simpler estimation is instead weight of leaves per area (w_{leaves}/a).

$$number\ of\ harvest\ occasions\ per\ year \times weight\ of\ leaves\ per\ area \times total\ area\ available \times w/w\ oil\ content = total\ oil\ production\ capacity\ per\ year$$

Or

2) $$n_{harvest} \times \frac{w_{leaves}}{a} \times a_{total} \times \frac{w_{oil}}{w_{leaves}} = w_{tot\ oil\ t}$$

However, the volume of leaves that can be gathered most likely varies depending on seasonal and annual fluctuations as well as geographically, topographically and genetic differences. Also, the density of trees per area can vary. Another method to estimate the production capacity is by directly taking the estimated oil yield per area.

$$number\ of\ harvest\ occasions\ per\ year \times oil\ yield\ per\ tree\ area \times total\ area\ available = total\ oil\ production\ capacity\ per\ year$$

Or

3) $$n_{harvest} \times \frac{w_{oil}}{a} \times a_{total} = w_{tot\ oil\ t}$$

As previously described, the total oil production capacity is also determined by distillation capacity and availability. This is given by the number of distilleries available ($n_{distilleries}$), their average production capacity per day (w_{oil}/d), and the annual number of days they are used (d_{tot}).

$$number\ of\ distilleries \times average\ production\ capacity \times annual\ number\ of\ days\ available = \text{total oil production capacity per year}$$

Or

4) $$n_{distilleries} \times \frac{w_{oil}}{d} \times d_{tot} = w_{tot\ oil\ d}$$

The average production capacity is measured in the local unit bottles or whiskey bottles (b) per batch (B),

$$oil\ per\ bottle\ \times bottles\ per\ batch \times batches\ per\ day = average\ production\ capacity\ per\ day$$

Or

5) $\frac{w_{oil}}{b} \times \frac{b}{B} \times \frac{B}{d} = \frac{w_{oil}}{d}$

The third basic factor for production depends on labour availability. One way of describing this is to use the number of farmers ($n_{farmers}$) and annual working days (d_{tot}) in relation to how much oil that can be produced by one worker in one day (w_{oil}).

$$number\ of\ farmers \times annual\ working\ days \times amount\ produced\ by\ one\ worker\ in\ a\ day = total\ oil\ production\ capacity\ per\ year$$

Or

6) $n_{farmers} \times d_{tot} \times \frac{w_{oil}}{d} = w_{tot\ oil\ f}$

How much oil that can be produced in a day is limited by how long time it takes to gather enough leaves for one batch in addition to the time the distillation requires.

$$(days\ to\ gather\ leaves + days\ for\ distillation) = days\ to\ make\ one\ batch$$

Or

7) $d_{leaves} + d_{distillation} = d_{batch}$

Where d_{leaves} is the time required to gather enough leaves for 1 batch, $d_{distillation}$ is the time required to distillate 1 batch, while d_{batch} is the total time for one worker to make 1 batch of bay oil. This can further be used to determine how many batches that can be produced in a year by one farmer.

$$\frac{annual\ working\ days}{days\ to\ make\ one\ batch} = total\ amount\ of\ batches$$

Or

8) $\frac{d_{tot}}{d_{batch}} = B_{tot}$

The total amount of bay oil that can be produced in a year is thus given by

$$number\ of\ farmers \times total\ amount\ of\ batches \times oil\ per\ batch = total\ oil\ production\ capacity\ per\ year$$

Or

9) $n_{farmers} \times B_{tot} \times \frac{w_{oil}}{B} = w_{tot\ oil\ f}$

A pay-off analysis is presented in chapter 5.2. Costs. The pay-off method is used to estimate the time it takes to pay off an investment. Usually, less than three years is considered a good investment, but for larger investments more time can be acceptable. (Barnette 2019)

These equations will later be used to make estimations on the production capacity of bay oil in Dominica.

2.3.3. Transfer of units

Both the metric system and the imperial system is used in this report, the conversions were made with the numbers from Table 1.

Table 1: The conversion between standard units has been made using the following conversion values

Unit Standard System	**Metric**	**Imperial**	**Local Standards**
Volume	1 litre	0.26 gallons	-
	119 litres	1 barrel	-
	0.75 litre	0.195 gallons	1 bottle
Distance	1 meter	3.28 feet	-
	1 cm	0.39 inches	-
Weight	1 kg	2.2 lbs	-
Area	1 hectare	2.47 acres	-

Cost conversions are made with the conversion rate EC$ 1= US$ 0.37, and 1 EC$/lbs = 0.81 US$/kg.

2.3.4. Illustrations

All figures are illustrated by or photographed by the author unless otherwise specified.

3. Background

3.1. Dominica

3.1.1. Country Profile

The Commonwealth of Dominica is a small island country located in the Lesser Antilles of the Caribbean, see Figure 2. The island is approximately 290 sq. miles (750 km2) and has a very mountainous topography. Dominica is covered with lush rainforests and has rich assets of renewable energy sources, such as geothermal power, hydropower and wind. The annual precipitation is rich with an average of 78 inches (2,000 mm), although varying between the coasts and the mountainous inland. February to April is generally drier while July to November normally is rainier, with higher risk of tropical storms and hurricanes between August and October (Bardouille 2019).

About 90% of the approximated 73,000 people live in the coastal areas, and the capital city Roseau is located on the south-west coast (Government of the Commonwealth of Dominica, 2017 B).

The island is believed to have been populated by a people called the Arawaks, who were later driven out by the indigenous Carib people, also called Kalinago. Columbus first saw the island in 1493, and the Spanish were the first to attempt making a colony. However, Dominican terrain made it difficult to control and because of the European settlements on other islands, indigenous people fled to Dominica and pushed the Spanish out. The French and British also took turns in efforts of colonizing the island and during that time they brought in slaves from Africa. Dominica eventually became British in 1896, gradually establishing English as the official language although many still speak French Creole as their mother tongue. Dominica was finally granted independence in 1978 (Honychurch 1995). Today the people of Dominica are mainly of African and African/European heritage, with European, Syrian and Indigenous minorities (Government of the Commonwealth of Dominica, 2017 B).

Figure 2: Map of Dominica, (Government of Dominica, 2020). The island is located in the Lesser Antilles of the Caribbean, between the Caribbean Sea and the Atlantic Ocean. Capital Roseau is located on the South-West coast. Main focus of this study is located to the East, South-East and South coastal regions, St. David, St Patrick and St Mark.

3.1.2. Economy

The economy of Dominica has traditionally been based on agriculture, particularly bananas (The Commonwealth, 2020). However, today the main source of income to the country is Citizen By Investment Programmes, CBIP, while agriculture, industry and tourism are smaller but also important parts of the economy (Government of the Commonwealth of Dominica, 2018).

The average wage in Dominica was EC$ 1,500 (US$ 555) per month in 2015(Dominica Vibes News, 2015), while the minimum wage in 2015 was EC$ 4.0 (US$ 1.5) per hour, equal to just below EC$ 700 (US$ 260) per month. Another source provide a similar number, the average net wage after tax is EC$ 1,018 (US$377) (Numbeo, 2019). It should further be mentioned that living expenses in comparison to income is very high, see table 13.1 in Appendix 13.1.

Poverty is widespread, showing 28.8% in the most recent report of 2009. The unemployment levels in Dominica were approximately 13.9% in 2008. Improved access to services and widespread economic growth would not be sufficient to move people out of poverty, both social and economic improvements are necessary to counteract the poverty (Government of the Commonwealth of Dominica (B) (2017)).

3.1.3. Natural Disasters and Climate Resilience

Dominica is located on one of the most vulnerable places on earth for natural disasters, the area is especially exposed to tropical cyclones. Beyond causing harm to thousands of people, the exposed countries of the Caribbean suffer from extensive annual economic loss and development inhibition due to this exposure (Acevedo 2016). Furthermore, there are nine active volcanoes in Dominica, and geologic activity cause frequent earthquakes (The University of the West Indies, 2011). According to the Government of the Commonwealth of Dominica (A) (2017), the change in the climate system of Dominica is already noticeable, with increases of frequency and intensity of rainfalls due to higher sea temperatures. Intense rainfall often lead to flash floods and landslides, which is what causes most casualties and harm to the infrastructure.

In 2015, tropical storm Erika caused severe damage on the east coast of the island. Only two years later, in 2017, the island was hit by two hurricanes during the same hurricane season which had a severe impact on the whole island. The hurricanes are known as Irma and Maria, of which the latter was most severe, classified as a Category 5 hurricane with devastating effects. At least 64 people were declared dead or missing and the value of damaged assets were estimated to approximately 226 % of 2016 GDP, or US$ 931 million in total damages and US$382 million in losses (Government of the Commonwealth of Dominica, 2017 A). Prime Minister Roosevelt Skerrit declared Dominica an international humanitarian emergency a few days later when addressing the United Nations in a speech. He also stated that Dominica must become the first climate resilient country in the world due to climate changes that will enhance the frequency and severity of extreme weather events (Government of the Commonwealth of Dominica, 2017 B).

3.1.4. CREAD

The Climate Resilient Execution Agency for Dominica, CREAD, was established in the aftermath of hurricane Maria in 2017. Their mission is to lead and coordinate the navigation of reconstruction. It is a statutory governmental agency and they are responsible for realizing

the goal of becoming resilient through strategic guiding on what resilience is and how to achieve it for organisations within governmental and private sectors. This report is written with assistance from CREAD to contact key stakeholders.

3.2. Essential oils

Bay oil is one of about 70 different types of essential oils found on the global market with a wide range of usage areas. Differentiated from vegetable or petroleum oils, essential oils usually consists of several different hydrophobic and aromatic compounds, such as phenols and terpenes. Hence, they are known for having a distinct fragrance, and they can be derived from a number of different plants. Essential oils are appreciated food additives, as described in section 4.2.2.1. and they usually have a high pharmaceutical value, see section 4.2.2.2. Most commonly, essential oils are appreciated for their scent, they are used in perfumes, soaps, lotions and other cosmetics, see section 4.2.2.3. (Kusuma et al 2018). Essential oils are also considered to affect the mood and spirit, hence they are popular in aromatherapy, described in section 4.2.2.4.

The main use for essential oils can thus be divided into food, cosmetics and perfumes, health and medicine and aromatherapy. The production of bay oil in Dominica was identified by CREAD as a high value commodity, and with the potential to be an important source of revenue to the country. Beyond being a valuable product, it is an important part of the Dominican culture, with a long history and tradition among farmers. Furthermore, Dominica has a unique position and leverage of being the world's largest supplier of bay oil.

Because of the many areas of usefulness of essential oils their popularity and demand is increasing. According to Yan et al (2019) this is especially due to the aromatherapy characteristics of essential oils, about 70% of the market share is held by spas and therapists. This, in combination with "*the trend of the generation X and millennials for body health and awareness of the benefits in natural medicine*", is forecasted to generate a value of essential oils on the global market to reach a total of US$ 3,226.2 Million by 2025. Today, the largest producers, consumers and exporters of essential oils in the world are the USA, India and China, and the essential oil of highest demand is citrus oil.

The market for bay oil is to a large extent not certain, however it is believed that the traditional market for bay oil is limited to mainly North America and Europe, and to a smaller extent to South America and the West Indies. The global demand, supply and trading routes of bay oil are also not certain and will be discussed further into the report.

3.3. Historic Overview

Little is known about the start of bay oil production. Supposedly a priest from Germany encouraged people in the south-east areas of the island to build artisanal distilleries and export bay oil in the beginning or the middle of the 20th century (Interview with stakeholder). Investments in propagation were made and it was estimated that Dominica had about 1,000 acres (404 ha) of bay in the 70s. Today it has become a traditional profession, and Dominica has held a major production role on the global market for bay oil, holding up to 85% of global market share (Cooperatives Development Division, 2018).

Founded in 1968, the Dominica Essential Oil & Spices Cooperative, also known as DEOSC is the largest actor within bay oil on the island. It is a cooperative among farmers and distillers, with 562 alleged members of which 250 were active members before Erika in 2015. To become a member, it is required to own at least 0.25 acres (0.1 ha) of bay trees, the person must also pay an entrance fee and purchase at least 5 shares, although more could be bought afterwards. It is not possible to withdraw or exit the membership, and memberships are inherited by descendants.

Shillingford Estate's is another key actor on the market in Dominica. It is a private company with a few acres of bay trees and a distillery, although other crops are in focus. Before tropical storm Erika in 2015, the company produced their own oil from the bay trees and other producers could rent the distillery for a fee.

In the first decade of the 21st century, the bay industry in Dominica consisted of approximately 30-50 artisanal distilleries and 1 industrial distillery (Interview with stakeholders, Ministry of Agriculture, Food and Fisheries 2015, Ministry of Agriculture, Food and Fisheries 2009). According to the Ministry of Agriculture 2009, there were about 733 acres (297 ha) of bay in Dominica in 2009 but an exact number of available manpower in the country is not known. During the last decade the industry has faced several difficulties, resulting in decreased production since the middle of the 00s.

In 2008, Guava Rust infestation, decreased productivity with about 30% (Ministry of Agriculture, food and Fisheries, 2015). The disease is caused by *Puccinia psidii*, a pathogenic fungus infecting plants within the myrtle family. The disease causes deformation of leaves, shoots and sometimes flowers and fruits as well. The disease is known to cause defoliation, which may severely weaken the tree or even kill young individual trees if attacked repeatedly. Areas where fog or heavy dew occurs frequently are more exposed to the disease (Wardini 2016). Farmers used pesticides to control the spreading of the disease (Pacquett-Anselm, 2019). The pesticides did not work and are not used anymore, although the disease is still present on the island (Interview with stakeholder).

In 2015 the industrial distillery in the village of Petite Savanne, owned by the DEOSC, was destroyed in tropical storm Erika. As seen in Figure 3, the distillery was located below a hillside and beside a river, which flushed the whole distillery including equipment to the ocean after the heavy rainfall from Erika. Landslides also damaged bay tree groves, although it is unknown to what extent. It is believed that about nine artisanal distilleries were severely damaged or destroyed. Beyond material losses, there were several casualties including staff, members and directors of the DEOSC (DEOSC 2015).

