Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Department of Economics

Analysing costs for bio-based materials in agriculture

- An application of Activity Based Costing on crop coverage

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Independent project for master's degree • 30 hec • Advanced level
Agricultural Programme • Degree thesis No 1169 • ISSN 1401-4084
Uppsala 2018

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- An application of Activity Based Costing on crop coverage

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Credits: 30 hec
Level: A2E
Course title: Independent project in business administration
Course code: EX0782
Programme/Education: Agricultural Programme – Economics and Management
Faculty: Faculty of Natural Resources and Agricultural Sciences

Place of publication: Uppsala
Year of publication: 2018
Name of Series: Degree project/SLU, Department of Economics
No: 1169
ISSN 1401-4084
Online publication: https://stud.epsilon.slu.se

Keywords: Activity Based Costing**,** bio-economy, bio-materials, costs, forestry products, mulch film, process, value chain management

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Swedish University of Agricultural Sciences

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Acknowledgements

This thesis is the result of the contributions from many inspiring interviews with farmers, the contributions from researchers in the Bioinnovation-WP4 project who gave me the possibility to perform this study and my supervisors and friends supporting me in the process. I would like to thank you all for being engaged, supportive and positive to my study. You made this research possible!

I am truly grateful for the friendly reception and welcoming response from the Department of Forest Economics. It has been a pleasure working with you, and your help has made the process very enjoyable!

Most of all, I would like to give a huge acknowledgement to my supervisor Anders Roos, for being such an inspiring, supportive and experienced guide during all parts of the study. Thank you for all the support to provide higher quality to this thesis, and for the cooperation and interesting discussions along the way.

Emma Johansson
June 2018, Uppsala

Abstract
The transition to a sustainable economy is a major challenge of our time that concerns most sectors in our society. Environmental, economic and social aspects are all important dimensions of sustainability, and agriculture is one of the most essential industries for the transition. The implementation of a bio-economy, i.e. an economy based on bio-materials and products, is seen as a key strategy towards sustainability. In this thesis a bio-based method for crop coverage in was investigated. By analysing activities applying a process perspective, information about cost systems and the economics of using bio-materials in agriculture were revealed.

The main purpose of this study was to conduct an economic analysis of a bio-based production method in agriculture. The aim was to investigate existing cost activities which occur when using mulch film, and then to calculate the cost outcome for the different types of mulch film. The aim also included to find differences and similarities between the different types of mulch film, regarding the cost activities outcome.

Activity Based Costing, which requires both quantitative and qualitative data, was the main theoretical framework in the analysis. The study also applied the *mixed methods* as research method. For this study, it means collecting and analysing both quantitative and qualitative data about the activities performed in the process. Six respondents were interviewed regarding the mulch film process and the costs it generates. The analysis was made by comparing the data from the respondents and the cost calculated with ABC.

The result of the mulch film process was structured as phases containing activities, which occur during the mulch film process. Purchase, storage, lay out, maintenance service, end of season and final management were identified as existing phases. Delivery material, stock-keeping, setup machine, placing, and maintenance service were identified as principal activities existing in the phases. The activity of cultivation, collection and recycling depended and varied between the different mulch film materials.

The analysis was conducted from a process perspective. All indirect costs (generated from the cost activities), as well as the direct costs (direct material and labour), were compared to one another as costs per hectare. The study shows the resources with the largest influence on the total result; extra labour and fuel. In some cases, indirect material such as irrigation tubes had a significant share of the indirect costs. A further analysis was made by comparing the bio-based mulch film process with other mulch film alternatives. The analysis also contains a critical reflection of the limitations of this study and the ABC method.

The process perspective provided an informative overview of the costs connected to the mulch film process. The ABC method could probably be a useful and informative tool for understanding economic consequences of implementing certain sustainable methods in agriculture.

Abbreviations

ABC – Activity Based Costing
TCO – Total Cost of Ownership
WP4 – Work Package 4

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1 Introduction

This introduction presents the sustainability concept, how biological resources and bio-economy are connected to sustainability, and sustainable agriculture. Following is an overview of standard (plastic) mulch film methods and biodegradable alternatives, which leads to the aim of this thesis, the set delimitations and lastly the structure of the report.

1.1 Background

One of the greatest challenges of our time is how to incorporate sustainability in our way of living and working (Thiele, 2016). The term is sometimes described as an ideology, built upon the values, beliefs and moral claims that refers to organisations as well as individuals. Sustainability is divided into three dimensions: environmental, economic and social aspects. Behaviours and beings must meet all of those aspects, without challenging them, in order to be encouraged as sustainable. At its core, the sustainable concept is about the respect for the Earth's biophysical environment and how natural resources ought to be used (Brown *et al,* 1987).

