CHALMERS
UNIVERSITY OF TECHNOLOGY

A sustainable model for urban forestry

María Nortes Parra

Department of Product and Production Development

Chalmers University of Technology

Gothenburg, Sweden 2017

Master´s Thesis 2017

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1 INTRODUCTION

The background of the thesis is described in this section. The problem that we want to analyse will be put into context by naming data that make this study interesting to investigate, as well as other researchers who have been concerned. Likewise, the purpose of the work and the areas to be studied and improved will be defined (Moore, 2000).

Climate change, also known as global warming, is caused due to the alteration of the greenhouse gases cycle by burning fossil fuels and therefore increasing carbon dioxide emissions (CO_2) to the atmosphere. Consequently, global warming is causing temperatures to rise. It is a current global concern, so most countries around the word are committed (170 countries) with the Kyoto protocol targeting a reduction of greenhouse gas emissions, based on the premise that global warming exists and human – made CO_2 emissions have caused it (Dr. Sebastian Oberthür, 1999). Since this issue is to be solved on a large scale, politicians would have to change the law (Dr. Sebastian Oberthür, 1999) to help people improve the system in a sustainable way, and on a low scale, citizens have to get involved in this problem recycling or buying products whose production process are environmentally friendly.

Faced with this global problem, one of the challenges facing mankind is to find a way to mitigate climate change. Added to this problem the sources that we use are limited. So we must find other sources of energy that are "green", that is to say, they do not emit carbon dioxide (CO_2) and are renewable. Currently, some renewable sources which meet those characteristics, such as electrical sources and biomass (Boyle, 1997), have been found.

Forests have been receiving considerable interest as a climate change mitigation (Nabuurs, 2007) due to the fact that they store about 45% of terrestrial carbon and can sequester large amounts of carbon dioxide annually (Bonan, 2008), and, precisely, CO_2 emissions are the main cause of global warming (Dr. Sebastian Oberthür, 1999). Nevertheless, since the 1990s the world has lost about 10 million ha of net forest cover each year according to FAO (2001).

Nowadays, a controversial debate is open about which is the best way to extract wood from forests (Keenan, 1993). Most of the world´s forest extraction is based on the clear cutting process, which is not environmentally friendly because it harvests the whole forest. On the one hand, this drastic alteration in the forest makes temperature conditions more extreme and changes moisture conditions, on the other hand, it is the most economically effective method to harvest forests nowadays. The purpose of clear cutting is to prepare the stand for burning-over, seeding or plantation, increasing wood production (Heliövaara, 1984). Accordingly, other concepts to manage forest in a sustainable way have appeared, such as selection forestry and variable retention, which aim to protect natural and semi-natural forest by maintaining the social, economic and ecological value of forests (Mori, 2014). Along with sustainable forest management, protected areas play a critical role in conserving forest biodiversity and other ecosystem processes (Brooks, 2009). According to Angelstam (2004), sustainable forest management represents a vision for the forest use based on satisfying ecological, economic and social values.

Nevertheless, modern forestry management has to be improved (Carlsson, 2005); timing, transport and buffers need to be reduced in order to cut down costs and carbon dioxide emissions and, at the same time, increasing wood quality and on time delivery.

On the basis of the foregoing, climate change is a global problem, and the city of Gothenburg cannot be left behind given that, among the aims of the city, are those related to biodiversity and sustainability in forests. The city has also decided to let the land available for projects and research that want to contribute with "green" ideas that can help the environment (Göteborg stad, Forest policy, 2015). One of these projects is the Climate – KIC programme in which some companies and organizations are working together to find a sustainable business model in some areas of the city. By definition, a sustainable business model has to incorporate a triple bottom line approach considering the economic, social and environmental perspective (Bocken, 2014).

Key words: sustainability, biomass, forestry, electrical devices, global warming, value stream mapping.

1.1 POSED PROBLEM

As stated in the introduction, the climate change is a global problem in which all countries are involved. People are aware of it and willing to mitigate it. Several ideas and research to solve this problem have become a reality in the last decades (Boyle, 1997). As forests represent a contemporary interest to mitigate climate change (Nabuurs, 2007), this thesis is going to focus in possible modifications that can be applied to the current harvesting method in urban forests to make it more ecologically sustainable.

At the same time, this project is going to analyse the current process due to the existing wastes, both monetary and temporary linked to it. There are some buffers in the current supply chain where the row material quality gets spoiled, increasing the cost of the process by avoiding it and, therefore, affecting efficiency as well.

1.2 RESEARCH QUESTION

Referring to the above mentioned, a way is to be found, in which we can analyse the current process and evaluate alternatives to the traditional approach from a sustainable point of view. Steps of this way include trying to unify the environmentally sustainable green way with an optimized technical productive way. The purpose for this thesis is to evaluate the potential solutions and improvements on the combination of both ways in the forest exploitation and suggest a business model with these two assumptions.

The following research questions are linked to the posed problem:

RQ1: How can we mitigate CO_2 emissions, focusing on sustainable forestry in urban environments?

RQ2: How can technology devices/machinery be developed to help solving this problem?

RQ3: Which important factors should a sustainable business model address in order to be able to mitigate this problem?

The first point to answer these questions is to research about the current situation in forestry, looking for different ways to work on the land (RQ1), with Gothenburg Region as a potential case. Once the barriers and the challenges in the city are defined, technical knowledge will be applied in order to solve the challenge (RQ2) and find a way to develop a business model which motivates investments for these solutions (RQ3).

1.3 LIMITATIONS

In order to implement the results in practical forestry, this research is carried out in and around the region of Gothenburg. Nowadays, there is no forest where we can test this idea and verify the model, so it is impossible to quantify data to compare the current method with the optimized modification of the current process. In order to solve this problem, the support of some experienced people in the topic will be necessary. They can check the research idea and verify some assumptions.

1.4 STAKEHOLDERS

This section describes the different stakeholders of this project: the first ones with ecological knowledge and concerned with the sustainability of forests and environmentally friendly technologies and innovations; the second ones are more interested in technical applications but are also connected to the mitigation of climate change; and, finally, the ones that want a mix of these two topics, they are the customers, and they are worried about the ecological process as well as about the effectiveness and reduction of costs.

Field	Definition	Benefit
Ecological companies/people	Have experience in sustainable environment, forest and environmental friendly methods	Have a sustainable solution that can be carried out in their forests
Institutions	Cities with forests in and around them	Cities can implement a sustainable business model improving their environmental policies and at the same time create employment
Academic	Sustainable business developers and climate change mitigation	Technical knowledge and some useful tools to apply to the thesis. Solve some doubt about the thesis and structure
Electrical devices	Green technology, forestry tool companies and electrical devices	It is an opportunity to use their electrical machineries in a sustainable process and extend their applications
Forest companies	Saw-, pulp- mills. Companies with a forest related business	Improve their process with the optimization in modern forestry
Customers	Carpenters or wood companies that buy wood from forest companies and whose products are wood based	High quality of wood for their products. Sustainable wood goods as a corporate image improvement
Citizens	Habitants that enjoy hiking in forest and are worried about sustainability and environmental processes	Sustainable forest to enjoy

Table 1 Stakeholders.

1.5 CHALLENGES

The following challenges are to face in solving the research questions:

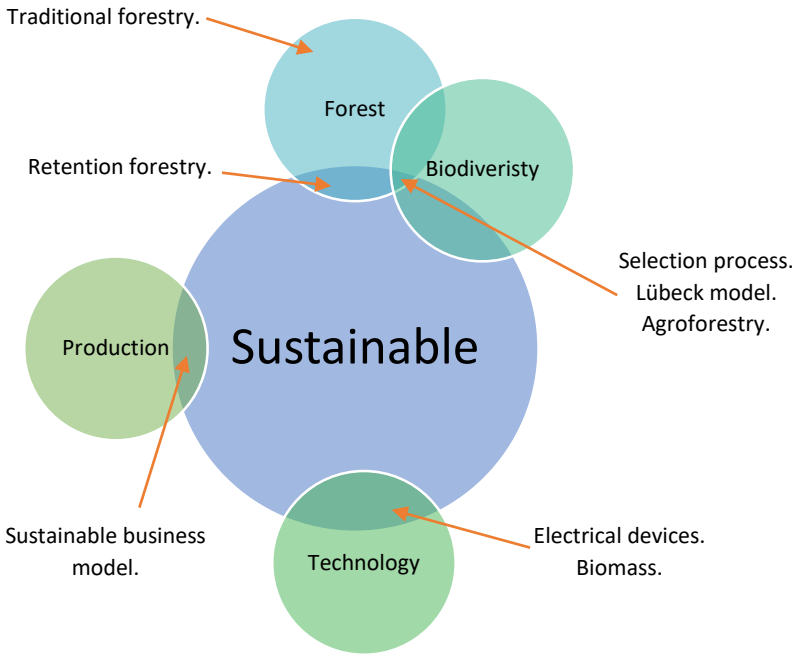
- To find a sustainable way that can be implement in urban and peri-urban forest raising the local market and promoting biodiversity.

To optimize the current harvested process, reducing lead times and buffers in order to keep wood quality in an environmentally friendly way.

2 FRAME OF REFERENCE

In the section below, an introduction of the study is conducted displaying a more specific vision on the subject while considering some methods to solve the problem raised.

To reach a solution and respond the research questions, an outline of the current situation is necessary, where all the required elements to solve the problem and understand the need to investigate it are considered. This section delves into different elements related to sustainability, the ones that may help to mitigate climate change. The points that will be approached are shown in the next image, they are: forests, biodiversity, production and technology. All of them have to be managed in a sustainable way.



2.1 FOREST AS CLIMATE CHANGE MITIGATION

According to Canadell (2008), forests can contribute to the climate change mitigation through carbon sequestration as well as by offering economic, environmental and sociocultural benefits. That is one of the reasons why forests are included in this thesis as an essential part of the research.

The forest industry is very important in many countries such as Chile, Sweden, Canada, Finland and New Zealand. Forests provide both products, such as wood and biomass, and services, which are used for leisure by inhabitants. Planning problems in forestry cover planting, road building, harvesting, transportation and production saw, pulp, paper – mills and heating plants. For more than 30 years, a lot of industries have tried to improve the modern harvesting process in light of deforestation and the direct connection between clear cutting, which is the current harvesting method, and climate change (Rönnqvist, 2003). Interest in the forest has changed over the years, forestry has been focusing on multiple values in addition to timber production. Biodiversity has

been one of the crucial issues (Bengtsson, 2000). The importance of biodiversity has been taken into account in numerous studies demonstrating that managing the ecosystem to maintain biodiversity has many practical benefits (Duffy, 2009).

2.1.1 Modern harvesting process: traditional forestry

Nordic countries are forest-dominated, with approximately 60% of the area covered with forests (FAO,2006) located in the boreal and hemi boreal forest (Ahti, 1968). Being mostly private, the ownership is divided, 79% private and only 24% belonging to public organizations.

Since decades, mechanized logging operations have been put to practise and now more than 90% of all the productive forestland on the Nordic countries is managed with modern forestry based on the clear cutting harvesting system (MCPFE, 2007). This process and the subsequent artificial replanting causes many species not to regenerate in this type of forest that are classified as homogenous young forest. This fact generates a decrease in biodiversity (Niemelä,1993).

To preserve biodiversity is important with the aim of maintaining raw materials such as food and fresh water. This helps prevent insect pests and floods, i.e. if we preserve biodiversity we will help mitigate climate change and we can continue to enjoy the natural resources that we use daily for food, energy, construction, etc. (Dunlop,2013). The maintenance of biodiversity is carried out by the sustainable forest management that will be discussed later in this section.

Clear cutting is the reason why the Sweden forest section has ranked the lowest in EPI 2016 (Environmental Performance Index). EPI provides a global view of environmental performance and country by country metrics to provide foundation on the decision-making process. Launched at the World Economic forum, the EPI is in its 15th year, more relevant than ever and trying to achieve the United Nations' Sustainable Development Goals as well as carrying out the recent international climate change agreement (Khramov, 2013). The section of forests shows the number of trees that have been lost from 2000 to 2014. According to the Global Forest Watch, this measure considers both dead trees and those that have been harvested. This comparison is made in those areas where the trees cover at least 30% of the surface, the minimum percentage to be considered a forest.

NAME OF INDICATOR	SCORE	RANK	10 YEAR CHANGE
Health Impacts	99.03	5	1.57%
Air Quality	93.26	22	3.37%
Water and Sanitation	99.57	16	-0.03%
Water Resources	96.08	12	0%
Agriculture	100	1	7.3%
Forests	16.32	107	0%
Fisheries	50.82	63	2.58%
Biodiversity and Habitat	88.76	57	4.12%
Climate and Energy	92.73	10	0%

Figure 1 Sweden EPI indicator 2016 (Yale, 2017).