Figure 3: The site of the former industrial distillery, everything was washed into the ocean in Tropical Storm Erika in 2015, now there is no trace of it.

Petite Savanne was the main bay producing village, holding about 260 acres (105 ha) of bay trees. As large parts of the village were destroyed, it was later declared to be a hazardous zone by the government. The village is now officially abandoned and electricity, water and roads to the village has not been rebuilt and loans or insurances for investments in Petite Savanne are not allowed. The former residents have been provided with new homes by the government and many have been relocated to Belle Vue Chopin, dispersing the community. During the time after Erika, efforts were made to rebound from the destructions, such as the planning of a new industrial distillery and reconstruction of artisanal distilleries (Field visit to Petite Savanne, 17-10-2019). Two artisanal distilleries were rebuilt.

There are plans to build a new industrial distillery in the Geneva Area, located between Berekua and Fond St. Jean, see Figure 2. According to the DEOSC, constructing a new industrial distillery is the most important aspect of regaining Dominica's bay oil production.

Only two years later, in 2017, hurricanes Irma and Maria made severe damage to the whole island and several reconstruction projects were setback as a result. While it seems safe to say all distilleries were damaged or completely destroyed in this hurricane, it is unknown exactly how this affected the bay trees. Some productive areas were lost to landslides damaging the groves or the access to the groves. According to some people, a lot of trees died due to changes in the surrounding environment while other sources state that the trees are resilient and were ready for harvest six months after the hurricane.

4. Mapping of the supply chain

4.1. Overview of the Supply chain

This section provides an overview of the activities in the bay oil production process. The details around the practices of bay oil production may vary among farmers from different communities. However, the full process can be generalized to include procurement of raw material (propagation, maintaining fields, harvesting leaves from trees), transporting the leaves to the distillery, transport wood fuel to the distillery, distillation and transport to internal or external markets. This is illustrated in Figure 4, where the key factors in this supply chain are propagation, distillation and human resources, which will be presented in this chapter.

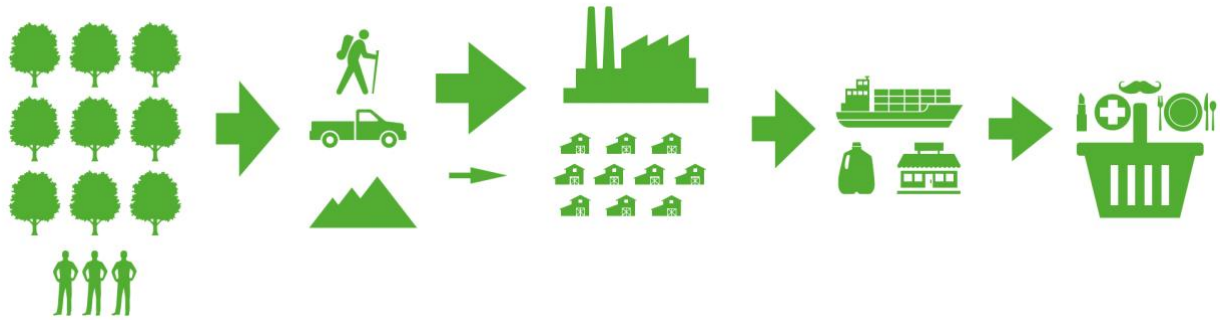

Figure 4: Illustration of the supply chain for producing bay oil. The first step is harvesting the leaves, they are then transported to distilleries and then to local or international buyers. The last step are the final products reaching customers.

4.1.1. Procurement of raw material

Bay oil is produced from steam distillation of the leaves of *P. racemosa*. It is a tree native to the Caribbean area reaching a maximum height of about 50 ft (15 m), although its usual height is 16-33 ft (5-10m). The trunk can be up to about 2 ft (6 dm) in diameter. It sometimes has a shrubby shape with angular and glandular twigs. The leaves are elliptic, oblong-elliptic, or obovate with a rounded tip, about 2-6 inch (5-15 cm) long. The color is bright green and finely veined and reticulated on both sides, they are quite thick and have a distinct scent. (Childers et al, 1945)

Bay trees are known to be survive harsh conditions. Preferring an elevation of up to 2,500 feet (750 m), *P. racemosa* is well suited for the challenging terrain and environmental surroundings in Dominica, very well known for its mountainous topography. The preferred temperature range is between 22-28°C, although 18-32°C and even very light frost is acceptable if briefly exposed. Bay trees prefer a precipitation of about 55-78 inches (1,400-2,000 mm) annually, although it can even tolerate 27-109 inches (700-2,800mm). The precipitation should be at least 50-60 inches (1,250-1,500 mm) annually for optimal regrowth after pruning. The adult trees prefer sunny locations. (Wardini 2016; Fern 2019; Childers et al 1945)

Bay trees prefer well-drained, deep, fertile and loamy soils with slightly acid to neutral pH (4.5-7). The trees are however mostly grown on marginal soils and slopes, to allow food crop access to the best soils (Wardini 2016, Fern 2019). A few farmers mentioned liming as part of their field maintenance.

After two to three years, the trees are topped at 9.8-16.4 feet (3 - 5 m) and maintained at that height. Bay trees coppice well and form rhizomes, misshapen or diseased trees can be cut back to ground level, allowing a new shoot to grow from the stump. As trees can regenerate from stumps, it is difficult to establish the life time of bay trees, but individual trees of 50 years are known in Puerto Rico (Childers et al 1945). In Dominica the trees are generally older and some say the trees live forever (Key stakeholder interview).

Figure 5: A bay tree growing by the side of the road.

The trees should be at least five years old before being harvested (Mercola 2015; Key Stakeholder interview). Leaves can be gathered once a year, all year around although maximum yield is achieved during the dry season in March to June, when the leaves supposedly contains a higher amount of oil. Small twigs and leaves can be picked by hand but where labour costs are higher larger branches can be cut and taken to the distillery to separate leaves from the branches by machines (Wardini, 2016).

In Dominica, leaves are harvested using two methods. Breaking means that twigs are pulled manually from the trees, or they can be cut off with a machete. Breaking the leaves rather than using a machete is said to be the best alternative for refoliation of leaves. In the old days, the leaves were separated from the twigs before distillation but today the conventional method is to distill the leaves along with the twigs. Exceptions were encountered during field visits, but according to one buyer, oil distilled with only leaves is of lower quality due to lack of an essential compound. It is not known which compound the source referred to.

4.1.1.1. Present Conditions

Today, the amount of productive acreages in Dominica is unknown, this chapter aims to compile different sources to give an estimation of how many acreages there might be. The last part of the chapter concerns the age and rejuvenation of trees.

Bay trees grow in the wild all over Dominica and can be found in forests and by the side of the roads, see Figure 5. They are also found in fields, especially in the South-East regions, see Figure 6. Maintenance of the fields vary between different areas but usually, fields are maintained twice a year for cutting the weed down, using manual or machine grass cutters. In some areas it is customary to spread lime in the soil. Other farmers plant other crops between the bay trees, this is done both to use the space more efficiently but also because the properties of the bay trees help to keep pest away from food crop. Another reason is that small food crops usually has a faster return time than bay, taking 5 years from planting until the first harvest.

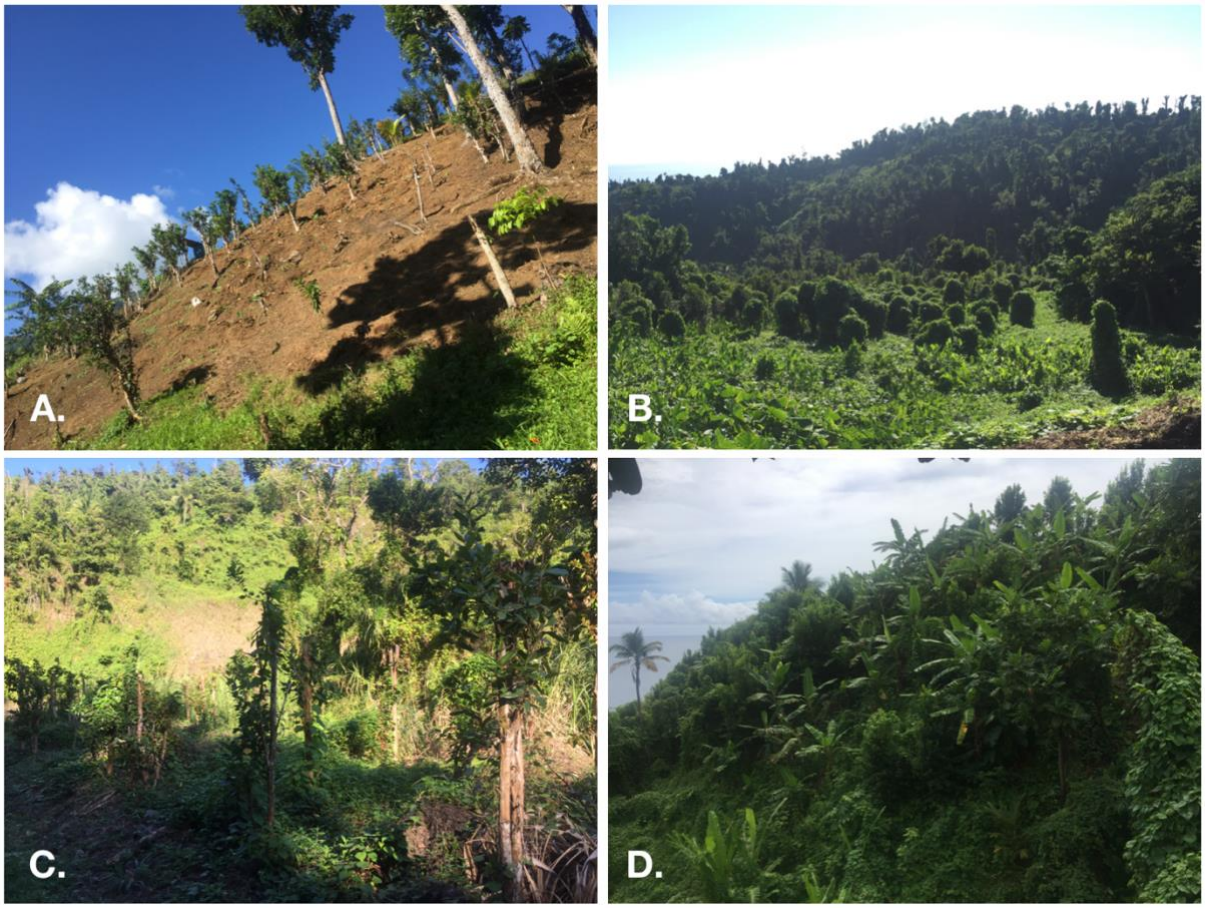

Figure 6: Fields of bay trees. A: A well maintained and cleared bay tree grove. B: A former bay field almost completely over grown. C. A field cleared and harvested a couple of months ago. D. A hillside of bay trees intercropped with banana.

According to the Ministry of Agriculture, Food and Fisheries (2009), there were about 733 acres (297 ha) of bay fields in 2009, distributed among 681 farms in three agricultural regions: South, South-East, East.

The regions are known as Saint Mark, Saint Patrick and Saint David, as shown in Figure 7. There were 373 acres (151 ha) of bay fields and 378 farms in the South Region (Saint Mark), 277 acres (112 ha) of bay fields and 230 farms in the South-East region (Saint Patrick) rand 83 acres (34 ha) of bay fields and 73 farms in the East region (Saint David).

Figure 7: The names and boarders of the perishes in Dominica. Saint Mark, Saint Patrick and Saint David are of most interest in this study, corresponding to the South, South-East and East agricultural regions where bay fields are most abundant.

According to the report the bay trees grow in different densities, varying between 2 feet (0.6 m) apart in groves, and being randomly dispersed in communities and forests. A majority of trees are growing 2-5 ft (0.6-1.5 m) apart, while the rest grow wider apart or randomly dispersed also see figure 4, 6 and 10.

Since 2009, several events may have caused a decrease in bay tree acreages, as described in chapter 3.3. For example, Guava Rust infestation had severe effects on about half of the farms, which may have killed trees. Due to the damage of homes and infrastructure caused in Erika and Maria, it is likely that some fields have been lost due to abandonment, lack of maintenance, and/or intercropping, see Figure 6.B and 6.D.

How large this loss is and what effect e.g. Maria had on the trees is to a large extent not known. It is said by some that their bay trees were ready for harvest again just 6 months after Maria and that it is a very resilient tree, especially compared to other tree crops such as coconuts or grapefruits. Others say that Maria caused changes in the vegetation, making the soil dry and exposing the trees to drought and causing them to die. The hurricane also washed up salt water on land on the east coast of the island, where most bay acreages are located, this is also believed to have affected the bay tree population. Some farmers say that their bay tree groves are not accessible while others claim that projects are undertaken to open up access to all fields, restoring the 733 acres (297 ha) again.

Based on the figures and a majority of the interviews with farmers and other stakeholders, it is clear that there has been loss of trees since the report from 2009 and propagation has not been done in an extent to replace the lost trees. However, it is difficult to make a certain estimation. Some people consider the loss to be up to 40 %, while others estimate about 20 % loss in the areas most affected by the storms. A possible estimation could be between 15-25% of lost acreages of bay trees, leaving 549-623 acres (222-252 ha). Another possible estimation could be 35-45% losses, leaving only 403-476 (163-193 ha) acres of bay still productive. These two estimates are used in section 5.1.1. to evaluate the current production capacity.

The age of farms in Dominica is presented in Figure 8 (Ministry of Agriculture, Food and Fisheries 2009), indicates a lack of rejuvenation to counteract the loss of trees. Since rejuvenation of bay trees is rare (Interview with farmers), the age of farms could give an estimation of the tree ages. Although *P.racemosa* is known to spread through rhizome, this proliferation could be inhibited by harsh clearing of fields, such as the one in Figure 6A. According to the Ministry of Agriculture, Food and Fisheries (2009), a majority of farms were between 60-100 years in 2009, a portion of farms were even older. The effect of tree age on bay oil yield is not certain but there are implications that leaves from older trees have a lower w/w oil content (Farmer Interview). Furthermore, the lack of propagation implies a lack of new investments in this industry.