Requirements for sustainability have prompted innovation activities in various businesses sectors, including agriculture and forestry (European Commission, 2012; Thiele, 2016). The idea is to implement functions and practices that are adapted to nature, instead of the opposite (Thiele, 2016; Portney, 2015). Additionally to the environmental aspects, economic and social aspects should not be neglected; neither in the long nor short run by those practices (Thiele, 2016). The most cited definition of *sustainable development*, which is closely related to the core concept of sustainability (Portney, 2015), is formulated in the Brundtland Commission (WCED, 1987):

"*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*"

Biological resources have come to play an essential role in meeting the global challenges, to secure an environmental protection despite a growing population (European Commission, 2012). Brown *et al* (1987) states how a *sustainable use of biological resources* is about having a sustainable yield attained from natural systems without a negative impact on other ecosystem services. In other words, the optimum level of growth for natural resources has to be identified. For agriculture, this means to be ensuring the land to grow a certain amount of crops, rather than striving for a continuously increased volume. The UN's *Sustainable Development Goals* (**SDG**), identifies components of a *Responsible Consumption and Production* (www, UNITED NATIONS, 1, 2018). The goals includes the improved understanding for product life cycles, the identification of patterns in value chains with great potential for environmental improvements, and the implementation of innovative solutions within businesses to reduce their environmental impacts (www, UNITED NATIONS, 2, 2018).

Biomass is a renewable resource, and as such will have a key role in the implementation of a sustainable bio-based economy. Biomass includes materials with organic origin (BMBF & BMEL, 2014; Saidur *et al*, 2011). Yuanchun (2013) describes that, in addition to being based on organic material, biomass is renewable in the form of crops, trees, wood, aquatic plants and other waste materials (figure 1). Biodegradability is also a feature that separates biomass from most fossil resources (Kaltschmitt, 2009). *Bio-based products* are thus products that consist of biological products, renewable agricultural products or forestry materials (Yuanchun, 2013).

With a focus on sustainable development, the idea of biomass being reintroduced into the market system constitutes the fundamentals of a bio-economy (Sillanpää *et al*, 2017).

Figure 1. Biomass Material provided from the forestry industry. Source: Pixabay

The bio-economy is the composite concept referring to both biology and economy (Kaltschmitt, 2009) and encompasses the utilization and knowledge-based production of products, services and processes from renewable resources (BMBF & BMEL, 2014). The concept takes all industrial sectors into account and is known as a step towards a sustainable economy. Within the bio-economy, pathways to create biomass-based final products are being investigated (Fichtner *et al*, 2017). The biomass-based utilization is comprehended by certain, specific steps or processes that includes activities e.g., pre-processing, harvesting, collection or conversion.

Challenges for the bio-based economy consists of ensuring a market for bio-products, to secure biomass resource supplies and to develop manufacturing possibilities through appropriate policies (Sillanpää et al, 2017). Currently, the attention for bioplastics and its possibilities is on the increase, which is reflected in the EU *Strategy of achievement for the EU recycling goals*, which is a part of the legislative package for the EU waste management (European bioplastics, 2018, 1). There is still no common legal framework within EU limiting the production of materials from fossil resources, but such regulations are being discussed. Such restrictions could improve the competitiveness of bio-based products. At the same time, the *EU strategy of plastic* has the purpose to create restrictions on the use of oxo-degradable plastics; a kind of plastic that also has a negative impact on the environment. Oxo-degradable products imitates the degrade process, but is not verified as degradable as it will remain as small fragments in the environment (European bioplastics, 2018, 2).

The forest sector has the potential to become a main part of the bio-economy. At the same time, forestry does not compete with products from the agricultural sector and also plays an important role for carbon storage. In conjunction with technological developments, the forest sector therefore has a key role for the sustainable development. Still, the cost of bio-based materials and processes needs to be reduced, and for that reason technological innovations and optimized organization are fundamental (Fichtner *et al*, 2017). Logistical processes are generating large costs in the biomass supply chain, for example when being processed for energy or food. The transportation costs are significantly higher for transporting biomass than for fossil fuels when measured as transportation cost per unit accessible energy (for each material) (Mahmudi *et al*, 2006). This is due to the biomass' lower density of energy and physical density. This calls for an ingenious biomass-based supply chain management (Fichtner *et al*, 2017).

1.2 Problem background

Plastic mulch films are widely used in the production of vegetables, berries and fruits (Ahokas *et al*, 2014; Shogren, 2000; Happala *et al*, 2014). The method provides control of the moisture and temperature of the soil and protection against weed growth. It also protects from erosion caused by weather and even makes it possible to reduce the usage of pesticides and fertilizers. Thereof, the mulching practice has itself become an essential part of modern field production (Haapala *et al*, 2014). As an outcome of mulching, the yields get a higher quality and are also increased in mass (Ahokas *et al*, 2014; Shogren, 2000). Globally, an area of about 80 000km² is every year covered by plastic mulch film (Ahokas et al, 2014; BioInnovation, 2018). After being used, the plastic mulch film is removed from the land but does unfortunately often leave fragments of plastic within the soil (see figure 2).

Figure 2. Agricultural land contaminated by used polyethylene mulch film (J. Ahokas, Turkey, 2012)

The biodegradable mulch film on the other hand does not need to be removed and can be tilled down since it will decompose. It has therefore no negative impacts on the soil (see figure 3) (Ahokas et al, 2014; Haapala et al, 2014; Jenni et al, 2006). Still, the most economical alternative for farmers using soil coverage is the plastic mulch film (Haapala et al, 2014). However, Paulsson (2016) found that other factors than costs were of importance for the farmers' decision of mulch film, such as its ability to prevent weed growth, keep the crops free from mulch pickings (which often appear during the mulch film biodegrading) and the possibility to use existing mulching equipment. Besides, the need for a biodegradable mulch film is not expressively demanded, since the recycling possibility for a plastic mulch film is available.