To understand this EPI indicator low score in forest section, the first step is to know how traditional forestry works, being aware of the supply chain of forestry model. The complete supply chain for a harvesting process includes harvesting, transportation of logs, production at the mills, storage, distribution to terminals and storage at terminals. The process starts at the harvesting area, where some trees are planted on a type distribution. Once they have a certain length, they are cut down and branches are removed. In most cases, the buck is done directly; in the Nordic countries, a computer on board is used with details about the bucking. These piles are moved to a clear area near to a road. If the bucked cannot be done in the harvesting area, the cut trees are picked by special machines and then the buck is place in an open area near a road. Harvesting is not a uniform process during the year, as it may be seen in Figure 2, because the machinery used damages the soil during summer, it is better to do harvesting process during winter. After that, the piles are transported to saw mills, to ship for export or pulp mills. The average time since the harvest to the pulp mill is 50 days (Carlsson, 2005). This transportation can be performed in two steps depending on the climate conditions. When the transportation is possible, it is performed directly from forest to mills, but if there is any problem during transportation, piles are delivered to intermediate terminals, increasing the cost of the process not only because it gets longer in time, but also because of the quality deterioration and reloading. Transportation can be spited in two types depending on the tree section considered: one that goes to pulp mills and another one that goes to saw mills. Usually the longer pieces are sent to sawmills because of the final product needs, while the shorter ones are sent to pulp mills. Another factor that is worth considering, is the fact that in the transportation of complete logs to mills, 50% more of the wood that we can take advantage of is being transported, since the most of it consists in humidity (Fuentes-López, 2008).

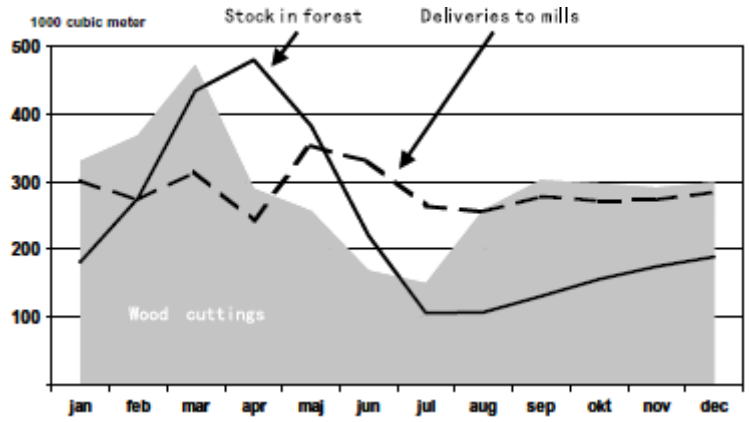


Figure 2 Annual harvesting and transportation of a company (Rönnqvist, 2003).

At sawmills, the logs are classified and sawn into boards of standard dimensions. Then they are dried and, depending on the quality and dimensions of the final product, they may be sawn again. Some sawmills have a greater variety of products and standard dimension, while others offer more specialised products. During the process, a large amount of wood chip is produced. Those are collected and transported to pulp- or paper- mills. The final product of those mills (paper-, pulp- and saw-) is later exported (Rönnqvist, 2003).

Modern forestry (industrial forestry) leaves some trees out of the process as national parks and nature reserves to preserve the biodiversity. This land is 7.7% of the global forest, for

conservation in the International Union for Conservation of Nature (IUCN). That percentage is insufficient to protect forest biodiversity (Schmitt, 2009). Due to this fact, a new direction of forest conservation has been adopted by some countries with the objective to protect forests and promote biodiversity (Lindenmayer & Franklin, 2003). Two examples of those new harvesting processes are retention forestry and selection forestry.

2.1.1.1 Retention forestry

Retention forestry (RF) is a modified form of clear-cutting that has been recently introduced in many countries. This modification attempts to conserve the biodiversity of forests with timber production and to maintain important elements during harvesting, keeping forest qualities, habitats and structures. Some of the benefits are the promotion of early species, the impact mitigation of harvesting and the improvement of the harvesting areas look. Some companies of Sweden have implemented this way of harvesting (Gustafsson, 2012).

Other countries imitate this forestry model calling it “new forestry”. Simultaneously, a critical movement started opposing the new forest implementation, and it extends until today. The quality and quantity of the implementation of retention forest is severely questioned, as well as its sustainability comparing it to a slight modification of clear-cut (Magnus Löf, 2016).

Figure 3 Retention forestry.

The main difference between traditional forestry and retention forestry is that trees are advisedly selected and left in the forest to sustain biodiversity. Heavy machinery is still used in this process, thus the disadvantages of the traditional forestry related to heavy logging remain in the retention forestry. These disadvantages are altered light, humidity and wind speed, consequently forcing the species to adapt to these new conditions, different from closed forests (Heithecker, 2007). Nevertheless, this fact might increase the number of species where their habitats are open (Swanson, 2011). Fedrowitz, and other researchers (2014) carried out a meta-analysis to study and check whether retain forestry help to conserve biodiversity. Their conclusion was that retention forestry is more beneficial to biodiversity than clear cutting.

2.1.1.2 Selection cutting

In this method, the harvesting process is executed in a way that considers the different tree species and ages in the forest. This fact gives to the forest a biodiversity. There are no drastic intrusions into the forest, thus the method is respectful with the environment and helps the natural cycle preventing pests and diseases from forming in the forest (Zviedris, 1949). Once the cut is accomplished, the forest owner needs no artificial regeneration (Mangalis, 2004). This

results in a cost decrease compared to the clear cut process. The ideal time to cut the tree starts after the diameter of the trunk has exceeded the diameter limit.

Compared to clear cutting, selection cutting is more environmentally friendly because the biological rhythm of a clear cutting harvested forest cannot recompose for several years (Miezite, 2006). The aim of applying selection cutting is to maintain biodiversity, stability and provide forest functions in collective nature and social system, which is one of the sustainable forest resource management preconditions (Lindenmayer, 2006).

The Lübeck model is a variation of selection cutting. This model is based on a selective logging but the selection of trees at the time of logging is different, because another environmentally respectful harvesting way is performed. This procedure is carried out by forest experts with years of experience in this sector (Karlsson, 2017). This new model of logging started in a village in Germany called Lübeck and some countries, such as Sweden, are imitating it due to the benefits conserving biodiversity of forests. In doing so, pests and floods are avoided, thus costs on chemicals to disinfect the forest can be cut back. The wood quality is higher, causing the market price to increase. After logging, the forest still looks good and people who like to go walking in the woods can enjoy it. There is little research to contrast long-term results with current logging methods because selective logging is a process that is being recently implemented. Nevertheless, the few works on the matter show positive results, as the research carried out in west Africa where an increase of biomass was verified when performing selective logging (Sawadogo, 2005).

2.2 AGROFORESTRY

Agroforestry is another very important technique in the climate change mitigation. About it displays trees and shrubs between grasslands or agricultural areas. In doing so, several species of plantations promote biodiversity in a sustainable way. There are a number of studies on how climate change can be mitigated through carbon sequestration thanks to trees, while crops adapt to climate change, because in areas like Africa many people rely on their agricultural crops to subsist (Mbow, 2014). Retention studies have also been found on the possible amount of carbon sequestration through agroforestry (Lal, 2004), and also on the need to involve both political and socio-economic forces to implement the agroforestry process and consequently face the existing problem on the high costs of measuring carbon sequestration (Torres, 2010).

2.3 SUSTAINABILITY

The following is a definition for the term provided by ITTO, Criteria and Indicators for Sustainable Management of Natural Forest in 1998: “Sustainable forest management is the process of managing forest to achieve one or more clearly specified objectives of management with regard to the production of a continuous flow of desired forest products and services, without undue reduction of its inherent values and future productivity and without undue undesirable effects on the physical and social environment”.

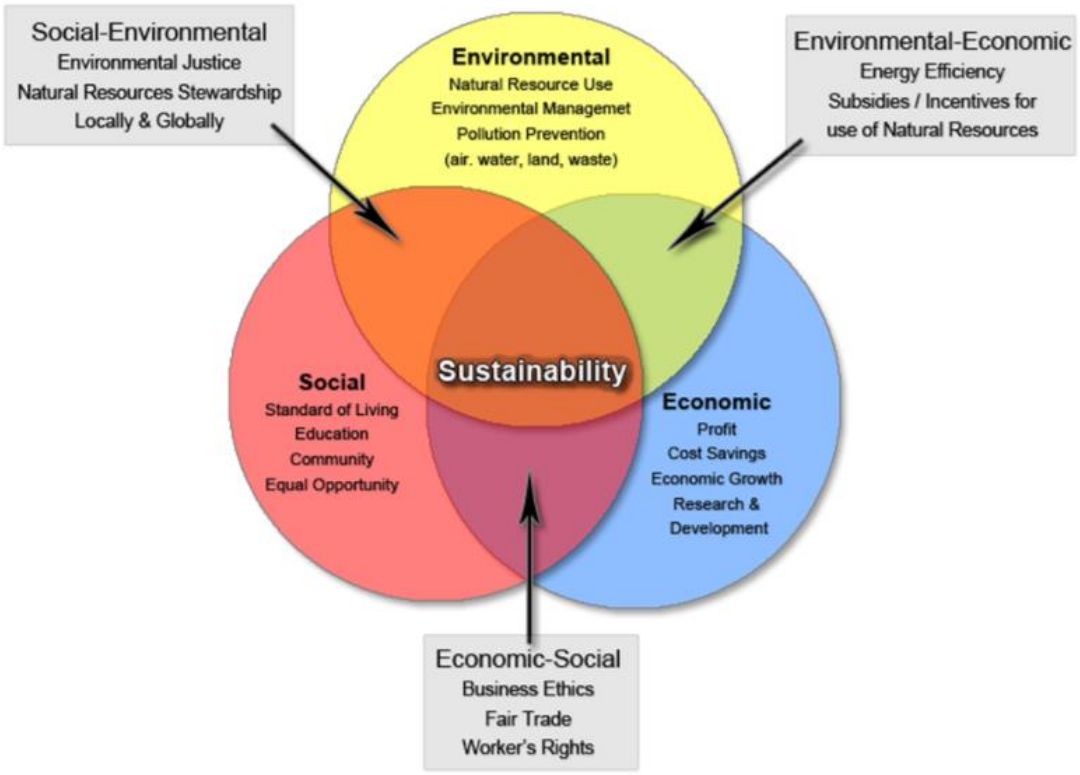


Figure 4 The three spheres of sustainability (University of Michigan, 2002).

2.3.1 Sustainable production

One of the causes of global warming, which has generated this globalized alarm towards a more sustainable and environmentally friendly world, has been the industrialisation of several products. Therefore, many companies are on board to develop a more sustainable production of their products (Vergragt, 2015).

The Lowell Center for Sustainable Production defines the term as: "The creation of goods and services using processes and systems that are: non-polluting; conserving energy and natural resources; economically viable; safe and healthful for workers, communities, and consumers; and, socially and creatively rewarding for all working people."

There are some indicators in order to achieve and get a sustainable production in factories which are related to the environment: measuring the emission of carbon during the process, the amount of energy used per product, the percentage of raw material from renewable resources, and also measuring the correct implementation of the process to achieve a sustainable production. Those indicators help companies to be more sustainable and to mitigate climate change (Veleva, 2001).

2.3.2 Sustainable forestry management

Forestry needs to be managed in a sustainable way, since, as it was already mentioned above, forests are key to mitigate climate change. The sustainable forest management needs to be respectful with the environment, as well as social and economic viable. Therefore, different objectives have to be met, and sustainable forest management must define a balance between the different tasks that are ahead (Higman, 2013).

A sustainable forest management presents some advantages for the three different approaches upon which sustainability is based, i.e. social, economic and environmental. Under a social point of view, sustainable forest management may help reducing poverty, since it promotes opportunities for local enterprises, translated as subsistence for the people. It also has to be environmentally friendly in order to mitigate climate change and carbon retention. The governance is essential in this aspect to create the right environment for sustainable forest management in the long term (Higman, 2013).

The future of sustainable forest is determined by the individual actions of governments, businesses and communities. There are already some companies that have joined the protection of forests. One of them is the Swedish company that sells furniture, IKEA, the wood of its products come from forests that have certifications and maintain and respect the natural reserves promoting biodiversity to mitigate climate change (Djurberg, 2004)

There should be a balance of forest income due to timber production and timber conservation by maintaining forest biodiversity, but a way to measure is needed. Lindner (2010) and his team have developed a tool called ToSIA (Tool Sustainable Index Assessment) for assessing sustainability impacts of forest-wood chains (FWCs). The tool calculates sustainability values as products of the relative indicator values multiplied with the material flow entering the process. Calculated sustainability values are then aggregated for the segments of the FWC or for the complete chain. The sustainability impact assessment requires carefully specified system boundaries. ToSIA offers a transparent and consistent methodological framework to assess sustainability impacts in the forest sector.