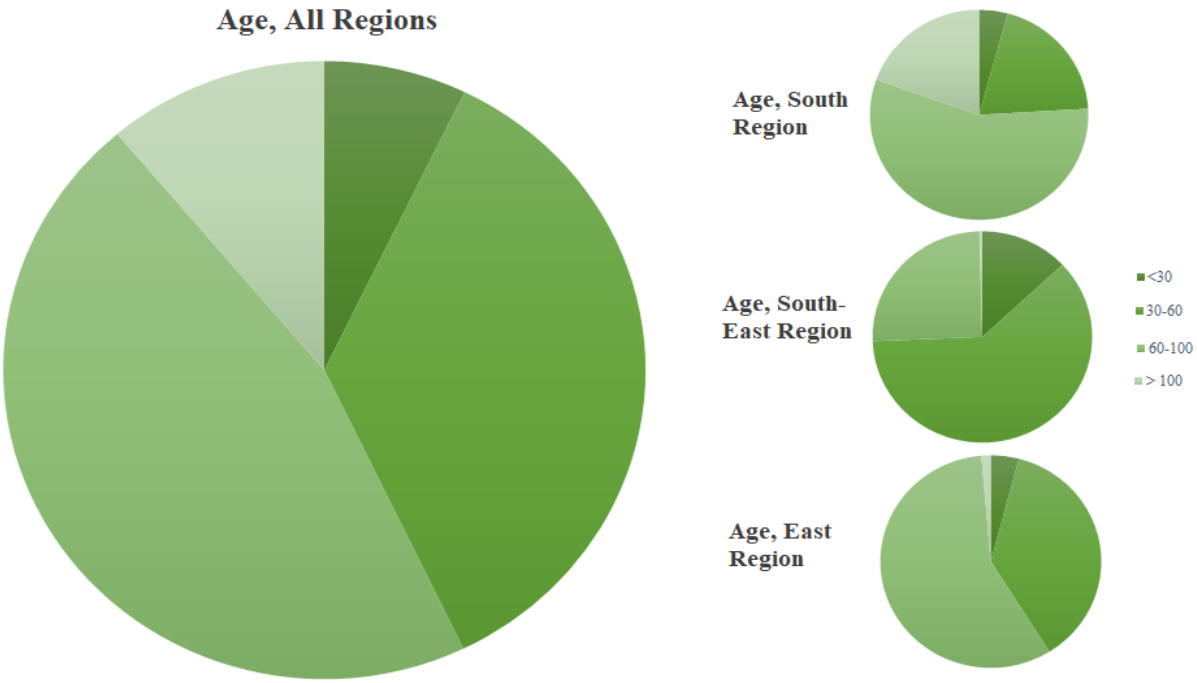

Figure 8: The age of the bay farms in the three main regions and the average age in total (Ministry of Agriculture, Food and Fisheries 2009).

There is a propagation project ongoing currently, with an aim of delivering 50,000 plants to farmers and 3,000 plants delivered so far this year (Stakeholder Interview). Estimating approximately 4,000 trees per acre, the goal of 50,000 plants is sufficient to cover about 12.5 acres of the lost acreages. An important aspect to consider for this project is the survival rate of young trees as Guava Rust can kill young plants.

4.1.2. Transport

Transportation of leaves and workers is a part of the supply chain which has been interrupted for several reasons: a portion of farmers have been separated from their fields due to relocation, the amount of local distilleries has decreased, vehicles and roads have been damaged in the hurricanes or lack of maintenance in the aftermath of the hurricanes

Historically, farmers lived close to their field and distilleries, making walking possible. This method requires farmers to carry about 1,000 lbs (454 kg) of leaves and additional wood fuel in steep topography to their distilleries for every batch produced. Before hurricane Maria and tropical storm Erika, the DEOSC used to have trucks available to members to facilitate the transportation of leaves for longer distances. Manual transport is still necessary in remote areas where motorable roads are not available.

Today, many farmers talk about installation of zip-lines, or cableways, to facilitate transport. The cables are attached to bay fields located far up on mountains and bunches of leaves can be tied to the cables and sent down to nearby distilleries or roads, using the force of gravity. One farmer mentioned this as the most important aspect of making bay farming more attractive. Other farmers also mentioned this as very important.

In addition to the challenging terrain, many roads are in poor condition, especially to Petite Savanne. Another major challenge to the sector is the destruction of a bridge between Petite Savanne and Delices, two neighbouring villages on the south-east coast of the island. The

former bridge connected the East region with the South-East and the South regions, the three main bay producing areas. The villages are now separated by a high mountain with a challenging terrain to walk, increasing the transportation time between the villages from 10 minutes to a 2 hours' drive. This has resulted in a divided community and overall interrupted communication and trading routes between the areas (2 Stakeholder Interviews).

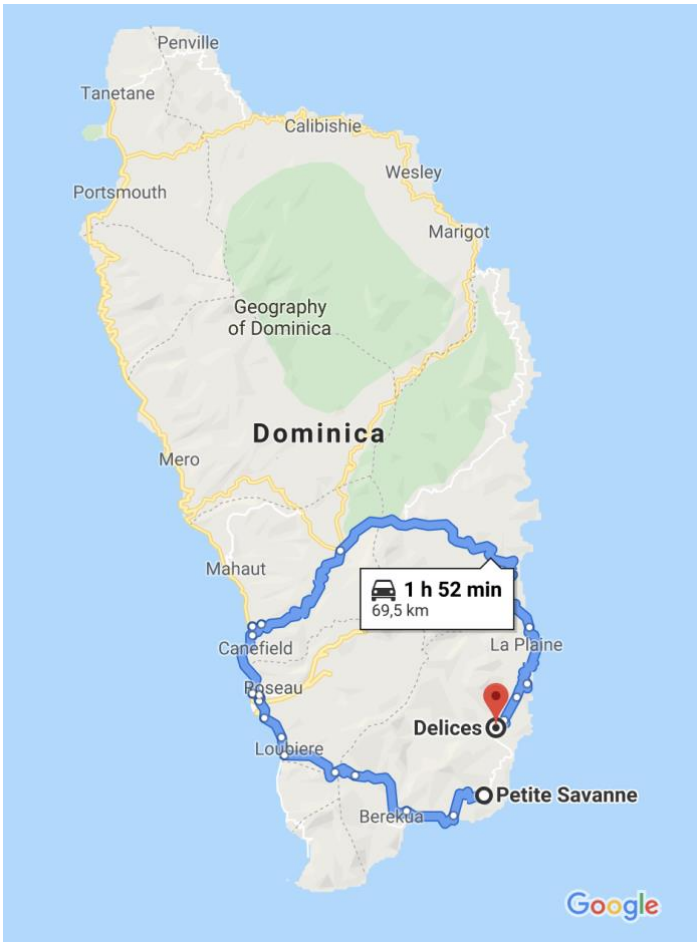

Figure 9:Map of Dominica highlighting the Road between Petite Savanne and Delices. Source: Google Maps.

4.1.3. Distilleries

After harvesting, the leaves should be distilled immediately but can be stored for up to a week without loss of oil if the storage conditions are well aerated and otherwise suitable (Wardini, 2016). The local method is to dry the leaves a couple of days or up to two weeks in the field or at the distillery, before starting the distillation process. Dry leaves contain less water, making them lighter to handle and gives less waste water (Farmer interviews).

The artisanal distilleries in Dominica uses a variant of hydro-distillation known as steam distillation. The distilleries may vary slightly in operation, material and structure, however the basic principle is the same. An overview of a typical artisanal distillery is illustrated in Figure 10, while photos showing the artisanal distilleries in reality are shown in Figure 11 and 12.

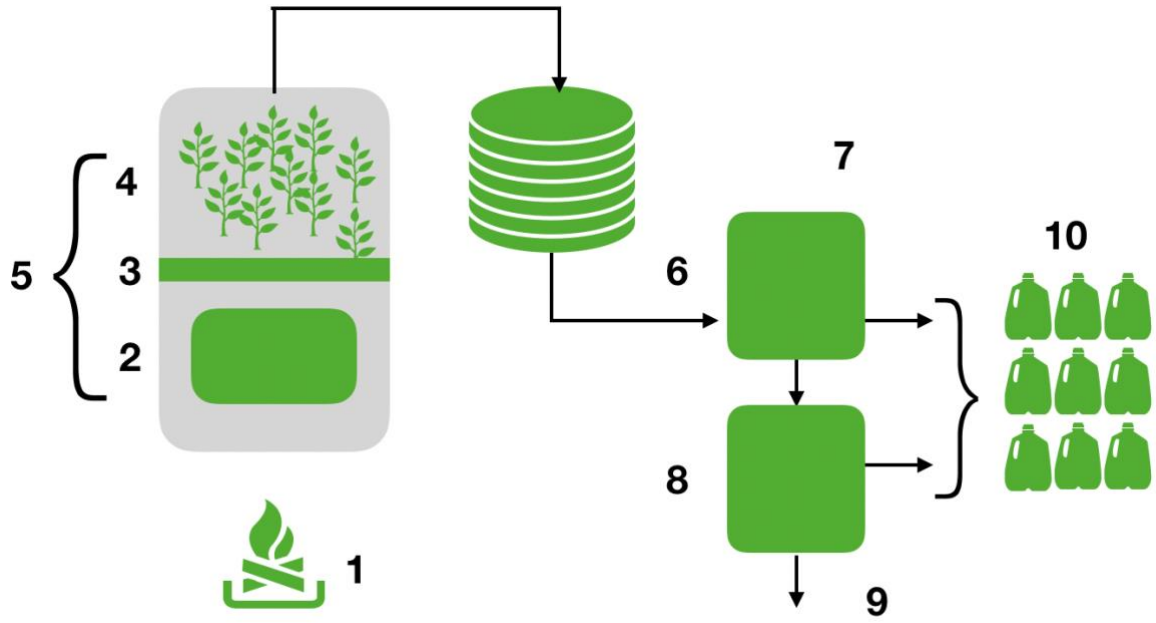

Figure 10: A schematic overview of an artisanal distillery, the parts consists of 1: Wood fire. 2: Water container. 3: Tammy. 4: Bay leaves. 5: Vat. 6: Condenser. 7: First separator. 8: Second separator. 9: Waste water. 10: Crude bay oil

The leaves and twigs can be put immediately into the vats (**4**), other farmers separate the twigs out while others chop them with a chainsaw before putting them in sealed stainless steel, aluminum or copper vats (**5**). It is common to use a mixture of water and flour to fill in gaps around the door to the vat. Wood is collected from the surrounding forests and used as fuel beneath the vats (**1**), heating and boiling water in a container (**2**) collected through a water pipe system. The steam from the water rises through a tammy (**3**), which is a circular wooden plate with holes, designed to let steam up without letting the leaves fall down. The moist heat extracts the oil from the leaves, which evaporate and mix with the steam. The mixed steam is collected through a pipe connected to the lid of the vats, the pipe then spirals downward in a condenser (**6**), allowing the steam mixture to condense into liquid. The material in the condenser determines the color of the finished product.

The liquid is collected in a separator (**7**), where the oil will separate from the water due to different densities. The process provides two types of oil, one with lower and one with higher density than water. A pipe connected to the bottom of the separator will lead the heavier oil and the water to an open tank, functioning as a second separator (**8**). When the process of one batch is finished the lighter oil appears in the second tank, meaning the first separator is filled with the lighter oil. Usually, the distillation process takes eight hours, but the work day also include loading and offloading the distillery, which requires about two hours.

The lighter oil is considered a finished product, while the heavier oil need further treatment. The water from the second tank (**9**) is a byproduct, it is sometimes discarded as waste but can sometimes be used for e.g. bathing animals. Any smell of bay oil in this water means that the separation can be improved. The heavy oil in the bottom is mixed with water and salt and heated up. What this process does is chemically unknown and was not observed for the report. It was described that this process makes the oil clear. A hypothesis is that as the salt dilutes in the water, the density of the water will increase, eventually making the oil float to the surface. After this treatment, the heavy oil is mixed with the light oil, constituting the crude bay oil (**10**). Other farmers were using two or more separators, which could have the same effect. The

entire process requires meticulous monitoring and takes about 8 hours of hard work maintaining the fire, regulating the temperature and water level in the vat as well as separating the oil.

Figure 11: photos of artisanal distilleries from field visits. A: harvested leaves being dried for distilling, this is approximately the amount of leaves for one batch. B: A fire heating the vat on top of it. C: A damaged tammy. D: A common but old-fashioned design of a condenser, when the process is running it is covered with flowing water: E. One of the separation methods. F: waste water container with heavy oil in the bottom.

According to some sources (Wardini 2016, Mercola 2015), adding salt to fresh water or alternatively using sea water is a way to increase yield and the concentration of phenols in the product. This method is however not recognised by the distiller visited during the field visits. A hypothesis is that salt water has a higher boiling temperature than freshwater, and using salt water could potentially increase the temperature for the steam, thus increasing the yield and quality of the oil. The material of the vat is also said to affect the quality of the oil, where copper vats makes the best quality, supposedly due to its heat conducting properties compared to e.g. aluminium. This fact strengthens the hypothesis that salt water could increase the yield and quality. Other means to increase the yield is to ensure no steam or heat escapes, which could be done through insulating the vats.

Figure 12. More photos from Artisanal distilleries. A: Collected wood fuel outside a distillery. B: Notes taken by someone to keep track of the production. C: A newly harvested field.

Another way to increase the income for distillery owners is to utilize the leaves after the process, the main reason this is not already done seems to be due to logistic challenges. Some useful ideas for future improvement of transport could be fertilizing, mentioned by farmers, or to fuel the distilleries or biogas production.

4.1.3.1. Present Conditions

The current condition and capacity of the distilleries varies a lot, see Figure 11, 12 and 13, as well as appendix 9.4. Two key stakeholders were asked about how many operational distilleries there are and where they are located, of which the answers are provided in Table 2. The information provided by the sources was that there are seven operational distilleries, although the locations given were different. This could either mean that there are seven distilleries with uncertain locations, or that the sources knew of different distilleries and the total number they knew of together is 14.