Within agriculture, soil fertility and the capacity to gain high crop yields is essential (Sillanpää *et al*, 2017). At the same time, the eco-balance needs to be maintained within the whole system (De Wrachien., 2003). S*ustainable land use* means that the availability of arable lands and the preservation of natural ecosystems are secured in agriculture (Cassman *et al*, 2002; De Wrachien., 2003). Portney (2015) describes the term *sustainable agriculture*, as farming practices attempting to produce food with a minimum impact on the environment, and at the same time contribute the nutrition needed with the smallest destructive effect on consumers.

One component of agricultural sustainability is the idea of *sustainable agricultural intensification,* which targets land sparing by increasing yields, without adverse environmental impact (Garnett *et al*, 2013). Pretty *et al* (2011) presented an approach to sustainable intensification that combines productive agricultural systems with sustainable, agro-ecological management. The strategy includes minimizing negative impacts on the environment through appropriate practices and technologies. However, current methods still depend on low-cost, fossil-based raw materials and energy made from non-renewable resources (Sillanpää et al, 2017). Plastic mulch film is a method to gain high crop yields, and there are bio-based mulch films on the market as well (Ahokas *et al*, 2014). However, with current (2018) low prices of crude oil, fossil resources is still less expensive compared to mulching products made by biomass (Fichtner *et al*, 2017).

Figure 3. Bio-based mulch film in vegetable farming, Sweden. Source: Respondent 2

There is a dependence of *technical development* for bio-based products in order to make them more attractive on the market. In addition, *cost effectiveness* within manufacturing processes using bio-based products is also necessary to create new markets for bio-based materials (Scarlat *et al*, 2015). According to Paulsson (2016), costs partly determine the farmer's decision to use mulch films and even though costs are not of primary significance according to the studies of Fichter *et al*, Sillanpää *et al* (2017), they are crucial for the performance of a supply chain. Creese (2013) also recognizes the influences of costs in decision making and analysis of given situations.

1.3 Problem

A challenge lies in finding bio-economic practices that combine sustainability with profitability (Sillanpää et al, 2017). Too high costs are often the major restriction for implementing bio-based practices (Sillanpää et al, 2017; Fichtner *et al*, 2017). S*ustainable profitability* has also the objective to reduce costs reduction. Whiteman *et al*, (2016) explains how the complexities of organizing a sustainable production could be eased by integrated improvement of processes. However existing research on organizing sustainability do rarely include a process perspective (Langley *et al*, 2013).

By using cost systems and economic documentation, valuable and measurable information about operations, costs and profitability could be revealed (Kaplan *et al*, 1998) and continuously support the improvement of costing, activities and functions performed (Lewis, 1995). With the adoption of a process perspective, organizational studies of sustainability could give clearer indications on how to engrain sustainability in all processes (Whiteman *et al*, 2016). More process studies regarding business practices would support the identification of potential solutions for environmental and social problems, and also improve the understanding of organizational sustainability. More focused research in the area of bio-economy is needed, and especially studies that focus on economic profitability (Viaggi, 2016).

In summary, high production costs are often a limiting factor for the growth of the bio-economy. It is therefore important to analyse and understand the real costs for alternative and hopefully more sustainable production systems based on bio-economic technologies. Such studies should, furthermore, examine the true process cost structure along the supply chain for these alternative systems. This would generate valuable and measurable information that could inform future development- and improvement efforts.

1.4 Aim

The purpose of this study was to conduct an economic analysis of a bio-based production method in agriculture. The aim was to investigate and compare the costs of different mulch film materials and the activities occuring in the handling. This includes identifying existing value/cost activities, find differences and similarities of the cost outcome for the different mulch film materials and to detect how costs for each type of mulch film are generated:

- What value/cost activities exist in the usage of bio-based respectively plastic mulch film?
- What resources are being consumed to perform the activities?
- What are the differences and similarities of the activities, regarding the activities and costs outcome for a bio-based respectively a plastic mulch film?

The study focus on conditions in Sweden on soil coverage used for one season vegetables.

This thesis is a part of the WP4 project, which is a project initiated by the need for new products made of forest raw materials, within the Bioinnovation programme (see Appendix 1). Studies have already been made about other dimensions and perspectives, especially within the production of bio-based mulch film, but this part is still unexplored for the WP4 project and is therefore needed. The comparison with a plastic mulch film is made to identify an alternative outcome of costs and activities when bio-materials are used.

1.5 Structure of the report

The content of this study has been structured in the following way (see figure 4);

Chapter 1 gives an introduction to the study's subject area of sustainability, bio-economy, bio-based mulch film, the WP4 project, problem, purpose and aim for this study and lastly specified delimitations.

In **chapter 2**, theories used for the study are described; Process theory, Supply chain and Value chain management, Total Cost of Investment and Activity Based Costing.