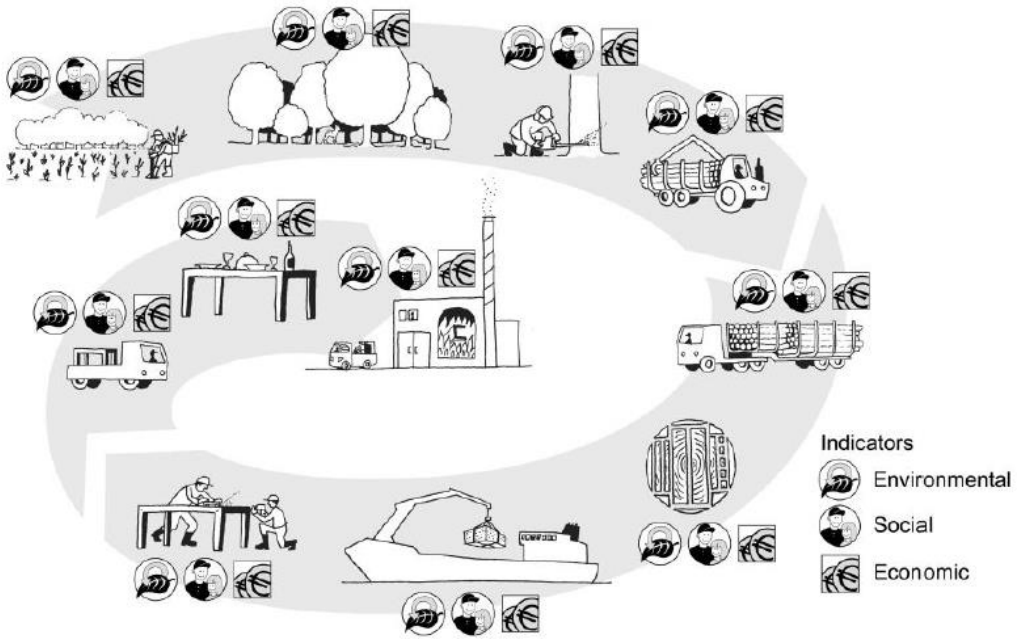


Figure 5 ToSIA analyses sustainability impacts of FWCs (Lindner, 2010).

The environmental index is quite hard to measure (Nilsson, 2017) because the consequences will be visible in the long term but not raising immediate awareness.

2.3.3 Sustainable business model

In order to generate an income from the forest in a sustainable way, a business model is interesting and necessary in which our idea can be structured and transformed into a company.

The difference between a business model and a Sustainable Business Model (SBM) is that a SBM incorporates a triple bottom line approach and considers a wider range of stakeholder interests, including environmental and society. Their importance in driving and implementing corporate innovation for sustainability is relevant. SBM can also help embed sustainability into business purposes and processes and serve as a key driver of competitive advantage. Sustainable business models can constitute a vehicle to coordinate the technological and the social business system – level sustainability (Bocken, 2014)

2.3.4 Sustainable technology and energy

Other tools to mitigate climate change are the advances related to the reduction of carbon emissions made in technology. To this point, we have been searching a way for carbon retention, but electrical devices have stopped generating carbon emissions.

The technological aspect had to be adapted to face climate change as well, and in the effort to mitigate it, several possibilities are available, in which this change has occurred, such as solar or wind energy and bioenergy. Technology is one of the keys to mitigate climate change, with bioenergy and carbon capture for storage, as well as electricity, being outlined as the most important choices (Kriegler, 2014).

Due to the increase in fuel prices since it is a limited energy and the environmental deterioration caused by greenhouse gases, commercialisation of the timber market has increased, according to FAO statistics, due to the energy demand of biomass to be a substitute of gasoline (Picchio, 2012). This biomass can be transformed into any state (solid, liquid and gaseous) to produce biofuel. It is generally accepted that biomass does not generate carbon emissions since the few that it generates are neutralized with the forests that are planted to produce this biomass (Vassilev, 2015). This is not entirely true since there are some carbon emissions, although they are few, which should be considered (Nilsson, 2017). A great amount of research papers focus on the production of biomass regarding the advantages they present in mitigating climate change, generating several kinds of biomass depending on their origin (agricultural biomass, aquatic biomass, woody biomass…). About 95-97% of the energy used worldwide comes from the combustion of biomass, with a tendency to increase this percentage on the long-term (Vassilev, 2015). Some researchers have tackled the subject of biomass from fruit trees (Lykidis, 2014 and Aguilera, 2015), to find out how to make the most of agroforestry.

2.4 VALUE STREAM MAPPING

This tool will be used to compare the current harvesting process and the implementation of the new harvesting process. Value Stream Mapping (VSM) shows all the activities involved in the fabrication of a product, whether they add value or not, from the raw material until the product reaches the consumer (Rother, 2003). It is a tool that is applied in lean development processes, identifying the weaker points of the process, where time and money are lost, in order to improve the supply chain and reduce them or eliminate them, if possible. It is a flexible tool that can be applied in many works or even the entire assembly line (Masadynski, 2007). It is usually more effective for linear production systems, but also applicable in more complex environments by adding typical tools used in industrial engineering environments (Braglia, 2006). This tool is widely used in several industrial areas where a lean methodology is to be implemented (Seth*,

2005). The process will be more efficient to avoid waste, saving time and money, as well as satisfying the customer based on the speed increase in delivery and the decrease in product price.

2.5 BUSINESS MODEL CANVAS

Business model canvas is a tool for the design of business models, which allows guidance on the efforts of an entrepreneur so that the course is not lost and the achievement of forming a company and prosper is reached, since many companies break down after a few years for a lack of defined objectives (Hernández Camacho, 2015). Taking this into account, Osterwalder alongside Pingneur (2011), renowned lecturers and experts in business innovation, created a canvas to help generate business models. This canvas consists of nine connected modules that reflect the logic of the company to reach its revenues, covering the four main areas: customer, supply, infrastructure and economic viability. It is a preliminary project later applicable to the structure, processes and systems of a company. It is a basic and agile tool to design and innovate in the business model as well as to help develop the company's strategy. These nine modules are shown in the figure 6.

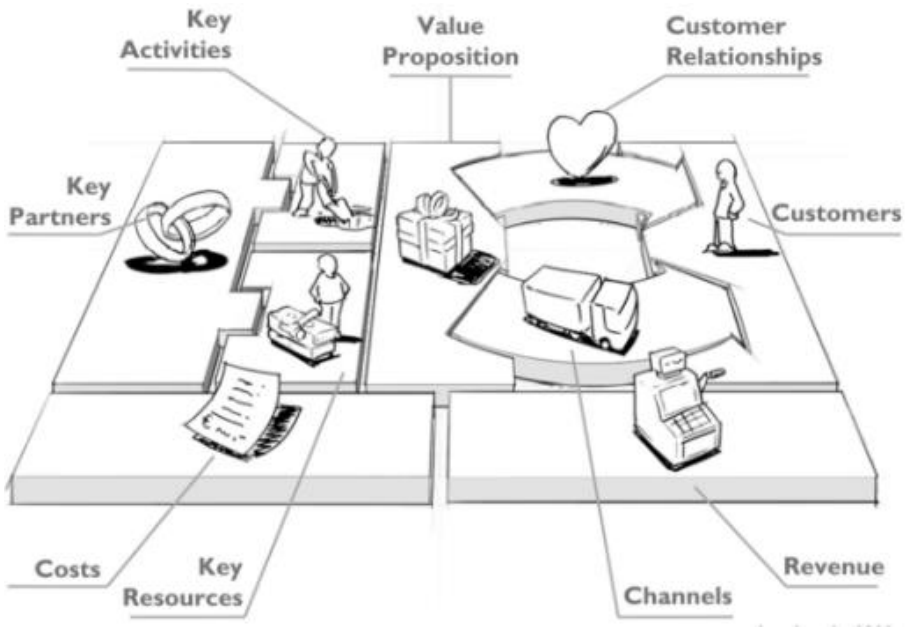


Figure 6 Modules for the canvas of business model (Osterwalder, 2014).

Before creating the business model, the entrepreneur must know if the intended product will be received in the market, so the value proposition canvas is a very useful tool before designing a business model, since it helps define the customer needs and look for the tool that best suits the company profile. This tool focuses on two blocks of the canvas business model: the value proposition and the customer segment. The value proposition canvas is structured as shown in the Figure 7. In the customer segment block, the customer problems, fears and wishes about the product, are analysed. Meanwhile, the value proposition block establishes the products or services that cover those needs and the way in which a product is to solve the fears of customers as well as is to meet the expected profits of the consumer.

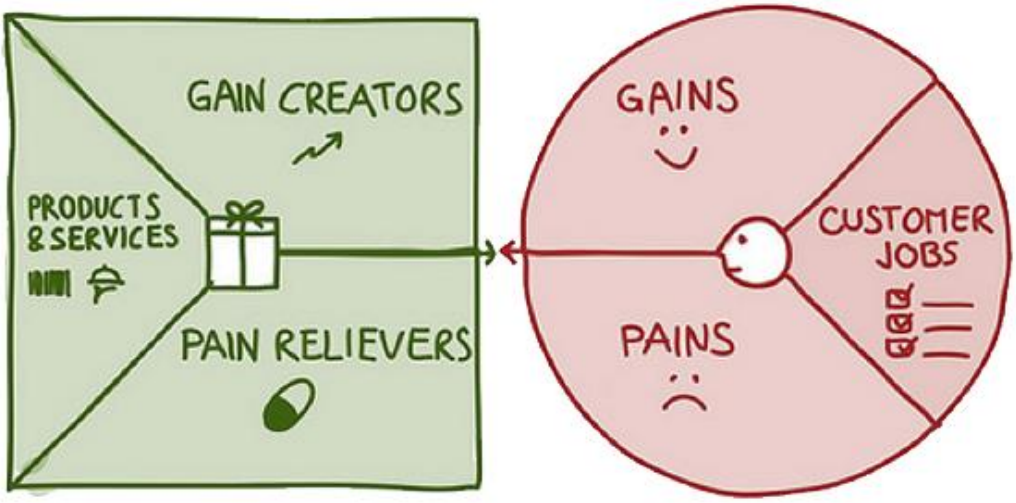


Figure 7 Structure of the value proposition canvas (Pokomá, 2015).

3 RESEARCH DESIGN

"Design deal primarily with aims, uses, purposes, intentions and plans" (Hakim, C., 2000). In this section, the followed method to analyse the Research Questions that will be addressed in this project will be outlined, as the followed steps, possible problems encountered and how to deal with these problems.

This section is linked to the previous one, since the introduction poses the questions to be investigated at a first general study, and this step indicates the way in which the solution obtained has been reached and how the entire research process has been developed.

3.1 METHODOLOGY FRAMEWORK

The research study carried out for this thesis corresponds to the flexible design (Robson, 2014). Flexible design consists of performing first a generic research on the matter of the study, looking for research gaps in the topic where a solution or improvement can be set along the process. Once this step is fulfilled, some ideas may shine on the potential concepts, research questions as well as some hypothesis to continue the study. These hypotheses will be treated as a basis for the beginning of the investigation and to verify their viability, after being compared to the collected information (Robson, 2014). During the realization of this project, an interview study related to sustainability of forestry has been undertaken to verify questions and hypothesis that have arisen during the research.

After a general research, some hypotheses are pulled out:

- The amount of the transported wood is 50% more than necessary. There are branches and some tree bark which is normally used to produce energy, but it is useless for the costumer. One solution could be to use a portable sawmill in order to transport only the wood that the costumer will use. With this solution, carbon emissions and transportation would be reduced. During the research, we have to check the viability of this solution to apply it to urban forestry in the forests of the Gothenburg region.
- Once the logging is finished, the harvested land is devastated, which is bad for the animals and the microorganism that lived there. The machinery used is heavy and invasive with the environment. One solution that may be taken into account is to generate a biodiversity in the plantation and select only the necessary trees that are going to be used. This solution could be complicated for different kinds of production but it may be useful in medium forests that are in and around the Gothenburg region. For this environmentally friendly harvesting process, light machinery as electrical saws could fit.
- The time between the cutting and the transportation is about 50 days, which generates a degradation of the wood, where fungus can grow and the wood quality could decrease. The customer can reject the product once they receive it if the quality does not meet their expectations. This problem can be solved if the customer demand and stock are planned. In order to schedule the process, the final product must be taken into account, because in order to make pieces of furniture and other wood products, the wood has to be dried.
- Another problem for the wood producer found in the forest is that the small trees planted around are eaten by elks that walk around forest. One possible solution is to

grow trees in a nursery or protect the small trees growing in the forest. An example of protection could be the following Figure:

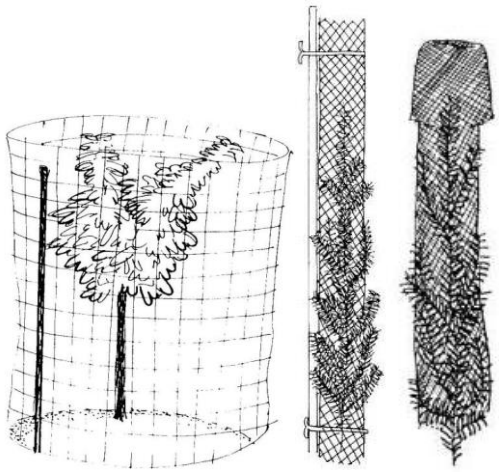


Figure 8 Example to protect trees from the elk.

- Due to the global concern about climate change, people are conscious about it and want to help to mitigate climate change. As well as the organic food market is increasing, the sustainable product market managed with a sustainable business model is available. Because the production of this products will be sustainable and environmental friendly will absorb carbon dioxide emissions.