As the answers deviated, field studies to the distilleries were made and 17 artisanal distilleries were visited and documented, of which 10 were found to be operational. These are also presented in Table 2. The total number of claimed operational distilleries is then between 14-24, depending on if the distilleries provided by the sources are the overlapping or unique. This chapter aims to present the condition, accessibility and capacity of these distilleries. As much as it is desired to give the distilleries a fair review, more is known about some distilleries than others depending on wether the owners were present or not.

Table 2: Number of distilleries and their location according to different sources

Villages	**Source 1**	**Source 2**	**Field visits**	**Minimum**	**Maximum**
Bagatelle	1	-	1	1	2
Delices	1	-	2	2	3
Fond St. Jean	1	-	1	1	2
Good Hope	-	1	-	1	1

Petite Savanne	1	-	3	3	4
Petite Soufriere	3	5	3	5	11
Sansouvre	-	1	-	1	1
Total	**7**	**7**	**10**	**14**	**24**

Distilleries are concentrated in the areas where bay trees grow, which means they are mainly located in the East, South-East and South regions, see Figure 7. Some of them are located close to highways making them easily accessible, others are located remotely but motorable accessible, and some are only accessible via walking. Some distilleries also have better facilities than others, such as electric lighting and washrooms. There is also a difference in the yield, which supposedly is the main factor affecting which distillery farmers decide to take their leaves.

The average capacity of the distilleries visited is about 7.2 bottles per batch, equal to about 10.75 lbs (4.9 kg), which can be seen in Appendix 9.4. It takes about 800-1,000 lbs (1,760-2,200 kg) of bay leaves to fill a vat for one batch, which gives slightly over 1% w/w ratio of oil content in the leaves, which is in line with most external internet sources as well. Normally, the distillery is used maximum once per day.

All the currently operational distilleries have been repaired or built since Maria in 2017. According to DEOSC (2015), the cost to replace an average artisanal distillery is EC$ 15,000, while the Ministry of Agriculture, Food and Fisheries (2015) claims the same cost to be EC$ 25,000. Today, that cost has increased to up to between EC$ 80,000-100,000 to build a new distillery (Interviews with two farmers and one key stakeholder), and the price to just replace the roofs is about EC$ 50,000, see section. This is partly believed to be due to higher prices on building material after hurricane Maria in 2017.

Figure 13: Some of the Distilleries visited and documented during field visits. A: the inside of a distillery under reconstruction. The owner recently took over his grandfather's distillery. Remotely located B: A newly rebuilt distillery, just a couple of months old, still not used at the time of the interview but easily accessible. C. A distillery rebuilt quite soon after Maria, quite easily accessible. The owner had several batches from other farmers waiting for distilling.. D. A damaged and abandoned distillery, however, only the roof missing. E. A recently reconstructed distillery sponsored by GEF Small Grants, it had electric lights and a washroom, also very easily accessible. F. A reconstructed distillery, the owner has installed zip-lines from close-by fields to facilitate transport of leaves, something many farmers talked about.

4.1.4. Human Resources

Bay oil production is a traditional profession, meaning that although the industry is not older than ca 80-100 years, many producers today farm bay because their parents, grandparents have been farmers and their villages are bay oil producers. Having family members involved with the business often means that you are involved with the business, as family members

cooperate and assist each other. A general perception from field visits and talking with producers is that bay is rarely the only business of a farmer.

The amount of time spent on producing bay or working within the sector depends on what facilities each individual person or farmer has access to. More trees growing on the properties means more time spent on maintaining the groves and collecting leaves, and more leaves means more time spent on distilling. Maintaining that distilleries is also time consuming. For some people, bay production is a side business and for others bay is the main source of income, although having other occupations as well. Many have other crops or livestock to tend, they could also be fishermen or working within construction or car mechanics. Traditionally, bay production has been a way to earn extra money before holidays, especially Christmas.

Producing bay oil is considered a heavy and tedious task that requires a lot of physical work. The leaves are gathered and transported to the distillery by hand and during the distillation process farmers are exposed to heat and smoke. Fatigue is also an issue as sleep is not possible during the process, the temperature in the fire must be maintained and constantly monitored. The average age of bay oil producers in the Dominica Spice and Oil Cooperative, DEOSC, were 55 years in 2015. Because membership cannot be withdrawn, and the cooperative have the exact same numbers of members today meaning no one has entered, the average age today is closer to 60 years old.

4.1.4.1. Present conditions

The number of people currently involved with the bay oil industry is not known, the aim of this chapter is thus to evaluate labour availability.

According to the Ministry of Agriculture, Food and Fisheries (2015), it is estimated that the bay oil industry employs about 2 people per acre and 2 people per distillery, supposedly adding up to between 740-1,200 people. However, this cannot be because 733 acres (297 ha), 45 distilleries and 2 people per unit would be 1,556 people. Another estimation could be based on what is mentioned in section 4.1.1.1. Assuming all the 681 farms in 2009 still exists and that there is almost two people per farm, 1,200 or more could be a plausible estimation.

From the field visits it is known that many farmers have abandoned farming and started to work within e.g. construction after hurricane Maria, because many who lost their facilities have not returned (interviews with farmers and key stakeholders). One key stakeholder mentioned in an interview that he experience difficulties in finding labour who wants to work with farming, and bay oil distillation. According to other farmers and stakeholders, the lack of labour is likely because of the low pay within this profession, especially in combination with the hard work required. The cost of increasing the salary to farmers within the bay industry is presented in chapter 5.2.1. and discussed in chapter 6.

In section 4.1.4. it is stated that the average age of members in the DEOSC was 55 in 2015. Since it is not possible to withdraw memberships, and the amount of members is unchanged since 2015, it is likely the same people who are still considered members. Some of the farmers interviewed were between 70-80 years old, and farmers in their 50s or younger acknowledged to be very young compared with the average farmer. From field visits it is known that the Ministry of Agriculture, Food and Fisheries is specifically targeting young people to start farming.

Another important aspect is the amount of time spent by the farmers on bay oil production. One of the farmers says that it takes him 14 days to harvest enough leaves for one batch while others say between 2-5 days for one batch. The density of the trees could explain the deviation in information as well as the number of working hours per day, however the total amount of hours should be the same and is presented in Table 3 in section 5.2.1. Further, the average time spent on the distillation is slightly above one working day, including two hours to load and offload the vat and eight hours to manage the distillation. Other time consuming or costly tasks are to maintain fields, transport the leaves and gather wood fuel.

As also stated in section 2.3.2., the number of times in a year it is possible to harvest affects the work opportunities. Regarding this matter, five sources says harvesting occurs once a year, one source say it is possible two times per year and another source says four times per year. As also stated previously, most farmers produce bay oil 1-2 times per year with a peak productivity around Christmas. Farmers are paid when delivering oil to resellers, and members of the DEOSC are being paid twice a year from the profits, depending on their shares.

Currently, farmers are paid EC$ 120/lbs (US$ 97/kg) bay oil. In section 4.1.3.1., the average capacity for a batch is calculated to be around 10.7 lbs (4.9 kg) valued to EC$ 1,290 (US$ 477), slightly above the average monthly pay in Dominica. In some areas a new strategy has developed. Fields which are not used by the owners are harvested by others who work in teams: some of the employees harvest the leaves, a driver is paid to deliver the leaves, the wood fuel is bought and distillers are employed to maintain the distillery. This is described more thoroughly in chapter 5.2.1.

4.2. Market

4.2.1. Market

The oil is being shipped in barrels to brokers by boat, mainly to the US or Great Britain. There are two main distributors on the island, and they seem to have a very strong relationship with their buyers. The business relationship has been ongoing for up to 30 years. According to the DEOSC, new business contacts are occasionally established on business fairs and markets. Recently, other small scale exporters are also known through interviews with buyers.

As shown in Figure 14, the production in 2009 may have been up to more than 35,000 kg, equal to about 80,000 lbs. However, the statistic varies between different reports.

According to the Ministry of Agriculture, Food and Fisheries (2009), the production from the three main producing areas is the total production. These numbers are equal to the numbers from the Ministry of Finance and Social Security (2009). However, this data deviates from presented by the Ministry of Finance and Social Security (2011). This means that the possible production before tropical storm Erika in 2015 varied either between 15,000-25,000 kg per year, or up to twice that amount.

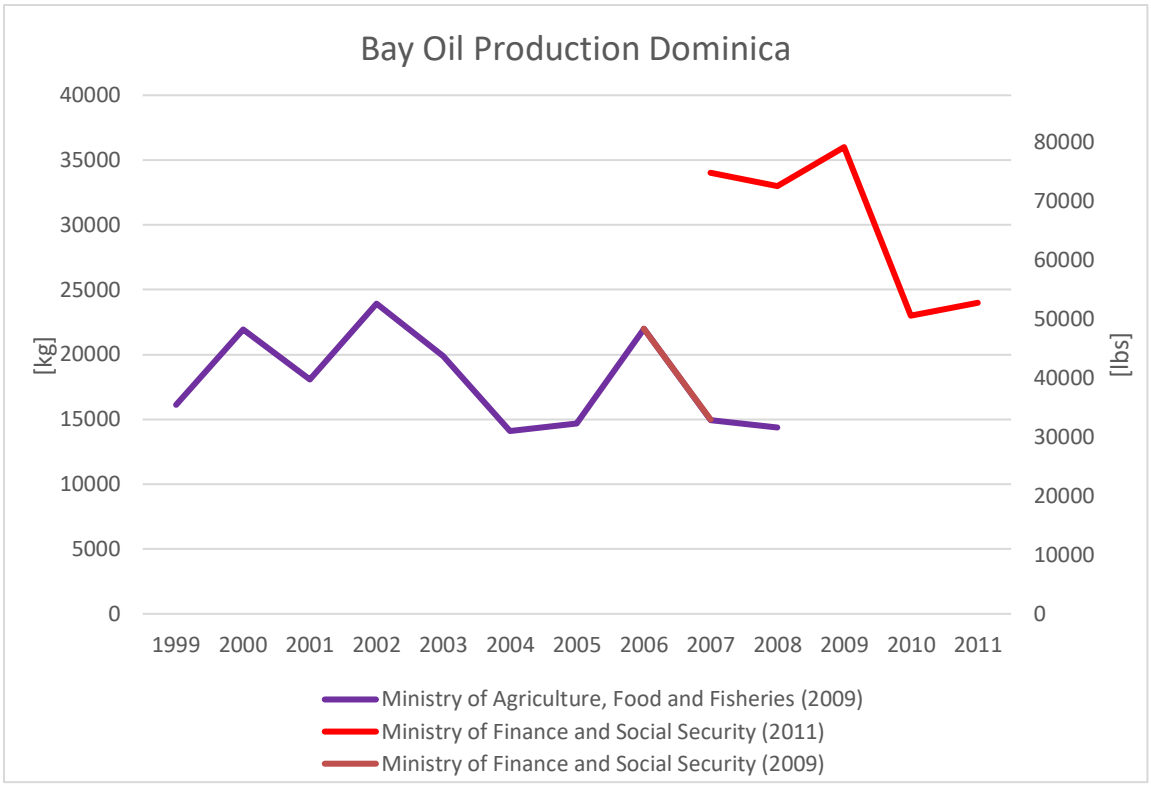

Figure 14: The export volumes of bay oil from Dominica in [kg] and [lbs] according to different sources: the Ministry of Agriculture, Food and Fisheries (2009), the Ministry of Finance and Social Security (2009), the Ministry of Finance and Social Security (2011).

The reason for this deviation is unknown. One explanation could be that they represent different statistics, such as the definition of bay oil or production vs. export. Either way, the figure shows a significant drop in production between 2009 and 2010. The production continued to drop to about 10% of normal production in 2018 compared to a normal year according to the DEOSC.

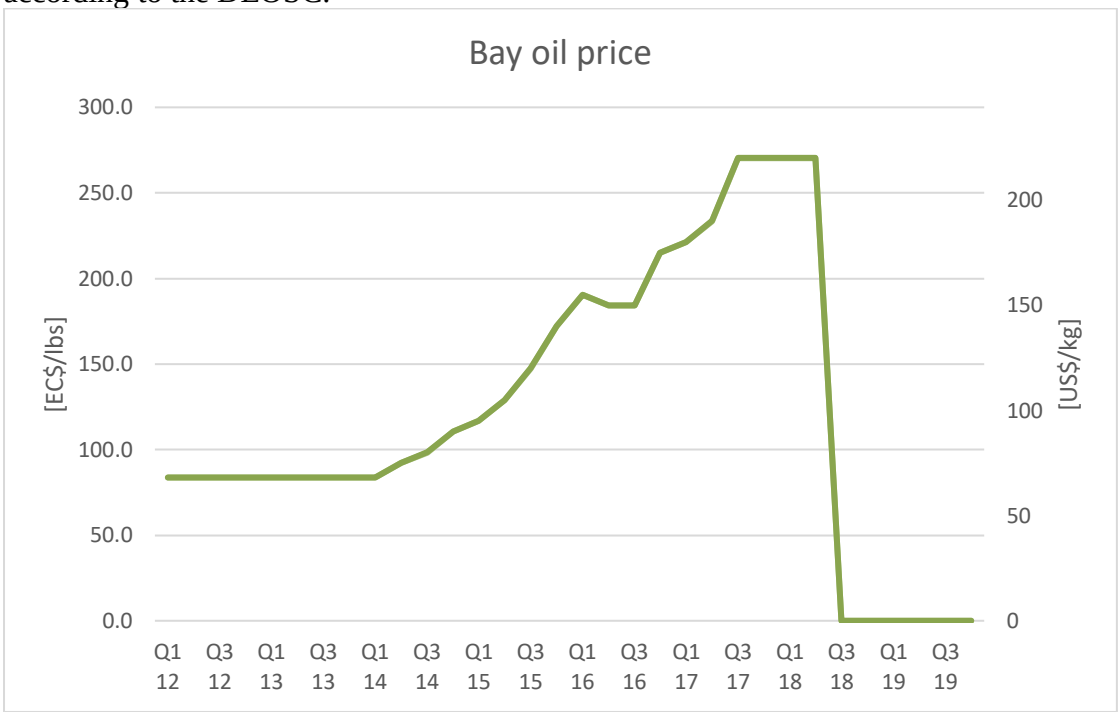

Figure 15: An example of the price development of bay oil on the global market. The price was stable until about 2014 when it started to increase. After 2018 it seems to have dropped, although the reason is unsure, source is Berjé, see Appendix 9.2.