Chapter 3 describes the methods and performances applied to this study. It contains a minor systematic literature review, a description of the research approach and the comparative case study design, and discusses limitations and quality assurance aspects.

An empirical background has been provided in **chapter 4**, to further explore the subject and create a fundamental understanding for soil coverage, bio-innovations and relevant economic aspects of agriculture regarding this study of mulch film.

Chapter 5 displays all empirical data collected and the result for this study. First, the qualitative data is presented and explained. Quantitative cost data is also presented in various tables showing actual activities and resources.

Chapter 6 holds the analysis and discussions of this study, regarding the empirical result and aspects considering the chosen *activity based costing* method.

The final chapter of this study, **chapter 7**, presents the conclusions, methodological reflections and thoughts of future research within the bio-economy subject.

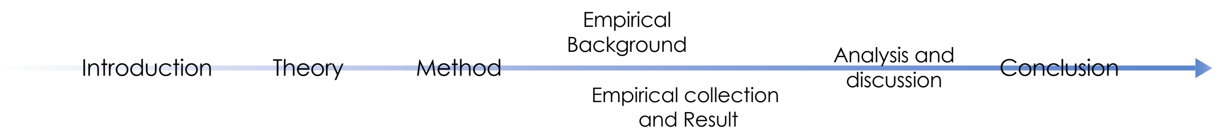

Figure 4. Structure of the report, own illustration

2 Theoretical perspective

Theories on practices and costs within organizations have been fundamental for this study. The selected framework consists of theories regarding: processes, supply chain, value chain, total cost of ownership and activity based costing.

2.1 Process theory

Success among enterprises and companies are strongly connected to effective and efficient processes (Beheshti, 2016). For this study, a process perspective was essential to map realistically how costs in an agricultural process were connected to the bio-based mulch film. *Business process analysis* originates from a focus on performed improvement activities, concerning a particular process (Beheshti, 2016). The view has been slightly altered in this study to embrace the understanding of ongoing processes, by collecting various process-related data and find information and opportunities for future improvement of the bio-based mulch film. However, in modern enterprises where data is dispersed between many different systems and data sources, process analysis may become complex. That is why before the process analytics starts, an understanding for the available data has to be established to capture and organize the collected process data.

There is a variety of definitions of the term *process*, both when it comes to content and scope (Aouad, G. *et al*, 2008). Processes are rarely well defined and there is no given model, mainly because the delimitations may look different depending on the perspective from whom it is based (Beheshti, 2016). An understanding for the actual processes within a business is required though, to enable the design of realistic cost calculations and accurate financial parallels within made calculations (Andersson, 2009).

A *business process* itself can be explained as a set of coordinated tasks and activities, being performed automatically or manually, to reach a business goal (van der Aalst *et al*, 2003). An activity is in turn the smallest unit of work or action (van der Aalst *et al*, 2003) that contributes with value to the production (Andersson, 2009). These could be divided into primary and general activities, depending on how an activity is connected to the chosen part of the process. This means that a decision concerning the level of details is necessary for framing the scope for a process analysis. Process modeling is recommended as a method to identify improvement opportunities for a certain industry (Egan, 1998). Rosenau (1996) argues for graphical process models to display generic principles in the business, and the models are also effective when demonstrating how a process works. To be able to conceptualize an improved process, the scope and perspective needs to be defined (Aouad, *et al*, 2008).

Business analytics is a collective name for methods and tools that can be applied in process analysis (Azvine *et al,* 2003). The analysis can either consist of observing behaviors of completed processes to gain more control (Muehlen, 2004), or investigate ongoing processes, to generate a monitoring decision base (van der Aalst *et al*, 2003), or to gather data for future forecast (Chaudhuri *et al*, 2011). The foreground of the analysis should consist of shaped flows of experience occurring over time, together with enacted "doings" in the moment.

To explore process data, a close observation of the supply chain is necessary. A proper selection of experienced respondents and suitable theories can consequently provide the appropriate information and guidance about a process and the process analysis (Tsoukas *et al*, 2002). The purpose involves gaining an understanding of "typical" activities within the phenomenon. Theoretical tools provide a base for the chosen analysis (Langley, 2016). Boundaries need to be defined by selecting and focusing on a specific subsample of data. Data should be selectively drawn to provide and keep a stable focus throughout the study.

When performing process research, the timing of arrangements needs to be explained (Tsoukas *et al*, 2002). Significant interpretative work is required, the extent of which depending on the researcher's capability of a deeper understanding of the observed phenomena. To make a process analysis, a selection and development of a suitable theoretical framework is needed, as well as a restricted amount of principal activities regarding the focus area (Langley, 2016).

2.2 Supply chain and Value chain

Common for *supply chain management* (SCM) and *value chain management* is the process perspective used for the analysis (Walters *et al,* 2004). Supply chain management usually focuses on flows going downstream to the customer and is coordinated by in-house manufacturers or large resellers. The model of value chain management offers both strategic and operational analysis at macro level (process) as well as micro level (activity). It also includes costumer and corporation prospects. In this study, the supply chain and value chain perspective is used to locate and investigate the process on mulch films. As Langley, (2016) explains, the process connection needs to be explained in a wider social perspective. The supply chain and value chain models are further described below.