In order to verify these hypotheses and answer the Research Questions, the research study is divided into a research and application phase. In the research phase the following topics will be investigated in order to collect enough knowledge to answer the Research Questions RQ1 and RQ2. The topics that have been investigated are:

- Current forestry and identified areas that can be improved.

- Analysis of different methods of sustainable forest management.

- Search for tools that can perform the tasks of sustainable forestry.

In the application phase, nevertheless, the research has been more specific, looking for ways to generate a sustainable forest business idea. To answer Research Question RQ3, we have investigated:

- State of the Gothenburg forests.

- Market interest in environmentally friendly and sustainable products.

- Information about sustainable business model.

According to Robson (2014), this can be considered an action research. This type of research is aimed at a modification or improvement, definitely, a change in an activity. Involving other stakeholders to achieve the research objective (Robson, 2014). Those stakeholders that have been identified in the introduction are a fundamental part of the implementation of this research.

3.2 RESEARCH PROCESS

This section details the process followed to answer the research questions, as well as the tools recurred to for this purpose. The steps followed are shown in the different parts of the project, which are: introduction, frame of reference, solution, analysis. This research process is reflected in the following Figure.

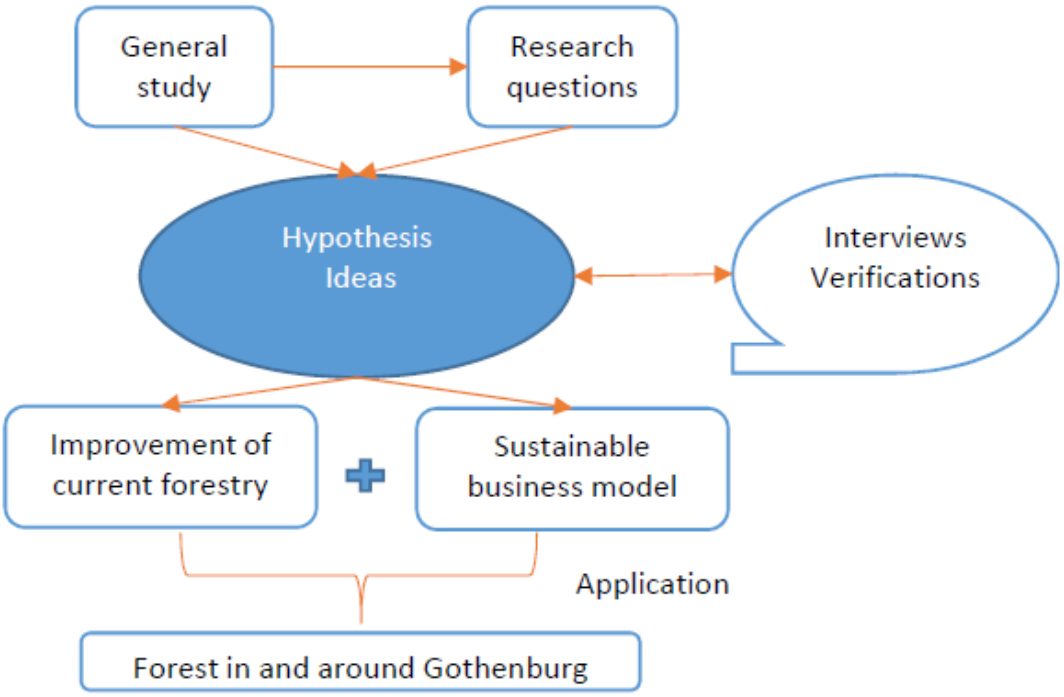


Figure 9 Research framework.

3.2.1 Outline of the thesis

In the introduction section a global vision was presented to reduce carbon dioxide emissions and addressing the challenge through sustainable forestry, determining the different points that will be highlighted throughout the project. Among the above mentioned are: mitigation of climate change through forest management, current wastes of the modern forest process and present concerns of the unsustainable way of logging with the traditional process.

Once the Research Questions are raised, information related to this topic is sought in order to answer them in the most concrete possible way. This information is included in the frame of reference. Such information primarily depicts the current way of forestry, analysing the supply chain, from harvest in the forest until the customer receives the wood based product.

In the analysis chapter, possible improvements in the process are presented in an attempt to verify them using value stream mapping. This tool helps to visualize the steps of the supply chain where wastes (e.g. time, money, buffers, overproduction are identified) to be able to work on them trying to eliminate or reduce them referring to the Lean production paradigm.

In parallel and due to the lack of sustainability of the current forestry process, alternative processes of harvesting wood from the forests are sought. A few identified alternatives are “selection cutting” and “agroforestry”. These processes are studied, with an overall ambition for

application in urban forestry. Since the machinery used today in traditional forestry is very invasive, we will look for alternative ways and potential use cases for new and improved machinery dedicated to the harvest that are environmentally friendly and are applicable to these processes.

The next step evaluates potential concepts to the urban forests in and around the Gothenburg region. Therefore, the current state of the city's forests was studied, as well as the current and normative policies that follow on urban forestry. In this investigation several stakeholders were interviewed.

Finally, an attempt to describe the concepts from a sustainability perspective is presented using business models concerning sustainable forestry in and around the region. The intention is to generate new business opportunities, focusing on employment, promotion of the local market and identifying use for sustainable forest products.

All the ideas and hypotheses generated throughout the development of the project have been contrasted by other similar studies collected in articles, books and interviews.

3.3 METHODS OF COLLECTING DATA

In order to verify the theories of the investigation, this work has resorted to related studies collected in articles, interviews and conferences, in which experts on the matter of the environmental sector were consulted. A number of them have businesses related with forests.

3.3.1 Interviews

The interviews that were conducted followed a semi-structured process. This is typical for cases when researchers want to identify structured information, feelings or beliefs about a phenomenon (Moore, 2000). Further we wanted to discuss the viability of concepts and to obtain qualitative data to measure some aspects of the investigation. Meetings conducted within the project are presented in Table 2. Three meetings were face-to-face meetings and two online meetings. Before each meeting, questions were developed to clarify concepts and to obtain qualitative data as to verify the viability of the idea.

Person	Company	Kind of meeting
Anna Ternell	COWI	Face-to-face interview, conference
Mikael Karlsson	Silvaskog	Online interview, conference
Dan Melander	BRG/Stadslandet GBG	Face-to-face interview, conference
Anders M Nilsson	Västarvet	Face-to-face interview
Björn Ohlén	Västarvet	Face-to-face interview

Table 2 Meetings.

In addition, the researcher attended a conference held to determine the KIC-Climate programme, in which ideas were generated regarding sustainable business models. The conference further presented the possibility to meet people and ask questions about data related to the project.

This conference was attended by different stakeholders from the KIC-Climate programme. They presented their ideas and projects to apply in urban and peri-urban areas of the city. Some of these ideas were in the test period, others were ideas within companies. All of them had a

common framework, to generate a business that was sustainable and promoted the local market.

The whole of the information was collected in a notebook. After the interview, these notes were reviewed and supplemented with additional interview information that had arisen during the meeting (Moore, 2000).

3.3.2 Literature review

According to Robson (2011), literature is what is already known has been researched and provides data relevant to a project. Among the reasons to carry out a literary research, the credibility acquired when it comes to doing your work is the most relevant, since it can support a work through the work of others. It also may provide knowledge and background on the subject to study helping to clarify the ideas and solve the gaps of the research.

Many of the data and information used in this project has been drawn from other research related to it, in which data had been collected and processed. This type of research has been defined as "desk research" according to Moore (2000).

The articles were selected when the title contained keywords that could be relevant as the abstract indicated that the article or book contained important information for the project. Information that referred to the text and other sections was drawn in the process of reading. The articles were found in Google Scholar and in the bookstore of Chalmers University, which has a large repository of articles and books related to the subject.

At the beginning of the research, many articles related to the environment and forests were reviewed in order to get an idea of what the harvesting process was like. Some definitions were also consulted on the internet to clarify the concepts found in articles. The consultation of articles and books has been a constant activity during this work, because there were concepts that needed clarification and ideas that appeared in the meetings or conferences, which were investigated thanks to previous studies. To verify the veracity of the information, similar concepts from a multitude of sources were reviewed to contrast differences in e.g. approaches, results and conclusions of the studies.

3.4 RELIABILITY

The study of the work must be justified in such a way as to be credible. The reliability of a study is proved when the results of the collected data is the same repeatedly; however, in a research study the reliability becomes more complicated, since the collected data come from interviews, and if they were to be repeated after a while, the answers may well vary because the situation could have slightly changed or the interviewee could have changed their mind (Moore, 2000).

To verify the consistency of this report, this work has contrasted ideas collected from interviews with studies of articles to verify the veracity of these ideas and its possible implementation. Besides, information has been collected from and contrasted with different studies that proposed the same or similar hypotheses as this research.

4 RESEARCH ANALYSIS

The Research Questions find an answer in this section following the methodology explained in the previous section. The research analysis is divided in three cases where suggested solutions are proposed. The first one is an analysis of the current harvesting process, the second one is an analysis of the selection process and the last one is an analysis of agroforestry.

As the solutions are thought to be implemented in the city, information about the situation of city forests was collected while the interviews, conferences and search for information on the web was conducted.

4.1 FORESTS IN AND AROUND THE CITY OF GOTHENBURG

Gothenburg is the second largest city in Sweden and the fifth-largest in the Nordic countries with a population of 550.000 habitants in the city and about 1 millions of habitants in the metropolitan sector. The city is located in the west coast of Sweden.

Gothenburg is a green city with about 70% (Hulter, 2013) of the urban space consisting in green areas; forests cover more than half of these areas. The Figure 10 shows the green areas and major rivers and coastlines (in blue). The green portions are forests; those can be cultivated or uncultivated areas within municipal limit and the light green neighbourhood.

Figure 10 Green areas of Gothenburg (Hulter, 2013).

Most of the land is owned by the city but it receives no attention, and it is not subjected to crops or planning. Those areas are typically left untouched, used just by grazing animals or dedicated to timber production based on monocultures that go against biodiversity, as explained in frame of reference. The city of Gothenburg is the first city that decides to change the modern harvesting method to another more environmentally friendly as selection forestry, prohibiting

clear cutting, this fact is reflected in the changes on the forest laws that are written in the forest policy (Gothenburg stand, 2015). For all those uncultivated and unplanned areas, there is a potential business in which advantage can be taken, benefiting the cultivation and forestry in a sustainable ecosystem and, at the same time, encouraging local management and products. Generating business related with the forest and agriculture, increasing the economy of the region and promoting local products while protecting biodiversity and meeting the needs of a growing population. During the recent years, foreign people are coming looking for jobs opportunities, trying to get involve in the Swedish culture.

The region of Gothenburg wants to maintain and develop forests. A diverse and environmentally friendly organisation has established a series of laws to promote and implement this. For the same purpose, this organisation has decided to make forests available to researchers or companies wishing to generate environmentally friendly services, and to improve biodiversity. As already mentioned, the city has banned clear cut process introducing the selection process and the Lübeck model which are more respectful with the environment and promote biodiversity (Gothenburgs stad, 2015).

The city owns about 60% of the land in Gothenburg and the private owners own about 40%. Public land owners are divided into two groups: the planning office and the park and nature management office. The latter one is responsible of the recreation and culture. This constitutes 11,000 ha of which 8,000 ha is forest and agricultural land. The planning office manages those areas, about 8,000 ha, where is possible to build and make infrastructure, (Naturvardsprogram Gothenburg stad, 2015).

Private forest owners belief that clear cutting is more economically viable. That thinking is changing since a few years ago; Öster (2016), in his article, debates that nowadays more forest owners think that clear cutting is economically unviable based on the low wood prices.

4.1.1 Forest supply

The current forest management plan states that approximately 115,000m^3 could be harvested during the next 20 years, between 2010 and 2020. The forests grow a 10% each year (Melander, 2017). An important issue to consider is that in some places of the forest there are no roads to transport the timber, and they cannot be built as these forests are close to residential areas. Thus, the access to the forest is becomes quite complicated for the harvesting or thinning activities. Most of the city's wood is sold to large companies related to the forestry industry in national and international markets. Information about the market of local products is not currently available, because it is necessary to do a study of the potential market and check if customer will accept it and buy local products.

4.2 CASE I: TRADITIONAL FORESTRY

Many researchers have been working in optimising the forest supply chain of the current harvesting process to produce biomass (Kanzian, 2009), furniture (Ouhimmou, 2008) or pulp (Carlsson, 2005). Those researchers focused on reducing the amount of transport between forest and mills in order to reduce the costs of the process and the delivering time. Other researchers develop an algorithm that seeks out new ways that optimise transports (Bredström, 2004). Those ways consider the distance between forests and mills, delivery times and product sequences that have to be produced each day.

As mentioned in the frame of reference, delivery time reduction is important because it entails a reduction of the process costs and also avoids wood damages. Currently, piles of logs wait in the forest to be transported to mills. This situation generates fungus and insect pests in the logs decreasing their quality. In order to avoid fungus and insect pests, it is necessary drying the wood. Drying activity maintains the wood quality and also increase the wood resistance, it is necessary to all final products related to wood.