The drop in availability can also be validated through the increase in price over the same period, see Figure 15. According to this example, the value of bay oil on the global market more than doubled in less than four years after the outbreak of the Guava Rust disease, (Berjé, 2017). In this figure it looks like a drastic drop of value in 2018, however, it is more likely due to lack of supply rather than lack of value. Today, the price of a small bottle of bay oil on Amazon is about US$ 12.99/5ml (≈ US$ 2,338 /kg, EC$ 2,886 /lbs)(Amazon 2019)[1], depending on the size of the order. Currently, the price a farmer is being paid is in general US$ 97/kg (EC$ 120/lbs). This gap will be discussed further into the report.

The best-known local markets are through Coal Pot and Jolly's Pharmacy. They make soaps, mosquito repellant and bay rum with the oil.

4.2.2. Application

Bay oil is used for a large range of properties, but as stated in section 2.2.1 the number of available articles in scientific journals describing bay oil is limited. However, in popular speech or within aromatherapy and natural medicines, there are many areas of usefulness. This chapter aims to present possible areas of application and marketing and thus, a variety of less validated sources is used in this chapter. In this context, it is important to note that bay oil from *P. racemosa* and consequently its components and properties, is easily mistaken and confused with other bay oils, see appendix 9.1. Validation of the statements in this chapter will be discussed in chapter 6.

4.2.2.1. Food

It is said that bay oil may be used as a scent additive in cooking. Another possible usage area is increased food quality, presented by Adjou et al (2017). According to McHale et al (1977), bay leaves is a useful ingredient for formulation of seasonings and sauces, and it goes well with meat (Anselm-Paquette, 2019).

4.2.2.2. Pharmaceutical

According to Moharram et al (2018), bay leaves are rich in phenolic compounds, explaining its traditional pharmaceutical value to treat flatulence, gastric disorder, osteoarthritis, colds and fever, as well as having analgesic and anti-inflammatory activities when consumed as an herbal tea. Supposedly, it also possess anti-rheumatic, antiseptic, antispasmodic, circulatory, anti-neuralgic, anti-cancer, nematocidal and insecticidal properties, as well preventing diseases carried by mosquitoes (Deviha 2018, Esoteric Oils 2020). In Dominica it is commonly used as a bug-repellent, preventing the spreading of mosquito borne diseases (Bardouille 2019). Kim et al (2008) found fumigant antifungal activity, while Contreras-Moreno et al (2016) has found antimicrobial activity in the oil, providing a possible alternative of antimicrobial agent to pharmaceuticals industry.

4.2.2.3. Cosmetics and Perfumes

Cosmetics, perfumes and other toiletries represent the highest global market share for essential oils (Yan et al 2019). It is within this industry that bay oil is most famous, known for being an appreciated ingredient in different hair lotions, aftershaves, shaving soaps, shampoos, fairness creams and other creams or toiletries, especially for men (Wardini 2016, Deviha 2018, A Virtual Dominica, 2018). Bay oil is a suitable ingredient in hair products as it

[1] Density of bay oil is estimated to 0.9 kg/litre

supposedly stimulates hair growth, can restore dull hair, greasy hair or dry hair and provides a healthy and glowing hair. Further, it is claimed to prevent infections in the scalp through its antimicrobial properties and consumption of herbal bay leaf tea is said to help combat dandruff and head lice. (Deviha 2018)

4.2.2.4. Aromatherapy

Aromatherapy is an alternative to conventional drugs and has contributed to an overall increase of demand in the essential oils market (Yan et al 2019). In this usage segment, bay oil is associated with activating the root chakra Muladhara. This counteracts nervous fatigue and athenia, as well as providing vitality, courage, and body energy (Laboratoire Altho 2018). Used in massages, it has an energizing and stimulating effect (Naissance 2019). The fragrance can also be spread in a room using a vaporizer (Deviha 2018).

4.2.2.5. Other uses

Thanks to its bug-repellent and antibiotic properties, intercropping bay trees with other crops could decrease the amount of pesticides used. This is a common method in Dominica (Pacquette-Anselm 2019). It also opens a possible usage area within the ecologic pesticide industry, and Deberdt et al (2017) found bay oil effective against the plant disease Bacterial Wilt.

4.2.3. Quality

4.2.3.1. Components

According to Contreras-Moreno (2019), bay oil will vary in components depending on the geographic origin. Naturally, bay oil is a product derived from plant parts, meaning that environmental factors affecting the tree, likely would affect the chemical compositions in the leaves. The description below is therefore a description of its common properties presented by global distributors and articles.

Bay oil is a colorless to light yellow, very fluent liquid. It has a strong aroma, with a muscular and spicy scent (Deviha 2018, Naissance 2019) , that also reminds of cloves (Laboratoire Altho 2018). The scent can also be described as familiar fresh and sweetly balsamic (Nature in Bottle, 2019). Another source, the Good Scents Company (2018) adds herbal, waxy, oily aldehydic aromatic and metallic to the scent description.

The crude oil delivered straight from the artisanal usually has a dark color, this is most likely due to the material of the condenser, which usually is made of zinc, see Figure 5D. Other condenser materials, such as stainless steel or glass, today found in a few artisanal, gives a light coloured oil. According to market research, there is a demand for both dark and light oil (interviews with 3 buyers).

As described in chapter 4.1.2., distillation gives two fractions of oil in the first step. According to Contreras-Moreno (2016), the different fractions have different composition, see Appendix 9.5. Although different sources are claiming somewhat different chemical composition, they have the main components in common, being myrcene, chavicol and eugenol.

Several of the main components in bay oil have pharmaceutical effects on humans. Some of them can be positive, such as being anti-inflammatory, neuroprotective, antipyretic,

antioxidant, antifungal and analgesic properties (PubChem 2019a). Other components are health hazardous, such as being potent irritant, cause allergic skin reaction, severe eye irritation, flammable, potentially fatal if swallowed and enters the airways, as well as being harmful to aquatic life with long lasting and acute effects. (PubChem 2019a, PubChem 2019b, PubChem 2019c, PubChem 2019d)

According to Moharram et al (2018), who isolated a different composition than other research concludes significant biological activities due to rich concentrations of phenolic compounds.

4.2.3.2. WONF – With Other Natural Flavours

The many different components of bay oil previously made it difficult to artificially replace. However, today there are artificial options to replace bay oil called WONF, short for *With Other Natural Flavours*. It is believed that the last years lack of supply has made many buyers replace natural bay oil with WONF, although it is unknown to what extent and how difficult it would be to regain market position. Two or three buyers state that everyone they know in the business has moved on to WONF or changed recipes, although highlighting that it is not the same as the natural product, which they would prefer. One of the buyers also acknowledged that the natural product is irreplaceable for aromatherapy purposes. Another buyer did not recognize this transition to WONF at all.

4.2.3.3. Certifications

The quality control of bay oil ensures safety for the final customers. As previously stated, the list of safety precautions for bay oil is very long, and potential contamination could be toxic. There are different grades of the oils which goes under different qualities, the higher grades are achieved through higher distillation. The quality checks are made with "*advanced technology machines and performed by highly educated personnel*" (Buyer Interview). This quality control does not exist in Dominica, and at least one reseller in the USA claim that this prevents them to deal directly with local producers in Dominica. Other, larger resellers, state that this is not an issue for them, and they would gladly deal closer to the distributors.

Beyond certifications of quality, there is also a market for certifications providing assurance to customers about other factors such as organic production. In the US, organic production is defined by the United States Department (USD) Agricultural Marketing Service (AMS). They require that the whole production process is free from pesticides, free from fertilizers with synthetic ingredients and without genetically modified organisms, GMO.

To make international trade of organic products easier, the US have organic equivalency agreements with the European Union, Switzerland, Taiwan, Korea, Japan and Canada. Within these countries, commodities can be transported as certified organic products. For other countries, the option is to open for recognition agreements, which allows foreign governments to accredit certified agents according to USDA organic standards. Within their standard, it is required that the soil must be free from contact with pesticide control since at least three years. (Petersen, 2019)

Certifications needed to access the organic market in e.g. the US, Canada and the European Union, the largest market for bay oil, products can be certified with "organic farming USA", "organic farming Canada", or "organic farming Europe". This is done through standards provided by the USDA, as mentioned earlier for the US, In Canada and Europe it is the Canadian Organic Regime and Organic EU regulation - (CE) n°834/2007 who are responsible for the requirements and control routines.(Groupe Ecocert, 2019)

Organic production enhances biodiversity in surroundings and in the soil, which gives a microbe-rich soil and helps trees absorb nutrients better. It can also counteract climate change by making the soil absorbing more carbon, which have effects such as preventing floods. For some crops the essential oil becomes of higher quality. All of these factors contribute to a higher market value for organic products. (Petersen, 2019)

4.2.4. Demand

The demand for bay oil is an important aspect when considering investing in reconstruction of the bay oil sector. This section aims to provide a buyers perspective on the current market and to give an idea of the current demand.

In the market reports from the company Citrus and Allied in December 2018, April 2018, September 2017, April 2017, the bay oil market is described as a "*disaster*" (Citrus & Allied 2018a, Citrus & Allied 2018b, Citrus & Allied 2017a), and "*on top of everyone´s crisis list*"(Citrus & Allied 2017b, Citrus & Allied 2016). The reasons given in the reports are mainly due to government policies and the consequences of tropical storm Erika in 2015 as well as hurricane Maria in 2017. Citrus and Allied (Citrus & Allied 2019) makes the following statement:

"*Over the past few years, the island of Dominica has been devastated by hurricanes and detrimental government policies, which have crippled producers and disrupted the supply. The immediate future for bay oil is not promising. In an effort to keep bay oil in everyone's portfolio, C&A offers a bay oil WONF (with other natural flavors). Additionally, we continue to encourage our Caribbean suppliers to reap bay from other nearby sources".*

Which government or what policies that are referred to is not known.

The overall impression from interviews with buyers and distributors is correspondent to the reports from Citrus and Allied, there is a general demand for bay oil on the market, it is popular in especially perfumes and hair products according to three interviewed buyers. The main issues are the insecurities when it comes to sourcing, the last five years with lack of supply has made many users change their recipes and look for other components, such as WONF.

A general opinion among buyers is that they would go back to the organic bay oil if the sourcing was easier and the price steady, although the hazardous components is an issue. Some of the requirements from the purchasing companies is to change the way the market works. For some companies, it is desirable to have direct sourcing with producers who they can contact, e.g. in case changes in the processing could be improved. In this case, they request a way of controlling and guarantee the quality of the product, which requires some special control during delivery. According to the buyers, the most important part about quality is the scent, which is the main factor to determine the quality of their products. A second important factor is the color of the oil which determines the quality. According to some sources, light oil is more preferable while other sources prefer dark color.

Many of the buyers highlight that they only buy in small quantities, which makes it expensive to source immediately from producers. Both in terms of the delivery but also because someone needs to conduct a control of the contents, which is an expensive process requiring special certifications not available in Dominica currently.

5. Assessment of Production Capacity

5.1. Current Capacity

As described in the previous sections the supply chain is broken in many key steps of production. The number of trees and productive acreages has likely decreased, the number of workers is unknown, the transportation is disrupted and production facilities have been destroyed. This has resulted in an uncertain production and an uncertain market.

Figure 16: An illustration of what has been lost in the value chain. It is estimated that between 20-40% of trees may have been lost to hurricanes and tropical storms. It is also estimated that there has been a loss of labour availability. Further, the transportation system has been disrupted and a majority of distilleries are not operational. This has led to a decrease of production and export, and in turn an uncertain market where some market areas have been lost as well.

These factors are taken into consideration in this chapter to estimate the current production capacity.

5.1.1. Procurement of raw material

Equation 2 and 3 from chapter 2.3.2. is used to estimate the production capacity limited by the available acreages of bay trees.

$$Eq.2) \qquad n_{harvest} \times \frac{w_{leaves}}{a} \times a_{total} \times \frac{w_{oil}}{w_{leaves}} = w_{tot\ oil\ t}$$

The first variable for equation 2 is the amount of harvests possible in a year, which is previously mentioned as one to four times. Since a majority of sources claims this value as 1, this is considered as the most likely number.

The second variable is the expected weight of leaves per area. This parameter is difficult to estimate, as sources provide a large range of answers. According to (Fern 2019, Wardini 2016), the expected annual yield of leaves varies between 7,138-31,226 lbs/acre (8-35 t/ha), which is a huge gap. Contreras-Moreno (2019) highlights that the yield may vary with location of crops and that different geographical areas will not give the same yield. The expected yield per acre also varies with the density of the trees. Another factor with a big impact is when the leaves are used, fresh leaves contain more water hence they are heavier than dried leaves, and all farmers interviewed let the leaves dry at least a week before distillation.

The third variable is area of productive acres, this has been evaluated in section 4.1.1.1. In this section, two assumptions were made, one with low and one with high loss of productive acreages, resulting in: 549-623 acres (222-252 ha) and 403-476 (163-193 ha) of productive bay acreages.

The last variable is w/w ratio of oil content. The theoretical oil content in leaves is often between 1-3%, the oil content can also be less than that while it tends to increase during the dry season or in drier areas (Farmer interview) and can be up to 5% (Fern 2019). During one field visit the weight of dried leaves necessary to produce 1 batch of oil was measured to 1,023 lbs (465 kg), this was done at a distillery with the capacity of producing a maximum of 7 bottles or 10.5 lbs (4.8 kg) per batch. This gives a w/w ratio of 1 % for the trees at that farm in that particular distillery.