Supply chain

A supply chain when observed in its basic elements is a sequence of processes, events and activities that are needed for a certain product's life (Blanchard, 2010). More in detail, a supply chain embraces the network of all parties that contribute value both directly and indirectly, in satisfying a customer's request (Chopra *et al,* 2016). These actors may include suppliers, manufacturers, retailers and transports. The supply chain is also dynamic and involves flows of constant information, products and resources, and these flows can take place in both directions. Often, also planning, management, coordination and collaboration are important parts in the concept (Blanchard, 2010). The sought objective for every supply chain should be to maximize the value generated as a whole (Chopra *et al*, 2016). The value generated, even called *supply chain surplus,* is counted by the equation; *Customer value – Supply chain cost = Supply chain surplus*.

Supply chain management has for several decades been an advanced tool to achieve competitive advantage for all enterprises (Mentzer *et al*, 2001). *Supply chain* is in addition containing the systematic and strategic coordination of functions within the business, and the tactics for these functions (Mentzer *et al*, 2001). The purpose is both to support the whole supply chain, and also the individual companies.

A closely related term to supply chain is *Supply chain planning,* which means building simplified models for the real supply chain. The supply chain planning has the task to supporting plan-related decisions (Fichtner *et al*, 2017). Another related term is *Supply chain performance management,* which is categorized in effectiveness and efficiency (Shepherd *et al,* 2006; Walters, 2006). The first of these two terms focuses on satisfying customers and the efficiency covers the processes and structures within the supply chain (Min *et al,* 2007). The supply chain efficiency is strongly connected to the reducing of costs and increasing of profit, which generates a high potential for optimization (Huan *et al*, 2005; Meixell *et al*, 2005).

Consumer behavior has evolved and turned towards a higher demand for sustainable products and services. This has in turn affected existing supply chains to become closer to *sustainable* *supply chains* (Kotler, 2014). *Sustainable supply chain management* regards the whole supplying process, through the life cycle of the product and includes economic, social and environmental aspects in a long-term perspective (Gruszecka-Tiesluk, 2013). It involves all stakeholders in the process (Gruszecka-Tiesluk, 2013) and additionally, a sustainable cooperation between manufacturers, suppliers, distributors and customers (Krykavskyy *et al*, 2017). Sustainable supply chain management, or a "green supply chain", principally means to have an efficient management of waste and natural resources, and also to engage a reduced impact on the environment in all processes (Gruszecka-Tiesluk, 2013).

Value chain

A value chain can be defined as a *chain of activities* performed of one or several companies to produce, distribute and promote a service or product (Law, 2016). Activities are identified by the creation of value for the customer and could be either value-creating activities or supporting activities. The value chain makes it possible to divide a firm's activities into strategic chains of doing and behavior, such as costs and sources of differentiation (Porter, 2004). From this point of view, every firm could be seen as a collection of activities that contributes value for its product. Using a value chain, these activities can be displayed. The analysis of value chain management also identifies the core capabilities and processes required to meet central corporate and value drives for the customer. A core process could furthermore be described as a business process, which provides value contributing to the competitiveness of the product (Johansson *et al*. 1993).

To construct the value chain and make it applicable, the scope of the business unit needs to be defined at a relevant level (Porter, 2004). A value chain can only be understood for a specific part of a firm, since there are differences in value chains among similar companies who have different sets of conditions available (*ibid*). A description of processes is essential for a value chain perspective, to enable detailed information and precision (Andersson, 2009). At the same time, the value chain itself generates a high rate of generalization. It is therefore appropriate to begin by analyzing activity areas before individual activities are identified and thereby creating a balance of validity. Though, it may be preferable to focus on general principles rather than too detailed information of activities involved, to reduce the complexity of the process model (Aouad, *et al*, 2008).

All activities that generate value to the company can be seen as the source of a firm's cost behavior and relative cost position (Porter, 2004). Therefore, a convenient cost analysis should investigate activities involved and examine the cost structure within a certain scope. This means the cost of a definite activity performance could be analyzed instead of the company as a whole. For a firm to reach a cost advantage, the aggregated costs of performances have to be lowered, relative to its competitors. Competitive advantage could be achieved either by cost advantage or by differentiation, and is reached when both types of advantage are being correlated. One way of pursuing cost advantage is by using the *value chain* as a tool for a cost analysis (*ibid*).

2.3 Total cost of ownership

The concept *Total cost of ownership* (TCO), makes it possible to look beyond the price of purchases to also include related costs, and thereby find the true cost of a purchase (Ellram, 1995).

Cost is in financial accounting defined as a *sacrifice of resources encountered for a future objective or benefit* (Lewis, 1995). The importance of TCO has increased for organizations that are searching for a deeper understanding of their costs and cost management (Ellram, 1995).

The approach can either be cost or value based, and can be complex since it investigates the most significant costs for obtaining, processing, using and disposing a service or good. Especially value-based TCO requires much effort to make the weighting of cost factors. Applying historical data in the TCO model will provide a glimpse of performance at a certain time, and the result will have the role of an evaluative tool for future decisions.