Another information to highlight, in the current harvesting method, is that currently more than 50% of the necessary wood is transported (Fuentes-López, 2008). Trees have a high percentage of humidity and not all the wood from the tree is needed in the sawmill. There are some wood waste (chips) that are transported to the pulp mill or the heating plant, as shown in the following Figure.

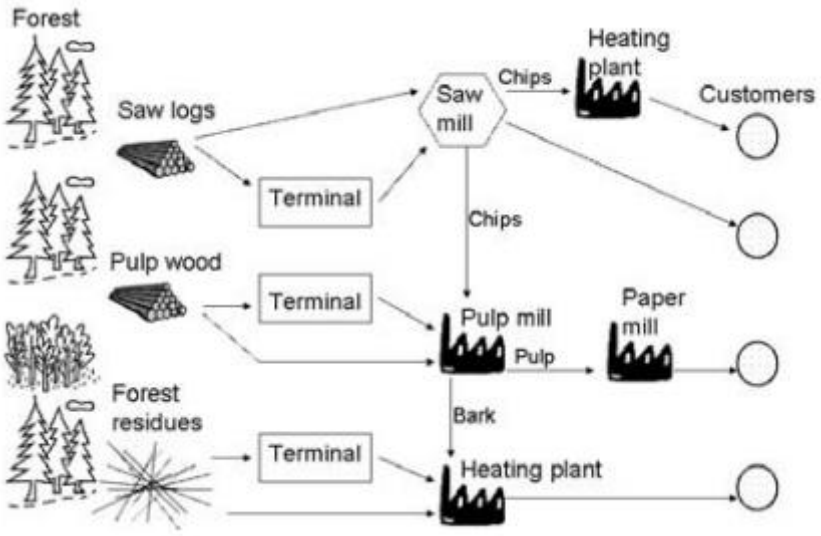


Figure 11 Parts of forest supply chain.

4.2.1 Analysis of the current harvesting process

The value stream mapping tool has been used in order to identify available optimisation activities. Value stream mapping is often used in lean environments and consists of analysing the current situation and designing flows in the system (usually material and information flows). With this tool is easy to see what points can be optimised and improved during the process. (Locher, D., 2011).

Collected data shown in Figure 12 focuses on four main activities: seedling production, silviculture, logging operations and secondary haulage. Secondary processes take place among those activities, e.g. seed production, cut-over clearing, soil clarification, natural or artificial regeneration, cleaning, logging operations and secondary haulage. Other kinds transportation are also included: transport of labour, machinery and supplies to forest work sites (Berg, S., 2005).

As shown in Figure 12, an improvement point is detected. It deals with the waiting time from the forest to the sawmill. According to Carlsson (2005), who made a research in a forest industry called Södra Cell, this step took 50 days and it may decrease the wood quality and rise the costs of the process.

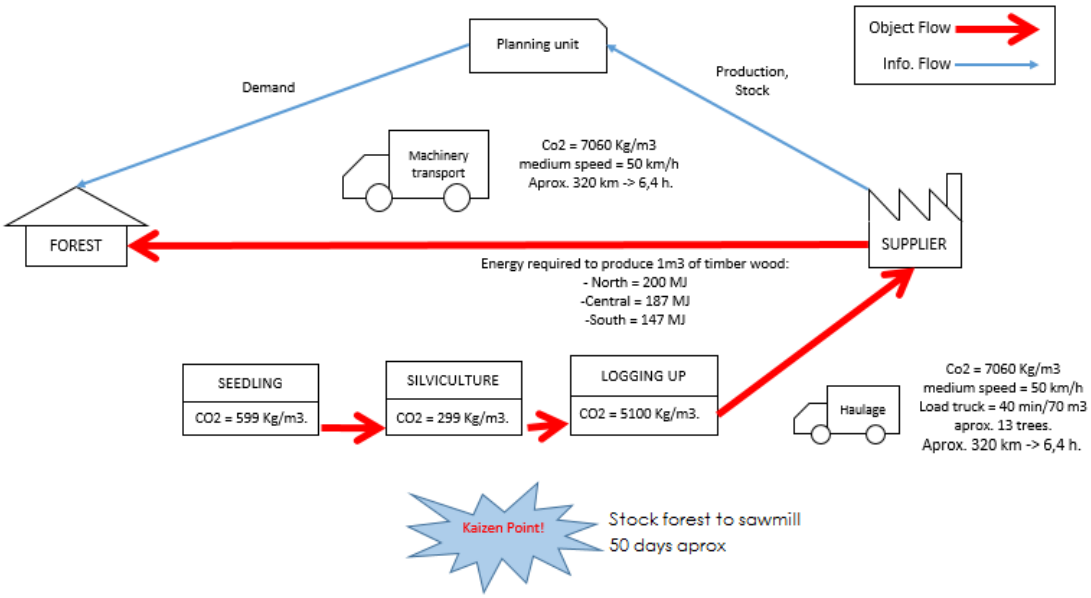


Figure 12 VSM of the currently forest situation.

4.2.2 Solution suggested

The solution suggested is to use portable sawmills. The process would be: once the harvesting process has been accomplished, logs are transported where the portable sawmill take place. Logs are sawn in the required sizes, usually there are standard sizes but it depends on the customer (Rönnqvist, M, 2003). Boards are placed in a specific position to start the drying process (Figure 13) avoiding the growth of fungus and insect pests. The remaining wood (chips) from the sawing process is transported to the heating industry or the pulp mill. This activity would decrease the transport of chips between mills, diminishing, as well, carbon dioxide emissions. Applying the drying process, the total amount of time to obtain the final product would be reduced.

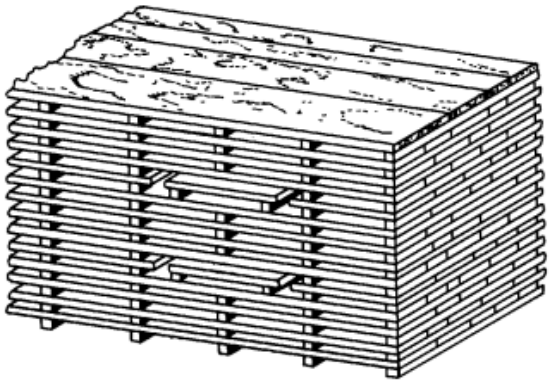


Figure 13 wood drying process (Denig, 2000).

Smorfitt (1999) shows in his article some of the many advantages of portable sawmill usage, such as: low establishment cost, flexibility with different diameters of trees, independence on delays like fixed sawmills. It has been implemented in US cities, in low scale organisations, developing rural areas (Lupo, 2010).

4.3 CASE II: SELECTIVE FORESTRY, THE LÜBECK MODEL

As commented in the frame of reference section, clear cutting process maximises forestry economy. This method generates high production with a simple process, it is an efficiently harvesting process (Heliövaara, 1984). During the past years and regarding climate change concerns, many studies have determined that clear cutting is not environmentally friendly based on its basic effects, i.e. it causes drastic temperature differences in the soil (Keenan, 1994) and reduces forest biodiversity. To avoid such effects, new harvesting processes come to light, e.g. the Lübeck model and selective process. Both follow the same procedure with the exception that the Lübeck model entails a more conservative tree selection not to interfere with the natural cycle (Karlsson, 2017).

The cut down trees in the selection cutting process are always the ones, whose trunk width exceeds the established limit and this varies depending on the tree type. Still, how does the selection cutting process affect to forest ecosystems? Piponiot research (2016) delves into the consequences of cutting big trees. Bigger trees are older and, as such, absorb less carbon dioxide. Once big trees are cut, younger trees find more place to grow stronger and have the possibility to reach for more nutrients absorbing a greater amount of carbon dioxide. Some advantages generated with the selection cutting process compared to clear cutting are: natural regeneration of trees, saving the planting cost, trees grow in a balanced ecosystem avoiding insect pests, the use of chemical products to eliminate pests is unnecessary, the price of timber rises as a consequence of the high wood quality (Hanewinkel, 2001).

The market requires currently a vast amount of wood production; for that purpose, the machinery used is powerful as well as heavy and it generates soil compaction and deterioration. This heavy machinery interferes with the stability of forest soil (Riggert, 2016) preventing long term natural regeneration (Klaes, 2016). Such soil variation is not respectful with the environment and contradicts the principles of the clear cutting process. Therefore, new environmentally friendly harvesting machines are needed. As already mentioned, the city of Gothenburg has included the selection cutting process among its forestry politics (Gothenburgs

stad, 2015). In order to accomplish this process in region forests, some tools are suggested to replace the current machinery:

- Electrical devices: Currently employed harvesting machinery damages forests, individual sawmills are suggested as a possible alternative. Some companies are researching to adapt their products to world changes as a means to mitigate climate change. Most of them are investing in machines that do not emit dioxide carbon (Boyle, 1997). An example that portrays this tendency is *Husqvarna*, which is commercialising electrical forestry machines. Such machines do not generate carbon emissions, thus, helping to mitigate climate change.

- Animal transport: The use of working animals in the forests presents multiple aspects of technical-commercial and socio cultural interest. The work they perform complements and partially replaces the human effort to carry out very heavy tasks. Animals transform crop residues productively and efficiently, and provide organic fertilizer in the form of manure that reinforces soil fertility. The use of animals creates employment opportunities not only for those who are directly involved in their use and care, but also for the small companies that prepare the sowing and assist in the work of transport; or for those who practice specialized crafts by taming the animals and teaching them the work routines, or for the artisans who work in the manufacture and maintenance of equipment and implements. Those harvesting processes that involve trunk transportation by horses, between the cutting area and the road, release fewer carbon emissions to the atmosphere than those machineries related processes (Waran, 2007). This transport promotes biodiversity because horses are not very invasive to forests and do not generate a high soil compact. Transport with horses in harvesting processes is appropriate if the terrain slope is small (Alex, 2013).

- Wires: The use of wires is the most economic and favourable method to transport wood. The surfaces need to be checked to find the more suitable ones. Since there are a lot of areas of the forest in the Gothenburg region that are inaccessible by road, this is a good method to extract trunks from the cutting area. Wires are advisable in areas with sloping terrain or hard access to machinery or other transport techniques (Samset, 2013). There are two types of wires: ground cables and air cables.

Other transports such as helicopters, zeppelins or drones were also studied. Nevertheless, helicopters turned out to be too expensive for the forestry sector. Zeppelins and drones present interesting characteristics but both need improvements to transport tonnes of product. Several research processes are being currently conducted on this matter.

4.4 CASE III: AGROFORESTRY

Agroforestry is another method to mitigate climate change, as outlined in the frame of reference section. This technique consists of a simultaneously integration of areas, pastures and animals to improve the productivity of the land, consuming resources in an efficient way. As a requirement, it has to be environmentally friendly. As it happens in forestry, today agriculture processes are based on monoculture, which is not biodiverse, and leads to drastic differences in temperatures, endangering the survival of animals and plants. This factor poses a risk for land workers, whose livelihood depends on the production of its cultivation. According to some researchers, agroforestry helps farmers of small lands to reduce the risk of climate change that jeopardises their crops. This technique uses the cultivated land in an efficient way and increases the economic benefits in 21% (Lasco, 2014 and Luedeling, 2014).

Another land cultivation related technique to mitigate climate change is farm mosaic. This method combines the cultivation of different species to promote biodiversity. The layout of these crops is placed to facilitate their production. It poses the risk to turn into a monoculture crop production if the plantation area is big. Figure 14 shows a comparison of the 3 techniques.

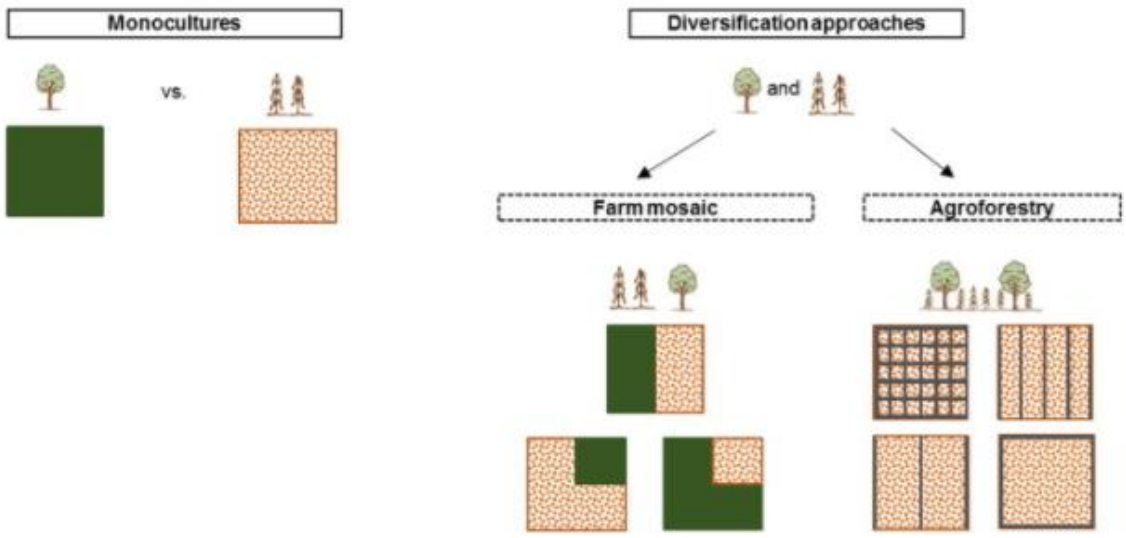


Figure 14 Different techniques for land cultivation (Paul, 2017)

Paul (2017), studied those three techniques and carried out a comparison about the economic and environmental aspects. Paul concludes that agroforestry is less affected by climate changes and generates more economic income than traditional agriculture. Meanwhile, the farm mosaic is a technic that allows land production and cultivation in an easier and more efficient way than agroforestry, since the division of plots is executed to facilitate the access for farmer machines and equipment.