The question about the yield of leaves per acre was asked to many farmers, an example of a typical answer is given below.

Example: *the farmers stated that they need to harvest 1-2 acres to have enough leaves for one batch. If one batch is 10.7 lbs (4.9 kg), and the w/w ratio of oil content is 1%, the harvest yield would be about 1,070 lbs/acre (490 kg/ha). This would mean that the maximum capacity with 733 productive acres (297 ha) in Dominica would be around 5,228 lbs (2,376 kg) bay oil annually for one harvest per year, see calculations below.*

$$\frac{\frac{10.7\ lbs}{batch} * 733\ acres}{\frac{1+2}{2} acres/batch} = 5{,}228 lbs$$

In comparison with the information in Figure 15, this is too low to be a probable estimate. The amount of harvests per year would need to be around 10 times annually to be corresponding with Figure 15, hence this information is discarded.

Since the harvest yields given by internet sources is between 7,138-31,226 lbs/acre (8-35 t/ha), is a huge gap, and nothing more specific is known about the leaf yield, Equation 2 will not be used for estimations. Instead, Equation 3 will be used.

$$Eq.3) \qquad n_{harvest} \times \frac{w_{oil}}{a} \times a_{total} = w_{tot\ oil\ t}$$

Again, the number of harvest occasions per year is 1. In this equation, an approximation of yield is given by weight of oil per area. There are three different sources for this:

- According to the Ministry of Agriculture, Food and Fisheries (2015), the average yield in Dominica is stated to be 70 lbs/acre (62 kg/ha).
- In an interview, a landowner claims his average yield to be 90 lbs/acre (80 kg/ha).
- Another land owner has an annual oil yield of 25 lbs/acre (11.4 kg/ha)

These three values are used to estimate Dominica production capacity and are shown in Figure 17, where 90 lbs/acre is the yellow line (top) line, 70 lbs/acre is the red (middle) line and 25 lbs/ acre is the blue (bottom) line.

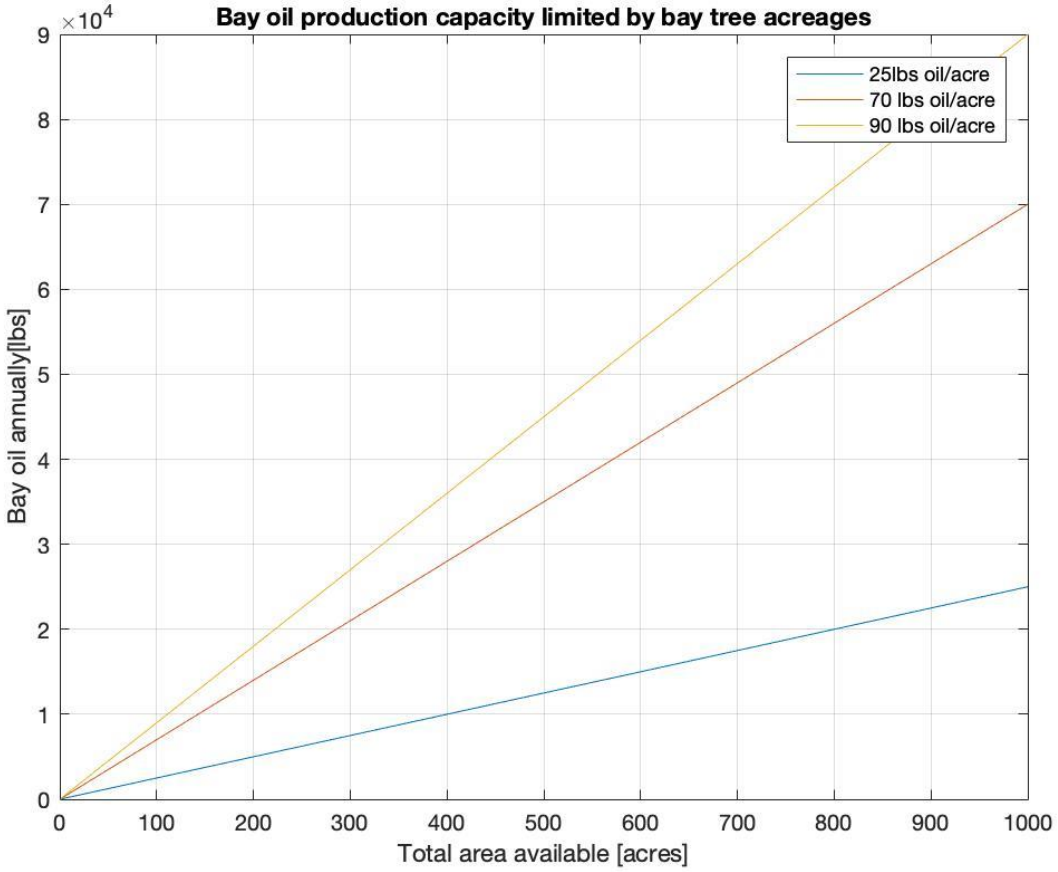

Figure 17: The Y-axis is the production capacity in lbs and the X-axis is the total available acres. In comparison with Figure 7, the red line is most realistic.

Using Equation 3, the total maximum production capacity for Dominica can be estimated according to Figure 17. According to the assumptions of low and high loss of productive acreages to 549-623 acres (222-252 ha) and 403-476 (163-193 ha), the production capacity with regards to available trees is currently ≈ 28,000 lbs (12,700 kg) as the lowest or ≈43,000 lbs (19,500 kg) at its highest.

5.1.2. Distilleries

To process the leaves it is important to understand the production capacity of existing distilleries, what is required to restore a distillery and how that pays off in the long term.

As mentioned in section 2.3.2., the total bay oil production capacity limited by available distilleries, $w_{tot\ oil\ d}$, can be estimated with Equation 4. Where $n_{distilleries}$ is the number of distilleries available, the w_{oil}/d is the quantity of oil that can be produced per day and d_{tot} the total amount of days when bay is produced.

$$Eq.4) \qquad n_{distilleries} \times \frac{w_{oil}}{d} \times d_{tot} = w_{tot\ oil\ d}$$

As also mentioned in the section, the quantity of oil produced in a day is estimated with Equation 5.

$$Eq.5) \qquad \frac{w_{oil}}{b} \times \frac{b}{B} \times \frac{B}{d} = \frac{w_{oil}}{d}$$

Where b/B is bottles per batch, B/d is batches per day and w_{oil}/b is oil per bottle. The bottles are known to be 750 ml, and is said to contain approximately 1.5 lbs (0.7 kg) oil. As described in the previous section, the average production from one batch is 11.4 lbs. The amount of batches per distillery varies, at one distillery visited the production was up to 3 batches per day thanks to an efficient system with many employees. For the distilleries only used by one farmer, the average production is 1 batch per month or even less. However knowing it is possible to produce at least 1 batch per day in a distillery the total amount of batches per distillery in a year could be up to 250, assuming Sundays and other holidays will be free. This number will be used for calculating the maximum production.

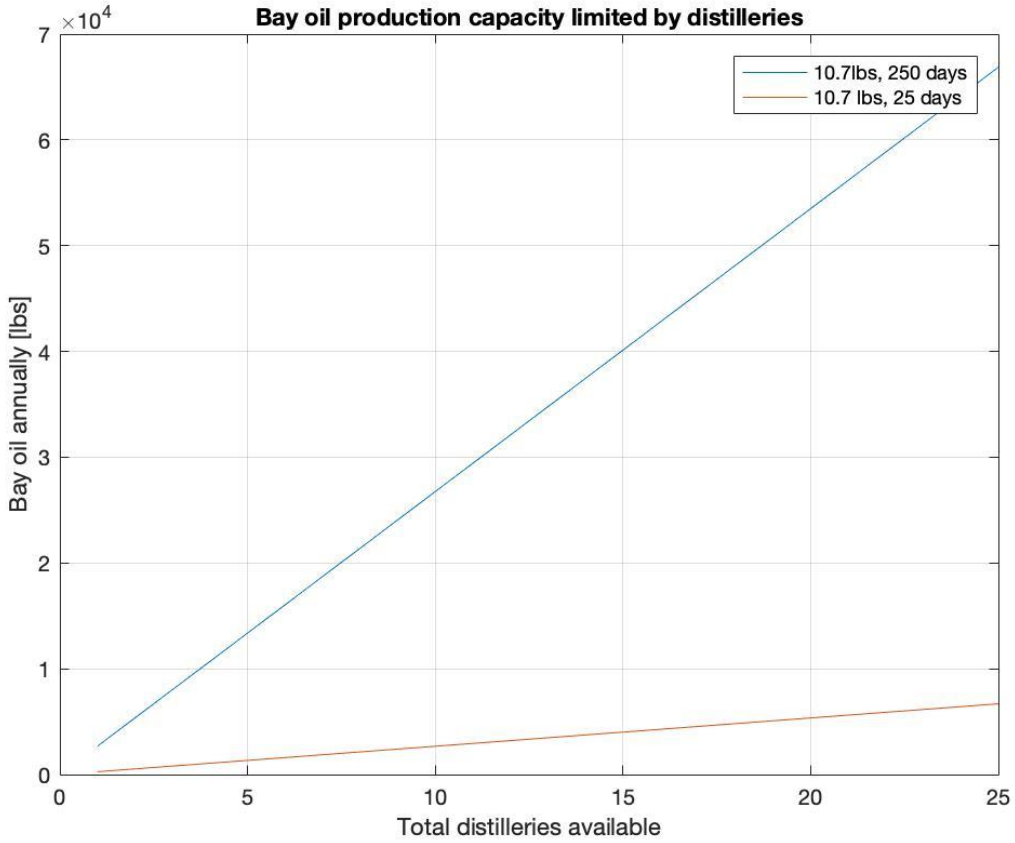

Figure 18: Diagram showing production capacity determined by distilleries. Y axis= production in lbs, X axis = number of distilleries, where woil/d = 10.7 lbs and dtot=250 days for line one and dtot= 25 days and one batch per day. For maximum oil production determined by trees between 28,000lbs (12,700kg) and 43,000lbs (19,500 kg), then the necessary number of distilleries is between 10 and 16.

In the previous section, it is determined that the maximum production determined by the available trees is between 28,000 lbs (12,700 kg) and 43,000 lbs (19,500 kg) oil annually. According to Figure 18, the amount of artisanal distilleries needed in the country to cover this production is between 10 and 16 if they produce 250 batches per year. According to section 4.1.3.1. there are currently between 14-24 operational distilleries in Dominica, with the average maximum production capacity of 10.7 lbs (4.9 kg) per day. If they would be used time efficiently all year around the production of bay oil in Dominica could increase. However, many distilleries are used far less, some of them even less than 25 times per year, more than 90% lower than what is estimated as maximum capacity. This productivity requires more distilleries to process the total amount of available leaves in Dominica.

5.1.3. Human Resources

The productivity of farmers can be estimated using Equation 9 from section 2.3.2., where $n_{farmers}$ are the total amount of farmers who work with bay oil, B_{tot} is the number of batches that one farmer can produce in a year and w_{oil}/B is the oil yield per batch. In section 5.2.1. it is estimated that it takes about 80 hours or two full working weeks to harvest and distillate one batch of oil. With approximately 52 weeks per year, the number of batches for one person in is then about 25 batches. This is however unlikely, and if the other tasks, such as transportation, gathering wood fuel and such cannot be made by others, the time would be insufficient. Figure 17 shows an estimation of how much oil can be produced if there are less than 1,500 workers making 7, 15 or 30 batches in a year. The w_{oil}/B is previously estimated to 10.75 lbs (4.9 kg).

$$n_{farmers} \times B_{tot} \times \frac{w_{oil}}{B} = w_{tot\ oil\ f}$$

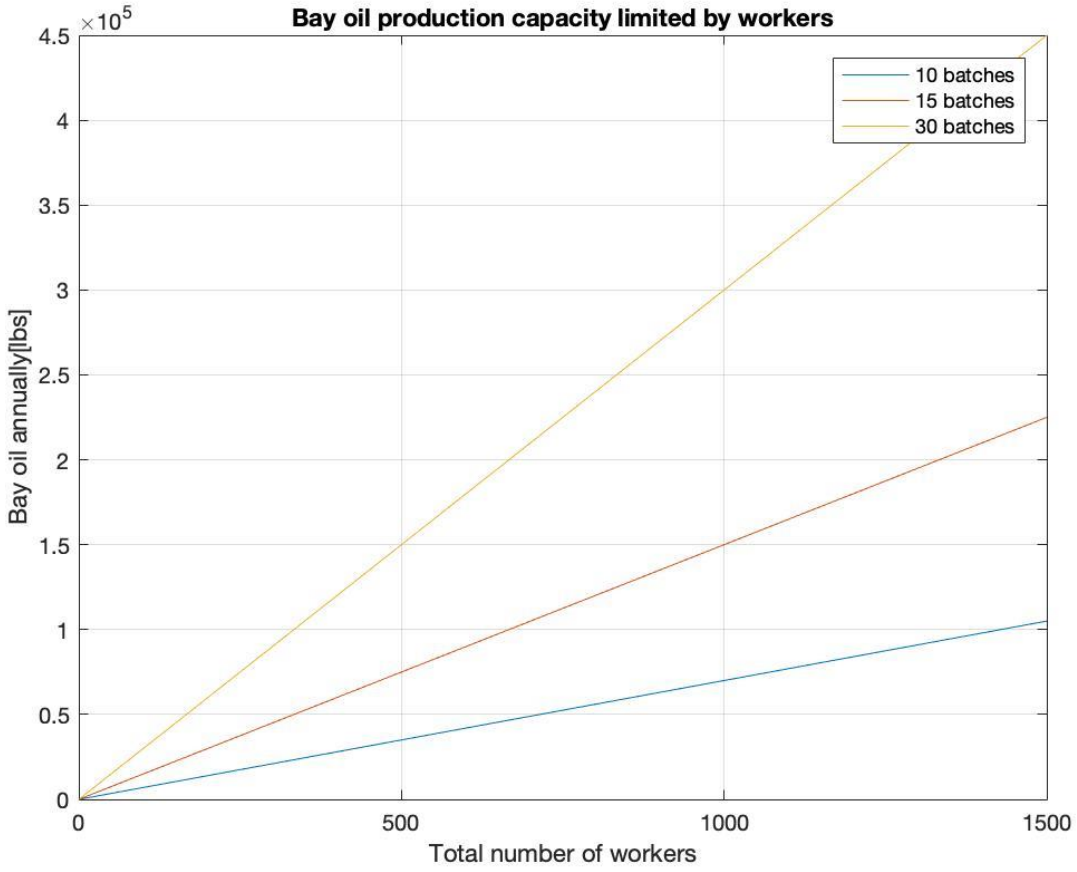

Figure 19:Production capacity of bay oil in Dominica limited by workers, where the Y-axis is the production capacity and the X-axis is the available amount of workers. The figure shows that for a production level of about 43,000 lbs, the necessary number or workers is less than 500. Even if a majority of the former 1,200 involved farmers have started other business, the labour for bay oil production should still be sufficient to cover maximum production capacity.