The concept of TCO is adopting a long-term perspective, in order to make an accurate valuation for a purchase situation (Ferrin *et al*, 2002). Though, in contrast to Life Cycle Costing, TCO has a shorter time horizon and is applying a purchaser's perspective instead of a product's perspective (Saccani *et al*, 2017). The valuation obliges an applicable measurement and understanding for all the cost impacts in concerned activities (Ferrin *et al*, 2002). Taking other business functions into account calls for a connection to supply management since the scope is broader than the specific purchase itself. The application should be used on cost drivers and systems of activity-based management (Porter, 1993). Though, for an accurate estimation in the TCO model it is essential to have customized cost drivers for the specific organization (Ellram 1994; Degraeve *et al*, 1999a). In Saccani *et al*, (2017), the TCO model was divided into phases, processes, and activities sorted into the categories according to where a certain activity appeared.

Avery (1999) found that companies focusing on reducing overall costs and involved both indirect and direct costs, would lower their total costs successfully. A combination with the activity-based costing methodology is fundamental to make an effective implementation of TCO (Ellram, 1995; Porter, 1993), and an Activity Based Costing approach is usually common (Kaplan *et al*, 1987; Ellram *et al*, 1993). Among the reasons for reducing costs with the TCO model, is it measures the current supplier performance, and enables process changes and supplier improvements through its revealed information (Ellram, 1995). A general TCO model will probably not exist, because of all different sets of cost drivers between organizations (Ellram, 1994; Ferrin *et al*, 2002). There are universal cost drivers but at the same time also cost drivers unique for a certain company. Saccani *et al*, (2017) explains how studies using the TCO models tend to be focusing on specific cases, instead of a general model application. In conclusion, TCO may provide an opportunity to further research and understanding of supply chains, costs and purchases (Ellram, 1995).

2.4 Principles of Activity Based Costing

Kaplan *et al* (1998) present *Activity based costing* (ABC) as a model for cost calculations based on the performed activities within a project. As the name indicates, ABC uses activities as the fundamental base for its investigation on profitability and expenses of organizations. The authors state that ABC is a suitable method for the analysis of new subjects, areas and changing production conditions. To find causes behind indirect costs are a key component of ABC (Lewis, 1995). This is done by revealing existing cost in companies operations, and also forecasted cost of certain activities and business processes (Kaplan *et al*, 1998). In tandem with activity, knowledge information will be provided about the individual cost and profitability for services, goods, operation units and customers. The system of ABC addresses the following questions (Lewis, 1995);

1. What are the activities performed, which is consuming organizational resources?
2. How large are the expenses (costs) of performing organizational businesses and activities?
3. What are the objectives of performing the activities and business processes?

4. When observing the activities, how much resources are needed for the organization's services, products and customers?

The ABC model is similar to the concept of prime-cost calculation (Olhager, 2015). Though, ABC was developed to be an alteration for the traditional cost structures by using activities instead of cost centers for the cost allocation to products. Cost of capital in the traditional structure was often put as an indirect cost in calculations, as well as administration and merchandise (Andersson, 2009). ABC allocates indirect costs to products by the products actual share of consuming them. With raised manufacturing costs, lowered cost for wage and increased non-volume related costs, the risk for misjudging the real profitability is high. Johnson & Kaplan (1987) argue that traditional calculations are not suitable for new given conditions, because the conditions are affecting the companies' variable and fixed costs in a different way.

The ABC model is built upon an investigation for a specific *calculation object*, where different direct costs and indirect costs are to be connected (Olhager, 2015). A *cost objective* is specifically the product or activity for which either the unit cost or total cost is to be determined (Lewis, 1995). In contrast to prime-cost calculation, the ABC indirect costs are distributed to the calculation object by activities, instead of by cost centers (Olhager, 2015). Kaplan *et al* (1998) describes how systems using cost centers often fail in the allocation, since overhead costs are being assigned to cost centers on arbitrary basis, and then distributed to the physical volume of products produced.

ABC has a special kind of structure when assigning activity costs (Lewis, 1995). Costs originate from actual resources consumed by certain activities. Each activity will then have a (total) activity cost, provided from the aggregated resources consumed by that activity. A further allocation to *cost objects* such as products, services and customers is then applied by the cost objects actual consumption of resources (figure 5). This way, the model takes both product variation and complexity into account (Kaplan *et al*, 1998).