4.4.1 Suggested solution

Regarding the above mentioned benefits, farm mosaic and agroforestry are the two methods proposed to carry out in the region of Gothenburg. For that purpose, the boundary between the forest and residential areas is suggested as the place to apply these cultivated methods. In those plantations a combination of fruit trees with vegetables is proposed in order to generate a constant production during the whole year. For the vegetable crops is advisable to use different species, whose plantation cycles do not overlap, to generate a rotation between agricultural crops; e.g., lettuce could be cultivated during summer and potatoes during winter.

Since food production would stay in a balanced ecosystem, insect pests number would decrease and the use of chemical products or pesticides would be unnecessary, and cultivation would be performed in an organic way. During the last years, the interest in organic products has been increasing between 20% and 50% annually. The underlying message for such interest is that customers are more concerned about their health and the environment (Tobler, 2011).

Organic waste is produced from cultivated crops. This waste can be sold to the heating industries as biomass to produce energy (Rosúa, 2012), as well as to make compost to fertilise the own crops.

5 ANALYSIS

Once solutions have been suggested in the previous section, we proceed to present the possible implementation in Gothenburg forest region. Some sustainable business ideas are shown with the value proposition canvas tool. The aim of such sustainable business is to increase the city's economy, generating new jobs and preserving the ecosystem.

Firstly, traditional forestry is compared to selection forestry, incorporating the use of portable sawmill, whose presence manifests an improvement on the current supply chain detected with the value stream mapping tool.

5.1 COMPARISON BETWEEN CASE I AND CASE II

Both harvesting methods are compared in order to estimate the differences between their carbon emissions and the time spent on each activity. As mentioned in the methodology section, those results cannot be measured because the Climate – KIC programme is at an early stage. The first test will take place in a few months, but the date has not been made public yet.

- Traditional forestry. As Figure 15 shows and was pointed out in the previous section, a waste point is detected, where the wood supply chain may be improved. This point is the amount of time required to pick the logs from the forest and transport them to the mill. This process lasts too long and the wood quality decreases, since fungi grow and the possibility of insect pests raises.

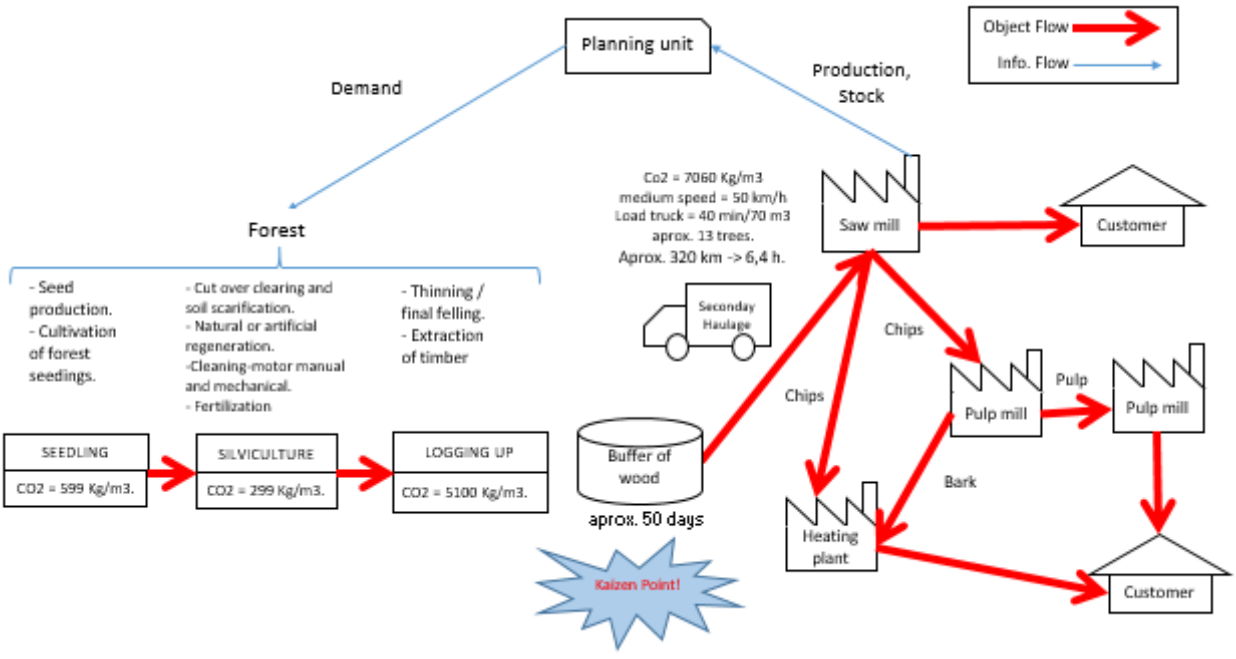


Figure 15 Traditional forestry.

- Selection forestry. In this process, as shown in Figure 16, the planting step is not needed, since a natural cycle persists and the balance among nature, biodiversity of the forest and the process is achieved, i.e. the forest is in natural equilibrium. To perform the value stream mapping, portable sawmills have been taken into account. Due to the suggested devices are electrical, those do not produce carbon emissions.

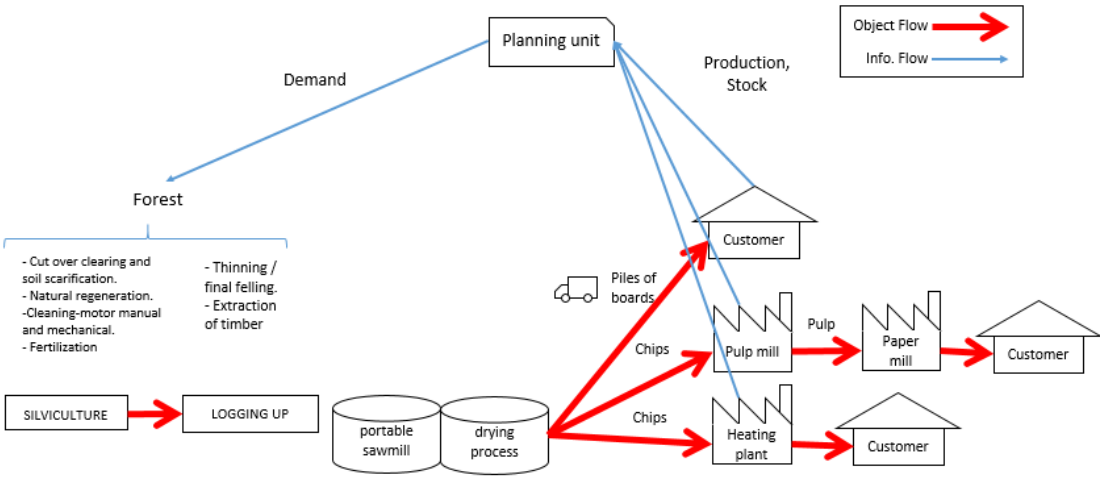


Figure 16 Selection forestry.

After analyse both situations, it is noted that the selection forestry process emit less carbon emissions to the atmosphere, due to the forest has natural regeneration because it is a biodiversity system and equilibrate with nature, it is not necessary to realize artificial planting.

Portable sawmill usage and the correct placing of boards for the drying process would help to maintain the wood quality. Regarding this last process, the drying time would be reduced and, ultimately, the production time. Drying time depends on the tree type and the width of the cut boards. Studies have determined that natural drying is effective to maintain the wood quality (Röser, 2011). Such quality is required to generate biomass among other uses, e.g.: furniture and construction.

The performance of the selection forestry process combined with portable sawmills reports an improvement on the production time of the wood, since the drying process is fulfilled sooner as in the traditional process. Transportation of chips and barks between mills would be reduced too, since such activities are carried out by portable sawmills near forests. The absence of transportation between mills would translate into a decrease of carbon emissions. Time buffers would also be reduced in the mills (pulp-, saw-, paper- mill)

5.2 BENEFITS OF URBAN FORESTS

Forests that are in and around the Gothenburg region can be called as urban - forest. According to FAO (2017), “urban and peri-urban silviculture is an integrative focus, interdisciplinary, strategic and participatory to plan and organize the forest and arboreal resources in and around cities”. It comprises the evaluation, pacification, maintaining, conservation and tracking of the forest resources and can be applied from a small scale (isolated trees) to a bigger scale (landscape and ecosystems).

Furthermore, USDA Forest service´s (2013) define urban - forest as dynamic ecosystems that generate environmental services such as clean water and air. They also help to increase air quality, generating green zones that improve social connexions and foment local economy.

Different studies emphasise the benefits of a sustainable forest management that are in and around cities, facing changes in economic, social and physical context that rise increasingly difficult challenges. Those changes are a consequence of the uncontrolled population growth. Currently, more than half world's population live in urban areas and studies forecast that this percentage will increase until 66% to 2050 (FAO, 2017). This urban growth, as it was planned wrongly, will generate a temperature increase, air contamination, soil degradation and public health problems. In the absence of integrated territory planning and sustainable strategies of urban development, quickly urbanization can damage forest and arboreal resources, reducing its contribution to the development of sustainable cities.

On the contrary, urban and peri - urban forests managed in a sustainable and healthy way can increase the city health and resilience. Irga (2015) developed a study released in Australia, demonstrating that thanks to urban forestry management, the air quality was improved in the city. Other urban forestry benefits are collected in the following table:

Urban Problems	**Possible benefits of urban and peri - urban silviculture**
Food security	Offers food, clean water and wood fuel
Urban poverty	Generates employment and increased income
Soil and landscape degradation	Improves soil conditions and avoid soil erosion
Air and acoustic contamination	Preserves and increase biodiversity
Greenhouse gas emissions	Removes polluting atmosphere and cushion the noise
Extreme meteorological phenomena	Absorbs carbon and mitigate climate change
Energy shortage	Saves energy and provides of wood fuel
Limit access to green areas	Provides shadow
Public health	Offers higher access to green areas
Water limit resources	Improves physical and mental habitants health
Limit recreation opportunities	Mitigates runoff rain waters and reduce floods
Islet heat effect	Recreation and environmental education opportunities
Runoff rain waters	Shelter offer
-	Reuse wastewater

Table 3 Benefits of urban and peri - urban forests (FAO, 2017).

5.3 SUSTAINABLE BUSINESS MODEL IN URBAN FORESTRY

To achieve the benefits afore mentioned in the Gothenburg region, the proposed process for the city collects solutions of the three suggested cases in the research analysis section. A set of these proposed solutions is shown in the following CONOPS (shown in the Figure 17). CONOPS, which stands for "CONcept of OPerationS", is a document which describes characteristics of a system proposal. It is normally used to inform about the process to all interested parties (Mostashari, 2012). CONOPS is usually use for one of the following objectives: develop a new system or product, modify or change a system or product, create a strategy involving system or products (ISO/IEC, 2008). In this case the use of the CONOPS is for introduce a new process.

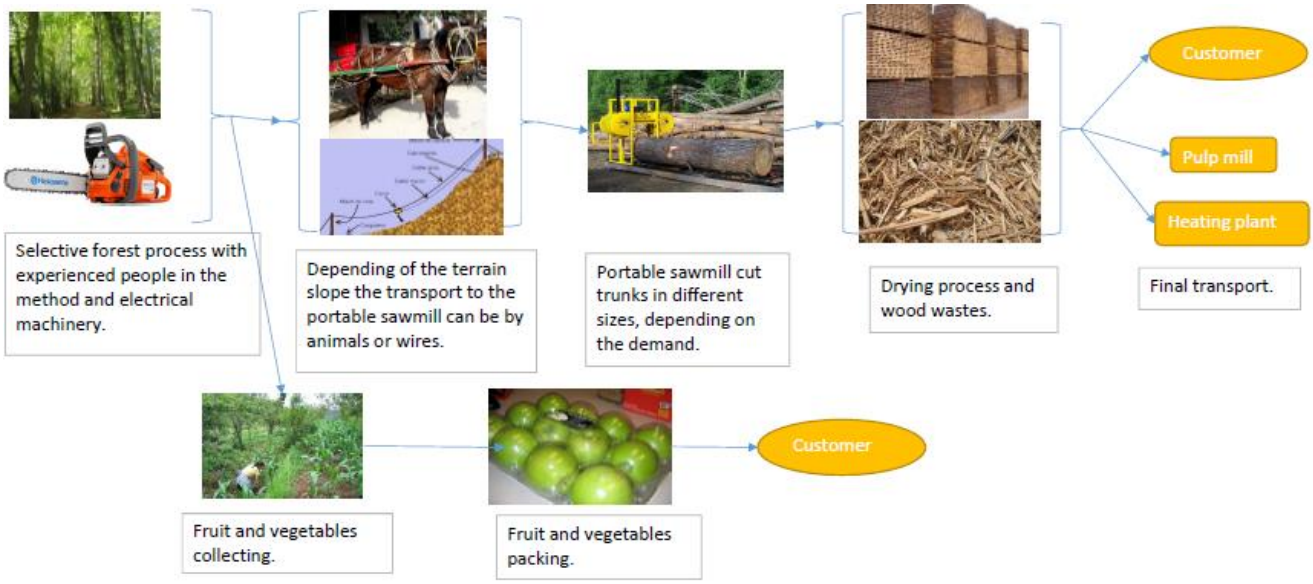


Figure 17 CONOPS.