Figure 19 illustrate the importance of labour efficiency, where the amount of oil batches that can be made by every worker has a high impact on bay oil production in Dominica. To cover the production capacity described in section 5.1.1. and 5.1.2. , less than 500 employees could be sufficient. This is however excluding the time needed to cover the gathering of wood fuel and transportation, which would provide even more jobs to Dominica.

5.2. Costs

5.2.1. Production Cost

The cost of producing bay oil is also an important aspect of the industry. This calculation is based on information provided by a local stakeholder talking with a local producer on what the different costs are. In this analysis, the cost is divided into the different activities and materials used when producing the oil.

It is assumed that the variable costs are the salary paid to the employees, harvesting the leaves and managing the distillery. The wages are higher for harvesting than for maintaining the distilleries because this is considered a more tedious task. The fixed costs are assumed to be services which can be purchased externally, such as transportation of leaves, procurement of wood fuel, ropes to tie the bunches and to maintain the fields twice per year. For every batch produced there is a fee paid to the distillery owner, in most distilleries, this fee is set to be the value of one bottle of oil, equal to 1.5 lbs (0.7 kg). Currently, this value is EC$ 180 (US$ 67).

The cost of producing bay oil must not exceed the value on the market, but at the same time the price for bay oil should be high enough to give workers a decent pay. The cost for producing a batch of bay oil, to a value of approximately 7 bottles (10.5 lbs, 4.8 kg) is presented in Table 3.

Table 3: Production cost for producing one batch of oil in an artisanal distillery, using a modern work arrangement with minimum wage

Cost Activity	**Amount of people**	**Working hours per person**	**Tot working hours**	**Cost per hour [EC$/h]**	**Tot Cost [EC$]**
Harvest leaves	2	30	60	8.3	500
Transport of leaves					30
Wood fuel					100
Distillation	2	10	20	5	100
Rope					95
Distillery fee					180
Clearing Fields					200

Tot Cost [EC$/batch]					1205

In the distillery used for this example, the average yield is 10.5 lbs (4.8 kg), meaning the average production cost is EC$ 115/ lbs (US$ 95/kg) with wages between EC$ 5-8.3/h (US$ 1.9-3/h).

In section 4.1.4.1**.**, the low salary for farmers is presented as an issue. The cost for increasing the wages to bay oil producers is presented in Table 4, and further discussed in chapter 6. If the salary instead would be e.g. EC$ 15 for the employees maintaining the distilleries, and EC$ 25 to the people harvesting the fields, the total production cost would be EC$ 2,405 for 10.5 lbs or EC$ 229/lbs (US$ 187/kg).

Table 4: Production cost for producing one batch of oil in an artisanal distillery, using a modern work arrangement with minimum wage times three. .

Cost Activity	**Amount of people**	**Working hours per person**	**Tot working hours**	**Cost per hour [EC$/h]**	**Tot Cost [EC$]**
Harvest leaves	2	30	60	25	1500
Transport of leaves					30
Wood fuel					100
Distillation	2	10	20	15	100
Rope					95
Distillery fee					180
Maintaining Fields					200
Tot cost [EC$/batch]					2405

There are also ways of producing bay oil where farmers do all the activities themselves, this method is not analysed.

5.2.2. Artisanal Distillery Pay-off Time

There is also a cost for the distillery, this chapter aims to evaluate the profitability of an artisanal distillery. In this report, the feasibility of a building a distillery will be calculated with the pay-off method, described in chapter 2.3.2. The return on investment depends on a number of factors, such as the initial cost of investment production cost, value of the product and the productivity, i.e. how often the distillery is used. Some of the documented distilleries were used only a few times per year while others were used every day or even more.

Five different scenarios are shown in Table 5 to illustrate how the different factors affect the pay-off time.

- **Base Case**
  For this scenario, the following assumptions are made:

  The number of batches per year is assumed to be around 250. This assumption is based on what is believed to be the maximum capacity of an artisanal distillery, where it in theory is possible to produce at least one batch a day although in reality, people do not work every day.

  The yield per batch is based on the maximum capacity for the average artisanal distillery presented earlier, 10.7 lbs (4.9 kg).

  The value of the product is assumed to be what farmers are currently paid, EC$ 120/lbs (US$ 97/ kg).

  Production cost is assumed to be the difference between the current production cost of EC$ 115/lbs (US$ 95/kg), and the distillery fee of one bottle per batch, EC$ 180 (US$ 67) presented in Table 3. This gives a production cost of EC$ 98/ lbs (US$ 80/kg).

  The net income is assumed to be the difference between the product value and the production cost, EC$ 5 (US$ ≈ 2).

  Initial cost of investment is assumed to EC$ 100,000 (US$ 37,000).

- **Decreased Productivity**

  In this scenario, the productivity is decreased ten times to about 25 times per year. Some of the distilleries which are remotely located are used even less.

- **Increased Product value**

  In chapter 4.2.1., the value of bay oil on the international market can be almost 20 times higher than what farmers are currently being paid. In this scenario, the value of the product is increased to EC$ 600/lbs (US$ ≈ 490/kg), which is about 5 times the current pay to farmers.

- **Increased Production Cost**

In this scenario, a higher production cost is presented based on Table 4 in chapter 5.2.1. Production, which is EC$ 229/lbs (US$ 187/kg). The value of the product is assumed to increase linearly with the increase of cost.

- **Decreased Investment Cost**

  In just four years, the cost for reconstructing an artisanal distillery has doubled. It is assumed the cost for building a new distillery has increased equally. However, if this increase is because of Erika in 2015 and Maria in 2017, the increased cost could be temporary, this scenario will analyse the pay-off time for a cheaper distillery, to a cost of EC$ 50,000 (US$ 18,500).

Table 5: Pay-off analysis for five different scenarios: Base Case, Decreased Productivity, Increased Value, Increased Production Cost, and Decreased Investment Cost.

	Base Case	**Decreased Productivity**	**Increased Value**	**Increased Production Cost**	**Decreased Investment Cost**
Batches per year	250	***25***	250	250	250
Yield per batch [lbs/batch] (kg/batch)	10.7 (4.9)	10.7 (4.9)	10.7 (4.9)	10.7 (4.9)	10.7 (4.9)
Value of product [EC$/lbs] (US$/kg)	120 (98)	120 (98)	***600*** *(488)*	***280*** *(227)*	120 (98)
Production Cost [EC$/lbs] (US$/kg)	98 (80)	98 (80)	98 (80)	***229*** *(186)*	98 (80)
Net income [EC$/lbs] (US$/kg)	22 (18)	22 (18)	***502*** *(409)*	***51*** *(42)*	22 (18)
Annual Net Revenue [EC$](US$)	58,850 (21,774)	***5,885*** *(2,177)*	***805,710*** *(298,113)*	***136,425*** *(50,477)*	58,850 (21,774)
Initial Cost of Investment [ES$] (US$)	100,000 (37,000)	100,000 (37,000)	100,000 (37,000)	100,000 (37,000)	**50,000** (18,500)
Pay-off time [years]	1.7	17	0.12	0.7	0.8

Four of the five scenarios give a pay-off time shorter than three years, which is usually considered the limit of whether it is a good investment or not. In Dominica, it might also be important to evaluate the frequency of natural disasters. The extensive work of conducting these calculations cannot be covered by this report.

5.2.3. Industrial Distillery Pay-off Time

Since the landslide destroyed the industrial distillery in 2015, there have been initiatives to build a new one. According to the DEOSC, this is the most important aspect of regaining Dominica's production capacity. The pay-off time for this distillery will be based on the same factors as the artisanal distilleries: initial cost of investment, production cost, value of the product and the productivity, i.e. how much oil that can be produced annually. This analysis will be based on two scenarios: Scenario 1 in regards to maximum profit and capacity and Scenario 2 in regards to minimum profit and capacity.

The cost for production can be based on the information in Table 3 for Scenario 1 and Table 4 for Scenario 2. The cost per weight of harvested leaves is assumed to be the same for an industrial as for an artisanal distillery. For Scenario 1, the cost for procurement of leaves is EC$ 500 (US$ 185) for 10.5 lbs (4.9 kg) bay oil, equal to EC$ 48/lbs (US$ 39/kg). For Scenario 2, the cost for procurement of leaves is EC$ 1500 (US$ 555) for 10.5 lbs (4.9 kg) bay oil, equal to EC$ 143/lbs (US$ 116/kg).

The new industrial distillery is planned to have the same fuel as the former industrial distillery: a mix of diesel and kerosene. According to the Ministry of Agriculture, Food and Fisheries (2015), the former industrial distillery required about 1 gallon (3.8 liter) of kerosene diesel mix to produce 1 lbs (0.45 kg) of bay oil. The cost is estimated to about EC$ 9/gallon (US$ 0.9/liter) kerosene oil.

The pay to the people managing the distillery is assumed to be the same regardless of batch size, giving EC$ 9.5/lbs (US$ 7.8/kg) for Scenario 1 and EC$ 28.6/lbs (US$ 23/kg) for Scenario 2. Further, it is assumed that the value of bay oil can be sold to at least EC$ 240/lbs (US$ 195 /kg), this will be used for both scenarios.

According to one of the stakeholders, the estimated production capacity is aimed to be 90% of Dominica's production. In chapter 5.1.1., the production capacity limited by the available bay fields is minimum ≈ 28,000 lbs (12,700 kg) and maximum ≈43,000 lbs (19,500 kg). For Scenario 1, 90% of maximum tree capacity is used to estimate the production, giving 38,700 lbs (17,590 kg) annually. For Scenario 2, 90% of minimum tree capacity is used, equal to 25,200 lbs (11,455 kg).

The construction cost of this distillery is estimated to between EC$ 2,000,000 ((US$ 74,000), Scenario 1, and EC$ 2,500,000 (US$ 92,500), for Scenario 2. This cost is based on the reports from the DEOSC and the Re-investment strategy, as well as Stakeholder Interviews.

Other costs are neglected for simplification.

Table 6: Pay-off analysis for an industrial distillery using two different scenarios, one with a high profitability and one with a lower.

	Scenario 1, maximum profit	**Scenario 2, minimum profit**

Procurement of leaves [EC$/lbs bay oil] (US$/kg bay oil)	48 (39)	143 (116)
Procurement of fuel [EC$/lbs bay oil] (US$/kg bay oil)	9 (2)	9 (2)
Managing distilleries [EC$/lbs] (US$/kg)	9.5 (7.8)	28.6 (23)
Sum of production cost [EC$/lbs] (US$/kg)	66.5 (54.1)	180.6 (146.5)
Value of Product [EC$/lbs] (US$/kg)	240 (195)	240 (195)
Net Income [EC$/lbs] (US$/kg)	173.5 (140.9)	59.4 (48.5)
Annual Production [lbs] (kg)	38,700 (17,590)	25,200 (11,455)
Total Annual Revenue [EC$] (US$)	6,714,450 (2,484,347)	1,496,880 (553,846)
Initial cost of investment [EC$] (US$)	2,000,000 (740,000)	2,500,000 (925,000)
Pay-off time [years]	0.3	1.67

The pay-off time for both scenarios are very short, indicating on a good investment decision. To put into perspective, Scenario 1 and 2 requires an average production of 106 lbs (48 kg) and 69 lbs (31 kg) per day respectively. The former distillery had a capacity of about 32 lbs (14.5 kg) oil per 8 hours, making both scenarios possible to achieve if the production is evenly distributed over the year.

6. Discussion

Overall, the lack of statistics and reliable sources was a challenge during this project. Generating reliable statistics is key to know e.g. the amount of productive acreages, making better economic estimates of how many distilleries are necessary for production and how high productivity could be expected. This would also facilitate identification of bottlenecks and analysing possible improvements of efficiency.

In this chapter, different possibilities along with suggestions on improvements are presented and discussed. The result show that it is likely the amount of productive acreages of trees that is the main limiting factor for the future of production capacity.

Because the production levels prior to tropical storm Erika in 2015 is uncertain, it is difficult to say anything in reference to former production levels.

6.1. Procurement of Raw Material

From interviews, two scenarios are estimated, one with a low loss, and one with a high loss. This would result in either 549-623 acres (222-252 ha), or 403-476 acres (163-193 ha) of productive bay trees. A more thorough study of the amount of acreages would be necessary to say anything more specific. The result show that the amount of productive acreages of bay trees is believed to be the main limiting factor for production of bay oil in Dominica compared with the result for distilleries and human resources.

These numbers are however based on assuming that fields of bay trees only exists in the three main regions, as stated by the Ministry of Agriculture, Food and Fisheries (2009). Rumours about other bay villages in the north regions were heard during the Minor Field Study, but never confirmed or discarded.

The age of the trees could also be an issue because of two reasons: decrease of w/w ratio of oil content in leaves with tree age, and risk of tree loss. Figure 8 indicate that a majority of bay trees in Dominica could be older than 60 years, while the only recording of bay tree age claims 50 years. This could be a major source of loss of trees.

Another uncertainty is the harvest yield, further studies are needed to establish the bay oil yield at 70 lbs/acre (62 kg/ha).