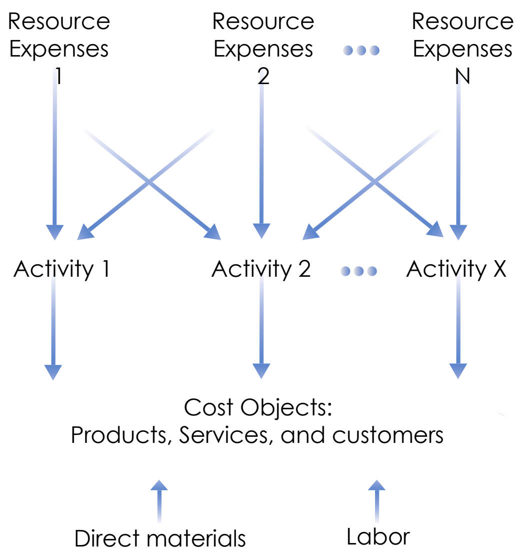

Figure 5. The activity based costing model (Kaplan et al, 1998), own illustration

Figure 5 illustrates how the business's identified indirect resource costs are being allocated on activities, and how activity cost are linked to defined cost objects. Direct materials and labor is allocated directly to the cost objects. The activity cost structure differs from traditional costing systems by the linkage of resource costs, to activities, to outputs. The output element (cost object) of an ABC calculation depends on what is being examined. Lewis, (1995) defined three major business categories that have an impact for the choice of suitable cost object: manufacturing (products), service industries (services) and merchandising (costumers). This study will use the ABC model for manufacture, since the usage of mulch film in agriculture is a part of the farms' vegetable product manufacturing.

2.4.1 The Activitiy Based Costing model

Applying ABC begins with an inventory of organization basic resources used in its performances (Lewis, 1995). Labor, material, factory services, marketing services and administrative services are such indirect resources, and could be either direct or indirect costs depending on business. The next step is to identify activities performed, and trace the resource costs to the recognized activities. The activities need to be made standardized and consistent, in order to present a truthful value (Andersson, 2009). The following step is to allocate the cost for every activity performed to each calculation object by the approximated used amount of (indirect) costs, described by the use of "cost drivers" (Lewis, 1995; Olhager, 2015).

Cost drivers are the key to take the variability of consumed resources (by a cost object) into account (Kaplan *et al*, 1998; Lewis, 1995). Hence, the total cost of a cost object includes costs from all activities performed to produce and handle it (Goebel *et al*, 1998). Resource allocation in ABC could be sorted into three categories; *direct charging*, with a direct allocation of resource costs to activities (i.e. precise consumption), *estimation*, a resource allocation by using cost drives (i.e. percentage) and *arbitrary allocation*, which casually allocates the resources to activities (i.e. estimated value) (Ostrenga, 1990). The level of details when allocating resources to the activities and type of activity driver used in the ABC model, i.e. precise consumption, percentage or casually estimated value, frequently alter the accuracy. Activity drivers can also be divided into three different varieties (Cooper, 1990; Spedding *et al*, 1999); transaction drivers, duration drivers and intensity drivers. *Transaction drivers* consider how many times an activity takes place, *duration drivers* signify time consumed by each activity and variations of time, and *intensity drivers* directly apply the cost of resources, every time an activity is performed. However, the structure of the calculated indirect costs (in the ABC model) is held consistent (see figure 6).

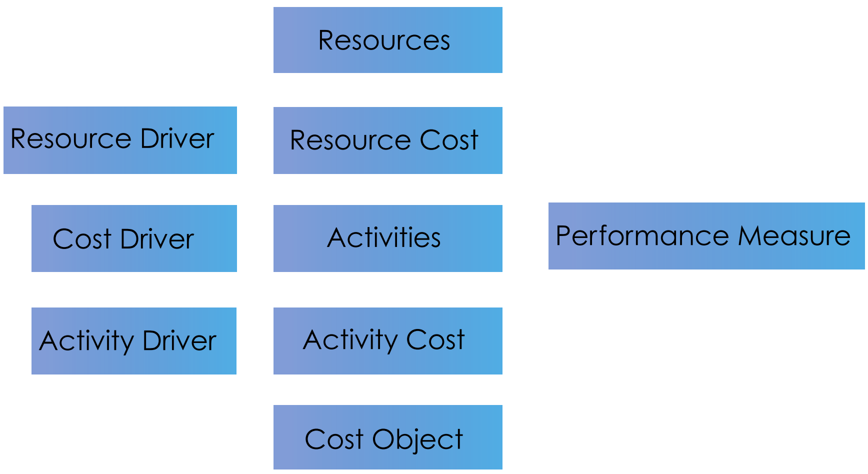

Figure 6. Structure, the ABC model (Lewis et al, 1995), own illustration

The design of the ABC model for manufacturing typically involves four process areas common to analyze; procurement, production, production management and quality control (Lewis, 1995). To know what data is needed for the analysis, information about the activities is required (Kaplan *et al*, 1998). To use the ABC model (figure 6), the following sequence of primary steps has to be examined (Kaplan *et al*, 1998; Lewis, 1995);

Identify activities performed (1)

- Quantify indirect and supporting resources (for a particular process)
- Determine number of activities used in the model, depending on the scope and complexity of a unit being studied (generally 25-100 activities (Lewis, 1995).
- *Example: Schedule production, purchase materials, inspect items, move materials.*

Trace resources used for performed activities (2)

- Find the resources necessary to perform the identified activities and the resource cost, for example by reviewing the financial ledger system.
- Apply the resource costs to the activities by direct charging or estimated percentage.
- *Example: Cost driver: time, Resources: salaries, indirect materials, travel, maintenance, computing, overtime.*

Figure (6) demonstrates how resources are identified and then calculated for by using an appropriate resource driver. Then, each activity's total cost will be revealed by calculating all its consumed resources, with support from the cost drivers (i.e precise, percentage or estimated amount of the resource in total). When all the activities cost are provided, the activity driver will multiply the activity cost by as many times the activity is performed. The activity driver is directly connected to the cost objects, to distribute the activity cost by the cost objects actual consumption on the activity.