A sustainable management of this kind would generate high quality products such as wood from forests and fruit trees from agroforestry areas. High quality wood may be used for furniture or fuel. It would allow fruits and vegetables to be picked up during the year. By means of these changes, the local market would be promoted and the city's economy would increase generating new jobs, i.e., a new sustainable business would arise.

As commented in the frame of reference, a sustainable business model is a model which achieves a balance between social, economic and environmental sections. The social part would be directly and positively affected by the management of urban forestry, since a sense of well-being would be generated throughout the cleaner air and water and the improvement of green areas. The generation of new jobs may help foreigners integrating into the Swedish system. The environmental part deals with the forest sustainable management related to the environment, leading to a reach forest biodiversity which respects the natural cycle. Finally, the economic part refers to the business ideas which are appointed with the value proposition canvas tool. By using this tool, the wishes, fears and necessities of the customer are contemplated.

- Ecological food customers. The ecological product market has increased during past years as a direct effect of the citizens concern about climate change and health. A great number of citizens choose to buy ecological products that have not been processed with chemical products such as

pesticides. The organic product market was estimated in 17.5 billions of dollars in 16 European countries, USA and Japan (Siderer, 2005). It is estimated that the organic food will increase 20% each year (Hughner, 2007). Customers are concerned about the veracity of those products, they want to know where they come from, whether they are the result of an organic process, since they pay 10% more than non-ecological products (Wier, 2002). For that reason, laws and regulations need to control food production for it to be ecological. In the agroforestry case commented in the previous section, the food production would be conducted in an ecological way because the products would grow in a sustainable and biodiverse environment. In a situation of this kind, no chemical products like pesticides are needed to avoid insect pests. Nature would regulate the fruit trees and vegetables cycles itself.

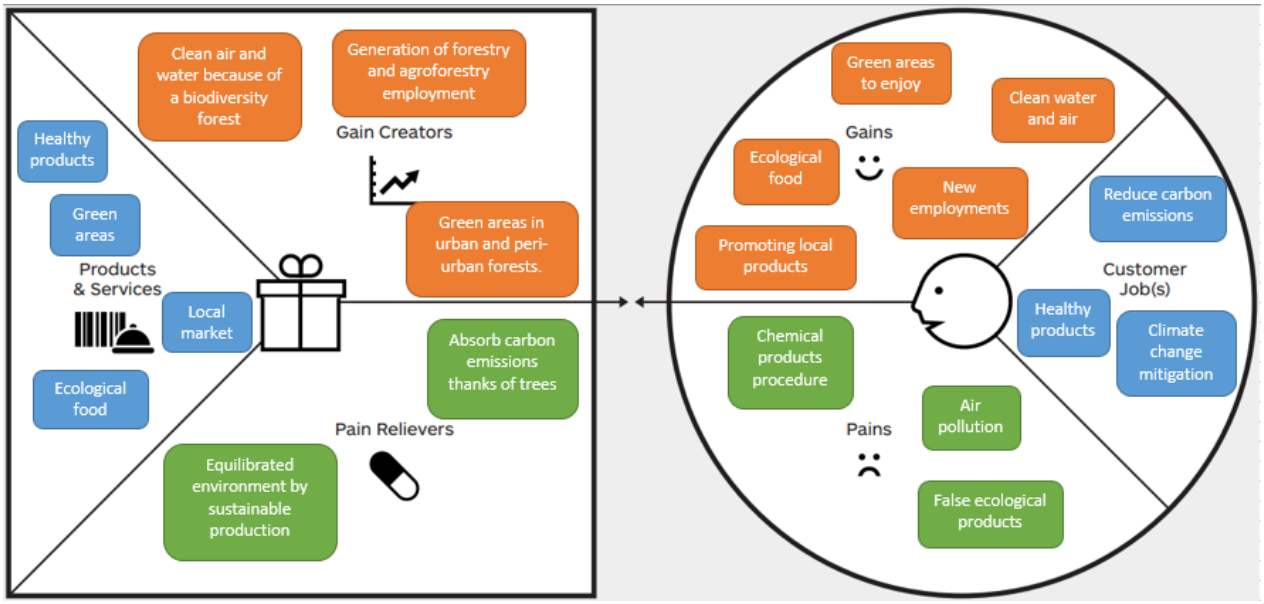


Figure 18 VPC for ecological food costumers.

- Wood product companies. Companies are also concerned about climate change. In most cases, a sustainable production is performed to avoid sanctions imposed by the law of each country. Currently, some companies are producing in a sustainable way. The furniture company called Lorraine portrait a good example of this phenomenon. The company changed the production way to a sustainable production in order to improve the supply chain and to be more competitive and efficient. Consequently, now the company works in a more sustainable way (Chéry, 2008). The worldwide known furniture company, IKEA, constitutes another example. IKEA promotes forest sustainability by assuring that the working wood do not come from natural forests or illegal exploitation (Djurberg, 2004).

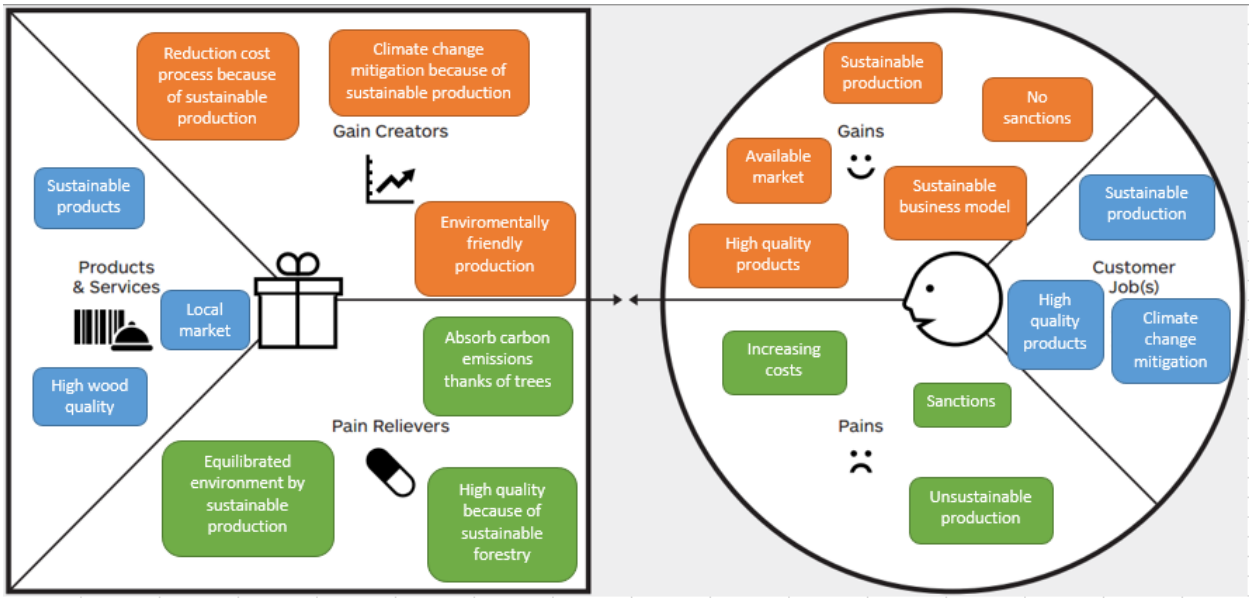


Figure 19 VPC wood product companies.

- Sustainable product customers. As previously commented, people are aware of the challenge that climate change mitigation poses, but they are also concerned about their health. As a repercussion, some buy ecological products despite the fact that they are 10% more expensive than non-ecological food (Wier, 2002). Therefore, we may assume that sustainable products resulting from a sustainable and environmentally friendly production, have an available market as well. A sustainable production of such kind would mitigate climate change. The products would not only be sustainable with the environment, but would also have a high quality, would generate new jobs and would promote local businesses.

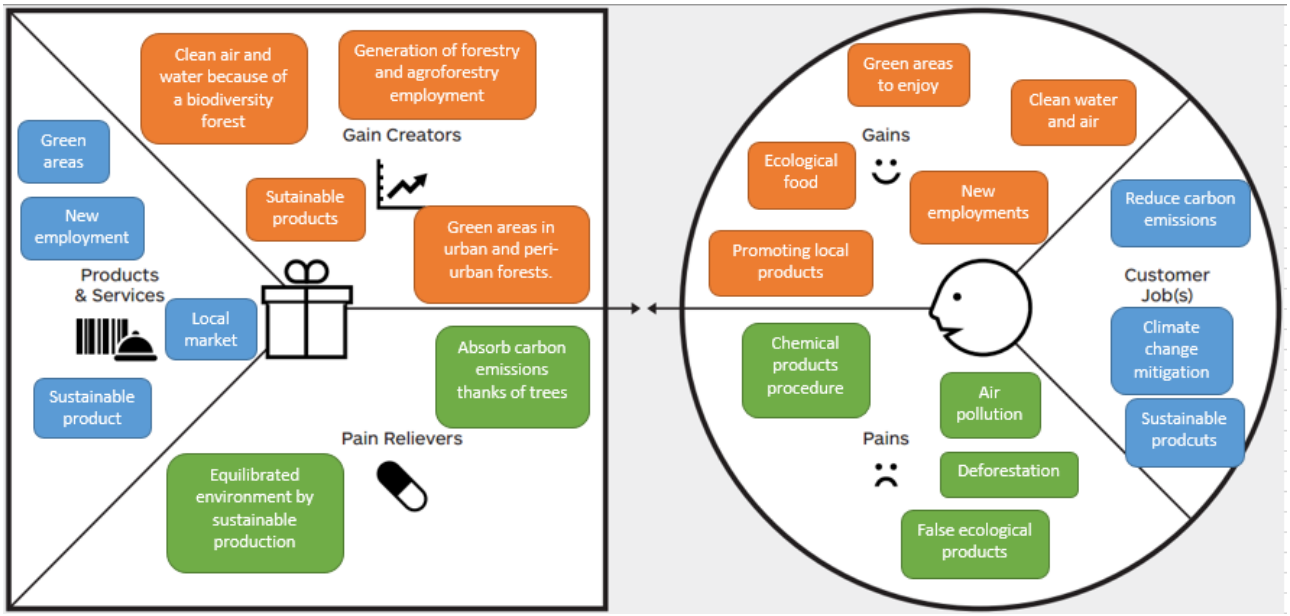


Figure 20 VPC sustainable products.

5.4 CONCERNED PARTIES OF FORESTRY SUSTAINABLE BUSINESS

An array of different stakeholders would be interested in the sustainable business model we are currently contemplating. The following have been identified and considered:

- Forest owners. Forest owners own around 10% of the Gothenburg region forests. According to Öster (2016), these stakeholders are interested in the selective forestry process, because the extracted wood product of the clear cutting process is currently not well paid. However, with the forest selection process, timber prices would double or triple the price further than the resulting wood from traditional forestry (Karlsson, 2017). This is the outcome of a higher wood quality. The quality is based upon different factors: the trees age, the older the tree, the higher the quality; the trunks width, following the same comparison; the thinning process, where the low branches are cut down as the tree grows –quality gets boosted since the knots generated by branches disappear, reducing the points where the board tends to break or lessen its resistance; the balanced environment, where trees may grow avoiding diseases and insect pests; portable sawmills , whose aim is to diminish the delivery time to the customer and to facilitate the drying process to begin sooner than in the traditional process, increasing wood resistance and maintaining its quality.

- Citizens of the Gothenburg region. Citizens would be directly involved and would be the first ones to notice the changes. Due to the urban and peri urban-forestry, the air and water would be cleaner (FAO, 2017), and there would be more green areas dedicated to leisure. Besides, they would buy sustainable local products and enjoy organic fruit produced in the Gothenburg region.

- Electrical and agricultural machinery companies. Electrical machinery companies would be benefitted since the devices used for wood production would be electric and would not emit carbon emissions as it is the case of the *Husqvarna* company. Currently, *Husqvarna* is also offering the possibility of electrical saws in the products catalogue (Husqvarna, 2017). Small agricultural machinery would also be benefitted, since the selection process needs machinery less invasive for the forest than the machinery used nowadays in traditional forestry.