In reference to the loss of trees in recent years, the current propagation project need to increase in size to cover the loss of trees. To succeed with this, it is important to record the progress of the current project to avoid problems with Guava Rust.

Harvesting the leaves is the most expensive activity in the production cost analysis and could likely be improved. Maintenance of the fields could likely also be improved, as many fields were found abandoned and not maintained during the field visits. Many farmers mentioned grass cutter machines as an important mean to facilitate this task and modernize the industry. A system where land owners can let other people harvest their bay could be an idea to decrease abandoned fields.

6.2. Transport

Transport is key to get the leaves to the distilleries. Transportation of leaves to the distilleries is mentioned as a challenge by several farmers, many distilleries are remotely located and difficult to get to. The installation of Zip-lines is one way to modernize the industry and to decrease the workload. Having motorable access to fields and distilleries, in combination with vehicles, is also an important aspect to streamline and develop the sector.

The reconstruction of the bridge between Petite Savanne and Delices is also an important aspect. This would make the fields and distilleries in the main productive areas more accessible. It is especially important for the construction of an industrial distillery in the Geneva Area in the South-East region.

6.3. Distilleries

The number of distilleries and their capacity need to be established to provide a more certain estimation of how much bay leaves that can be processed. According to the result illustrated in Figure 18, the current number of distilleries, between 14-24, is likely enough to process the maximum leaf yield determined by the available tree acreages. However, this requires a time efficient, all-year around production.

Peak of productivity could also be considered to occur during spring or early summer instead of late autumn. This would have two advantages: marginally higher oil content in leaves but especially it would give longer time between hurricane season and harvesting, which would make the industry more resilient.

There are likely many aspects to improve regarding the operation of distilleries. E.g. any smell of bay from the waste water implies an improvement opportunity regarding the separation process to increase yield. It is also recommended to establish what material in the vat and condenser that provide the highest quality of oil.

Another aspect is the different techniques and quality of the oil. Currently, farmers are paid equally for a pound (kilo) of oil irrespectively of quality. Higher quality should receive higher pay to give incitement for distillery improvements. Also, a standardisation of production method for all distilleries would make Dominican bay oil more homogenic, and would likely increase quality and value on bay oil.

In Table 5, different scenarios for variation in pay-off time is shown. It shows that building an artisanal distillery likely is a good investment irrespectively of variations in product value, production costs and decreased production cost. One of the most important aspects seems to be the number of batches made per year.

According to the DEOSC, a new industrial distillery is the most important aspect of developing the sector. The result from Table 6 shows that it is a good investment, and other benefits are modernisation of the sector as well as yielding a more homogenic product in Dominica. An industrial distillery would be more autonomous than an artisanal, hence require less workload. However, is it really a good investment if the current capacity of artisanal distilleries is enough if used efficiently, as shown in Figure 18? If this distillery would contribute with 90% of Dominica's capacity it would be in competition with the artisanal distilleries. This could pose a threat to their profits as Table 5 shows that 90% less than maximum productivity result in a 17 year pay-off time for artisanal distilleries compared to Figure 18.

6.4. Human Resources

In Figure 19, it is illustrated that less than 500 workers are necessary to produce what is believed to be the maximum production capacity determined by the trees. There are likely 500 people working with bay oil, indicating enough labour. However, it is believed that a majority of farmers have other main employments and sources of income. This makes labour availability difficult to determine.

Currently, bay farming requires heavy work in the exposure of the weather, to a minimum pay. One of the stakeholders that was interviewed gave his view on the difficulties in finding labour and two other stakeholders said it is difficult to engage people in farming, especially the young. In general, the farmers interviewed all agreed on a need for less workload, a higher pay and modernisation of the industry. They believe this is key to attract younger people into farming and into the bay oil production.

Less workload can be achieved through modernisation, of which some suggestions were mentioned in chapter 6.1., 6.2. and 6.3. In regards to a higher pay, this is likely essential to preserve and develop the production. According to the pay-off analyses, Table 5 and Table 6, a higher pay would be feasible if the value of the oil is increased. This is limited by the market, discussed in chapter 6.5.

6.5. Market and Product Value

Continuous propagation of trees and rejuvenation among workers is vital to achieve a sustainable industry. Attracting new farmers, especially among the young people, has been established as a challenge in the report, and modernisation and a higher pay could be part of the solution.

In chapter 5.2.1. it is estimated that an increase of pay to farmers would require an increase of value for bay oil to at least EC$ 229/lbs (US$ 187/kg). Although this analysis neglects a corresponding increase of pay for transport, wood fuel and maintenance of fields and distilleries, Table 4 gives an indication of what the price could be to give farmers a more decent pay. Table 5 indicate that the value of the product paid to farmers need to increase to cover the increased cost of labour.

In chapter 4.2.1. it is stated that the current price on the global market is almost 20 times higher than what farmers are paid currently, and it is about 10 times higher than what is required to give farmers a more decent pay. Although it is unknown if this value is sustainable in the long term for e.g. industries which procure large quantities, it is an indication that there is room in the market to increase the pay for farmers.

To achieve this, a higher portion of the value needs to be added in Dominica. As it is uncertain what happens with the bay oil after it leaves Dominica and why the value is increased after leaving the island, it is difficult to specify what improvements can be done. One suggestion is to look broad for customers and demand a higher price to reach Dominica when negotiating with customers and brokers. Another solution is to increase the value in Dominica. This could be done through e.g. different certificates, such as the ones mentioned in section 4.2.3.3.

One of the challenges with regaining the market after the years of struggle since Erika in 2019 could be to compete with WONF. However, the organic product cannot be replaced in aromatherapy, bay rum or mosquito repellent. Many of the buyers also stated that the scent

from WONF is less desirable than real bay oil, indicating that it likely will be able to regain market position. Buyers mentioned stability in the market as key to achieve this.

6.6. Other Aspects

Bay oil has a strong tradition in agriculture in Dominica, and it has a high value in culture to many of the people interviewed. To many people in Dominica, it is also a vital source of income. On a global level, it is a cherished product, highly appreciated in a variety of products.

The bay tree is well adapted to the climate in Dominica, and farmers claimed that although they have lost some bay trees in storms and hurricanes, bay survives better than other tree crops. In other words, bay is a resilient tree and might be a secure crop if natural disasters due to tropical cyclones increase.

Further, bay trees are more beneficial to the environment than other agricultural tree crops, mentioned in chapter 4.1.1.1. Bay fields are used for intercropping in Dominica, decreasing the need for pesticides. Currently, bay oil is produced with wood fuel, a renewable source of energy and does not contribute to greenhouse gas emissions. It is recommended to find other sources of energy for the industrial production than kerosene oil, maybe geothermal power, to prevent further global warming.

6.7. Future Improvements

Several simplifications and assumptions have been made in the calculations of this report. Therefore, it is recommended to improve the statistics on bay tree acreages, the number of distilleries and their capacities and other uncertainties before acting on the recommendations presented in this chapter.

6.8. Reference Reliability

Some of the references used in this report, especially regarding usage areas, are of less credibility. Some statements in this report need further research to be established.

7. Conclusions

The last couple of years, several things have happened to the bay oil industry which interrupts the supply chain. These include loss of trees, labour, and distilleries, as well as decreased accessibility. This has resulted in a lower productivity, which in turn has resulted in an unstable market difficult to analyse.

The current production capacity is likely lower than before Erika in 2015. It is necessary to invest in rejuvenation to achieve the earlier production levels as trees are the main limiting factor. This puts a higher pressure on utilizing the trees and distilleries more efficiently.

The price of the oil paid to the farmers need to increase to get more investments and raise the attractiveness of the profession. Another important aspect is to facilitate the labour intensity and modernization. A few examples mentioned by farmers are installation of zip lines, access to motor grass cutters and easier maintained distilleries.

An alternative to easier maintained distilleries is the construction of an industrial distillery. This could contribute to many benefits, such as a more stable product quality and modernization of production attracting more workers. However, it would compete with the already rebuilt artisanal distilleries.

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9. Appendix

9.1. Bay Tree

There seems to be a general confusion of what a bay tree, and its essential oil bay oil, really is. According to AyurvedicOils (2019), there are several tree species worldwide not related to each other that goes under the common name bay tree. One with a Mediterranean origin: *Laurus nobilis*, another is the *Cinnamomum tamala* from India, the West Indian bay leaf *Pimenta racemosa*, the Indonesian *Syzygium polyanthum*, a Mexican species with the Latin name *Litsea glaucescens* and *Umbelluria californica*, native to California.

The two that seem to be causing most confusion are *Pimenta racemosa* and *Laurus nobilis* (Mercola 2015). As a consequence, the stories of its history, origin of the plant and its areas of usage is very varied. The species grown in Dominica is most likely *P. racemosa* of the Myrtle family (*Myrtaceae*), which could originate from India (A Virtual Dominica 2018), although most likely it is native to the West Indies (Deviha, 2018; AyurvedicOils, 2019; Nature in Bottle, 2019; Moharram et al, 2018; Wikipedia 2019), while *Laurus nobilis* of the *Lauraceae* family is native to the Mediterranean area (AyurvedicOils, 2019). Alternatively, one source claims that the West Indian Bay essential oil is extracted from the *Laurus nobilis* tree, native to the West Indies, Venezuela and Guianas, although today mostly obtained in Morocco and Spain (Esoteric Oils, 2020).

To further confuse things, there are several varieties of *P. racemosa* such as var. *terebinthina*,var. *grisea*, var. *ozua*, var. *hispaniolensis* and var. *racemosa*. It is most likely only the latter one that is used for producing essential oil, while accidental mix of var. *grisea* has a severely negative impact on the quality (Wardini, 2016). Its scent has a more characteristic of lemon or anise (Childers et al 1945) compared to var. *racemosa*.

9.2. Living expenses in Dominica

Information in Table 7 is provided by Numbeo (2019) if not otherwise specified.

Table 7

Commodity	**Currency [XCD /USD/SEK]**
Eggs, 12	11/4.1/39.6
Fresh loaf of bread 1 lbs (0.5 kg)	(3.1/1.1/11)
Cheese 1 lbs (1 kg)	11.4/ 4.2/40.9 (25/9.3/90)
Average restaurant lunch	20/7.4/72
1 Bedroom apartment outside city, monthly rent	500/185/1,800
3 Bedroom apartment inside city, monthly rent	2,500/925/9,000
Electricity, 1 kWh residential*	1.04/0.384/3.744

Electricity, 1 kWh industrial *	1.01/0.375/3.636
Gasoline, 1 gallon (1 litre)	(3.1/1.1/11)
Preschool full day, private, monthly, 1 child	425/157.3/1,530
1 month prepaid phone plan (minutes, sms, data)	100/37/360

* National Renewable Energy Laboratory (2015)

9.3. Components

	Contreras-Moreno			https://uncategory.com/bay-oil/	https://essentialoils.co.za/essential-oils/bay.htm	McHale (1977)
Compound	LO*	HO*	RI			
3-Hexen-1-ol, (Z)	0.6		849			
α-Pinene	0.5		936	minor	present	0.1
1-Octen-3-ol	2.2	0.3	977			
Myrcene	11.7	1.5	989	25.1% – 29.4%	present	13.9
α-phellandrene	0.8		1003			0.4
p-cymene	1	0.2	1025			0.1
Limonene	5.4	0.9	1030	3.0% – 4.0%	present	1.4
1,8-cineole	2.9	0.3	1033		0.2	
β-ocimene	0.2		1049			0.4
Linalool	4.4	0.7	1100	minor	present	1.7
4-Terpineol	0.9	0.2	1178			0.3
α-Terpineol	1.3	0.2	1190	minor	present	0.1
Chavicol	6	9.3	1259	7.1% – 9.3%)	present	21.6
Eugenol	60.4	82.9	1364	45.2% – 52.7%	present	56.2
α-Copaene	0.3	0.2	1377			

Trans-(β)-caryo-phyllene	0.7	0.5	1417			
δ-cadinene	0.8	0.7	1524			
8-cineole				2.1% – 3.2		
neral				minor	present	
β-pinene				minor	Present	
Geranyl acetate				minor	present	
methyl chavicol					present	
β-Pellandrene						0.4
Octan-3-one						0.1
Terpinolene						0.1
Octan-3-ol						0.1
C15H24						0.2

9.4. Distilleries

Status: 0-2, where 0 is non-operational, 1 is under reconstruction, 2 is in operation
Access: 0-2, where 0 is access by walking, 1 is motorable accessibility, 2 is accessible from highway.
Maximum capacity: production capacity, in [lbs], (kg), {bottles}

Distillery	**Status**	**Condition**	**Access**	**Capacity** [lbs] (kg) {bottles}
1	0	Roof is missing, would also need to fix water pipesystem and access to water.	2	-
2	0	Pot is missing, other essential parts needed	2	-
3	1	Needs new roof, separator and seal leaks	2	-
4	0	No roof, overgrown, vital parts missing	2	
5	2	In operation since 2018. Roof and wall exists, Old style condenses. Ziplines installed.	1	[10.5] (4.8) {7}
6	2	GEF project, roof and concrete wall exists. Old Style condenser. Electricity and toilet available.	2	?
7	0	Destroyed in Maria	1	-
8	2	Walls and roof exists. Good layout for management. Modern Condenser.	1	?

9	2	Built in May 2019, used every day. Walls and Roof. Good layout for management. Modern condenser.	1	[7.5] (3.4) {5}
10	2	Roof and wall exists. Needs some operational improvements.	1	[13.5] (6.1) {9}
11	2	Roof and walls exists	2	?
12	2	Walls and Roof exists. Good separation system. Served 12 farmers since reconstruction in June 2018.	1	[7.5] (3.4) {5}
13	0	Destroyed in Maria. Only vat left.	1	-
14	0	Destroyed in Maria. Only vat left.	1	-
15	2	Serves mainly the owner. Roof and Walls Exists.	0	[15] (6.8) {10}
16	2	GEF Project. Roof and Walls exists.	1	?
17	2	Operational September 2019. Roof and partially walls exists.	2	[10.5] (4.8) {7}
Average maximum capacity				[10.75] (4.8) {7.2)