6 DISCUSSION

In the present section, the adopted solution will be analysed, possible problems found in the implementation of this solution in urban and peri-urban forests will appear, as well as some recommendations for the implementation will be suggested. The section is divided into two subsections: on the one hand, the suggested solution for the harvesting process, and on the other hand, the development of a sustainable business.

6.1 IMPLEMENTATION OF THE SUGGESTED SOLUTION

-Selection cutting process. In order to maintain forest biodiversity, a dexterous professional would be required to select the trees that have a determined trunk diameter - wider than the limit established for them - and, in doing so, to not interfere with the natural cycle. As previously mentioned, the limit diameter may vary depending on the tree type. Karlsson (2017) explained me during a meeting that the process of tree selection performed with the aim of maintaining the forest biodiversity entails great complexity. Years of experience are required to understand how nature works, and, therefore, to deliver a correct and environmentally friendly treatment to the target forest. Karlsson currently works in a company called *Silvaskog* in Sweden. This company bases its activity on advisement and organisation of forests for private forest landowners using the Lübeck model. Once the selection process or the Lübeck model are fulfilled, the impact to the forest will be drastically reduced. In those cases, which tools do we have to be familiar with if we are preserving biodiversity with these processes? Once the harvesting forestry process is carried out, to determine whether that process preserves the biodiversity is a difficult task. This factor is usually checked on the long term, because numerous animal and plant species need some time to adapt to new environmental conditions. Due this fact, researchers have determined some index to measure biodiversity. The most popular method to reach such index is the Shannon-Winer method, which uses the formula:

$$-\sum i=1sp_i \log p_i$$

Where "s" determines the number of species, and "p_i" the probability that this individual belongs to that species (Izsák, 2000; Lindemal, 2001). A biodiversity measure is also required to verify that the process is performed in a correct manner. In case the process was performed in a wrong way, the risk of appearing insect pests and diseases for the wood would be higher, and, thus, the risk of obtaining a worse quality final product.

-Transport from the cutting area to the portable sawmill. Once the selection cutting process or the Lübeck model are fulfilled, the extraction of the trunks may be carried out by means of animals or wires depending on the terrain slope. In case that animals were to perform this task, the maximum wood load would have to be calculated in order to avoid the animal suffering. The animals need to be taken care of by feeding them and looking after their health. Besides, a previous search in the vicinity of the chosen route is required to avoid accidents involving trunks or roots blocking the path. In case of in avoidable suffering for the animals, small trucks are another option to transport the logs to the portable sawmill. The difference between those methods is that the animals are less invasive with the forest, while small truck usage would compact the soil increasing.

As for the transport using wires, two options are available, by air or by land. The election of one or the other would depend on the forest situation –if the target forest is a closed forest, a route is difficult to plan, and air wires would be a better idea than terrain wires. A wire method that has aroused interest during the past few years is the use of the Wyssen system (FAO, 2017). This system consists of a fixed cable (skyline cable) in which a carriage or mobile crane operates controlled by a light cable (mainline cable). When the car reaches the area where the load would be collected, it stops with an aerial stop controlled from ground by the light cable. When it comes into contact with the carriage, it releases the pick-up hook that descends slowly to earth pending from a cable. This system requires resistant and tall trees, with capacity to stand the wire structure. Wyssen system is a suitable system for the forest of the Gothenburg region. Those forests, where the selection cutting process or the Lübeck model have been carried out have resistant and tall trees with wide trunks, because the vast majority of them are old trees. Thus, these trees could be used as a support for a wire system. This method can extract wood uphill, downhill or on the flat. In order to achieve safety conditions, the desired slope must be between 8º and 45º between the points of support (FAO, 2017). A wire system of such calibre may be loaded with until 2 tons and it may be installed by operators who have no mechanical knowledge (FAO, 2017). System components of the Wyssen wire system are shown in the following Figure:

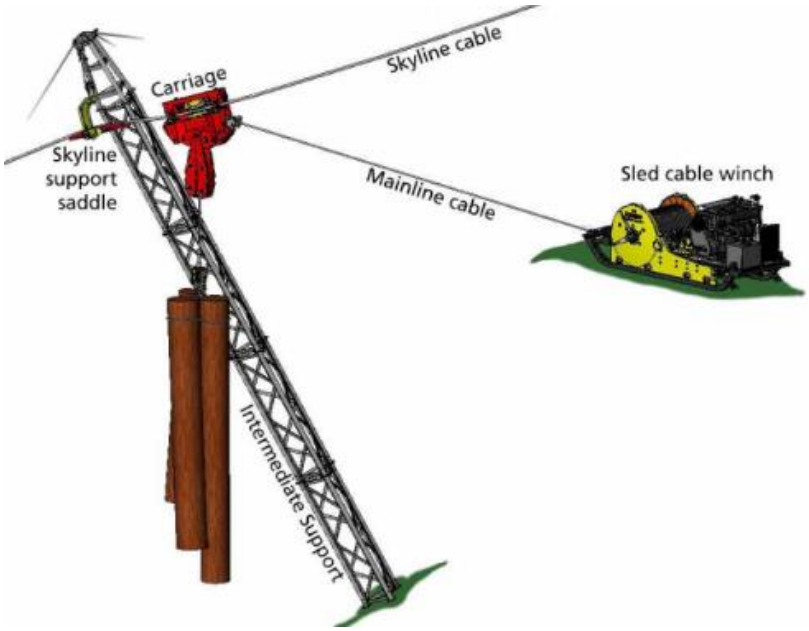


Figure 21 General layout of the Wyssen system.

A poor assembly of this system may have dangerous consequences when detaching the wires which bear great tension. This detachment might damage workers, as well as animals or trees in the nearby area. The system instructions must be followed and a maintenance routine of the wire system must be carried out.

-Portable sawmill. Studies, which were focused on low production, have shown that portable sawmills help to maintain forest biodiversity boosting employment and local products (Lindemalm, 2001). When using this device, the total amount of trees necessary to satisfy the demand of the customer needs to be previously determined and compared to the forest

capacity before sawing to verify that the order may be fulfilled. Portable sawmill companies claim/assure that hundreds of trees per day can be sawed with their products (Norwoodsawmills, 2017). An area is required where the portable sawmill is to be set up and where the drying process of the boards may be carried out. This area must be near between a road and the forest to facilitate the transportation of boards and chips. In order to protect workers from physical inconveniences, an ergonomic study of that work is also required.

6.2 IMPLEMENTATION OF SUSTAINABLE BUSINESS MODELS

As afore mentioned, the use of portable sawmill would promote the local market, therefore, promoting the economy of the Gothenburg region. In the solution section a number of business ideas were suggested and they are suitable to be implemented in and around forest of the Gothenburg region. Business ideas are raised in order to achieve sustainable business models. The sustainability of those models is determined by the equilibrium of three factors: economic, social and environmental.

- Economic factor. As previously mentioned, the sales made in the furniture and house building market, the sales of wood wastes to produce fuel and the sales in the agroforestry section of organic fruits and vegetables are the causes of the local market encouragement and a growing economy. When the selection process or the Lübeck model method are applied to harvest a forest, biodiversity remains preserved in a balanced environment. For that reason, the wood quality is high, although production is not as high as it happens in current forestry processes. The price would double or triple in comparison to the wood extracted with the clear cutting process (Karlsson, 2017). In this project the assumption is taken that a market for local products will be available, since there are some companies that sell sustainable furniture and ecological food. But such market needs to be verified, studying possible client sectors and different companies related with wood products. During that study the product price needs to be determined apart from the study of the market.

- Social factor. This paragraph has been approached from two different points of view. On the one hand, the management of forests in a sustainable way generates an improvement in the air and water of the region of Gothenburg. Taking care of the forests located in the zone may bring positive consequences to scene, since citizens have the chance to enjoy them as leisure, generating a sense of well-being. On the other hand, the creation of a sustainable business in the city of Gothenburg would translate into an employment boost, helping the growing population of the city to find a job and a sense of integration in the Swedish society. During the research of this project, I attended a conference related to generating sustainable businesses in the land of Gothenburg. People from different organizations are working all round to promote biodiversity with environmentally friendly activities. Some organizations have among other aims, the one to help non-Swedish people. Most foreigners coming to Sweden come from countries where jobs related to agriculture are mostly predominant and, therefore, they possess a wide knowledge about land work. This is an interesting experience to supplement to the ideas of the sustainable business models that were proposed in the solution section.

- Environmental factor. A sustainable management derives into a sustainable production of wood goods when the selection cutting and the Lübeck model are applied. Thus, biodiversity is maintained. By doing so, the balance is reached and the environment may help to improve the conditions of forests and natural resources, while absorbing carbon dioxide and reducing climate change. Forests play a very important role in the fight against climate change, and its conservation is fundamental.

7 CONCLUSIONS

Climate change is a topic that concerns almost every country around the world. Along this thesis, this concern has been reflected through the numerous researchers who have studied this topic and carried out different works looking for the way to mitigate this global environmental event. As trees are a key factor in the mitigation of climate change, since they absorb carbon dioxide and transform it into nutrients, this thesis has focused on forests and the management involving sustainability. Firstly, current forestry processes have been analysed. Such processes have generated a great deal of controversy over the years because the logging process is not performed in a sustainable way –it does not benefit trees or species that live in the forest. Throughout the analysis section, some activities have been detected where an improvement could be carried out in a lean way. The activities have been located with the value stream mapping tool along the whole production process. One of these activities is the waiting time in the forest, where the wood is placed to be transported to the mills. This is a long time and may generate flaws in the wood that decrease its quality. Another pinpointed activity is the amount of wood currently transported, which is 50% more than necessary, because the whole trunk including wood waste (chips) and humidity, which is useless to the client, is transported.

A portable sawmill is the proposed solution to those problems. By using this machinery, the boards would be cut in the demanded measures by the customer and they would be placed in a certain position to begin with the drying process, which increases the wood quality and resistance. The chips resulting from the cutting of the boards may be transported to the pulp mill or to the heating plant. In doing so, transport would be reduced, diminishing as well the carbon emissions send to the atmosphere.

The city of Gothenburg is one of the cities involved in climate change mitigation. In order to meet this challenge, the city has changed its forestry policies and offered the land to some organizations to test new solutions. Therefore, one of the objectives of this thesis has been a search to manage forests in a sustainable way mitigating the carbon emissions in the forests of the city and its surroundings. The search for this solution answers the RQ1. The way to reduce these emissions should be carried out in an environmentally friendly manner, preserving forest biodiversity. With this aim, the method of forest harvesting is going to be the selection forestry or the Lübeck model. Both of them are proposed in the forestry politics of the city of Gothenburg. Those processes, on the one hand, preserve biodiversity by maintaining clean air and water, and, on the other hand, maintain forest in good conditions, generating a good visual impact and giving the possibility to citizens to get the best out of them. Using those methods in the city is the answer of the RQ1, because trees represent a way to reduce carbon dioxide for they need it as nourishment to grow and both processes avoid deforestation.

Since the selection process and the Lübeck model are environmentally friendly systems, machinery respectful and less invasive with forests is required. A portable sawmill is suggested for that purpose, as well as transport with animals or wires (depending on the terrain slope) and electrical devices, this sort of machinery would help us to reduce carbon emissions in and around the city of Gothenburg, answering RQ2. Inasmuch as the selected devices have low forest impact, forest biodiversity would be promoted and carbon emission would be avoided along forest in urban and peri-urban areas.

Once the process was defined and the convenient sustainable tools were displayed, some sustainable business ideas have been proposed, as well as important factors that those ideas

aim to achieve, answering RQ3. Those ideas have the purpose to generate a sustainable business in the forests of the Gothenburg region increasing local economy and avoiding carbon emissions. Business models are based on the extraction of a product from a sustainable forest, avoiding deforestation. Another factor that reduces carbon emissions is, on the one hand, the use of machinery and devices that do not generate carbon emissions such as electrical saws and, on the other hand, reducing transportation between mills, since the only transported product is the final one that it is delivered to the client.

Since multiple benefits from the sustainable management of forest in urban and peri-urban areas are a consequence of this models, the application of this process to other cities or regions that have similar conditions to Gothenburg region is advisable. Some of those areas could be: The Dutch city, Arnhem; the Noweigan city of Bergen; the Austrian city of Vienna, (Konijnendijk, 2012); Bedfordshire in the United Kingdom; Branderburg in Germany; Peitou-Charentes in France; Extremadura in Spain, or west Macedonia in Italy (Rigueiro Rodríguez, 2009). Most of those cities are currently changing their urban and peri-urban management to a more environmentally friendly one.

Information about the benefits of a sustainable management needs to be given to those cities, since the decisions we make today, will affect us in the future. Thus, to promote forests is a fundamental activity in order to absorb carbon emissions and mitigate climate change in order to avoid extreme temperatures. Politicians and city government play an important role in this mitigation. New laws and political forestry rules are a necessity in order to achieve this environmentally challenge. Faced with an uncertain future, it may be a good idea to spread the risks and put our bets on heterogeneity for increased resilience for biological diversity, and production-oriented returns from the forest.

As in this case, neither the suggested solution, nor the business ideas were put to test in reality, because this study could not lead such tasks, we suggest for future projects to test and verify such ideas and solutions before considering its implementation in the forests in and around the Gothenburg region.

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