Identify the cost objective (3)

- To know the importance and function of an activity, the question of *why* the identified activities are being performed supports the ABC modelling.
- To further support the construction of an ABC model and why the activities are necessary, all the cost objectives an organization has should be identified.
- *Example: Products, services or customers.*

Select cost drivers, to link activity costs to the cost objective (4)

- Find the linkage between the activity costs and a cost objective (i.e. product, service or customer).
- Identify a suitable quantitative measure (i.e. transaction, duration or intensity driver) to calculate the activity cost.
- *Example: hours, resource costs, labor, number of output.*

2.5 Conceptual Framework

For this study's conceptual framework, theories based on processes and costs have been of fundamental importance. One main requirement for having a process perspective is a specified scope for the investigated process in the research. The purpose of this study was to investigate a certain bio-based business process. To put this particular process in a context, the *supply chain* view was suitable (figure 7). As figure 7 shows, the investigated process is one of the farmer's processes, which is after the mulch film is manufactured and ready to use. The *value chain* view identifies existing processes by the farmer and the mulch film process is one of the processes. This study's chosen investigated process, begins when the mulch film is ordered by the farmer and ends with the final management of the mulch film.

The following step to consider, involves the method for the investigation. The aim of this study was to analyze value/cost activities, resources consumed in the mulch film process activities, and find differences and similarities between the activities for a bio-based, respectively plastic, mulch film. With the ABC model, value/cost activities are identified, resources are to be investigated and the model require quantitative measurements enabling comparison between the cost outcomes for different types of mulch film. A few modifications of the model were made with the intention based on the TCO method. TCO determines the most significant costs within an activity, instead of tracing the whole company's (farm's) costs as ABC, and thereby provides a fairer picture of the cost outcome. This was one modification applied, which influences the empirical collection, result, analysis and discussion by having a focus on the most significant costs.

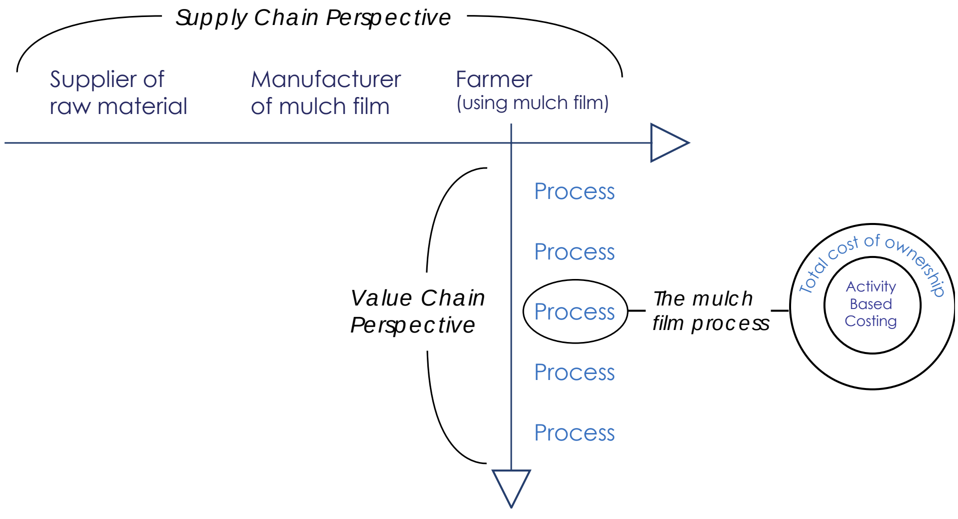

Figure 7. The conceptual framework of process theories, own processing

The figure (7) illustrates how the theories were applied in the study's conceptual framework. First the supply chain of mulch film was identified to set the suppliers in a context. Second, from the identified supplier "farmer" a value chain view determined the specific process of mulch film usage. Then, within this defined scope of the mulch film process, the ABC approach was applied. The aim was to identify the activities and resources in the mulch film process, with a further applied TCO theory to find the most significant costs to include in the calculation.

3 Method

The approach for this study was founded by the application of mixed methods. This chapter presents the research methods, mainly activity based costing. A systematic empirical literature review is presented, and lastly the chapter discusses aspects of quality and ethic assurance.

3.1 Research approach

In this study a mixed methods approach was applied to gain data with multiple methods, both quantitative and qualitative. Mixed methods are functioning at various levels regarding methodological approaches, paradigm frameworks and analytical techniques (Elliot *et al*, 2016; Johnson *et al*, 2004; Creswell, 2015). The definition of mixed methods though, is still evolving (Watkins *et al*, 2015). Mixed methods were a suitable method to apply in this study, both to gain qualitative data about the activities in the mulch film process and the quantitative data to be able to do the measurements. Mixed methods provides a richer and stronger evidence for more complicated questions, and could be seen as embedded case study research (Yin, 2009, figure 8).

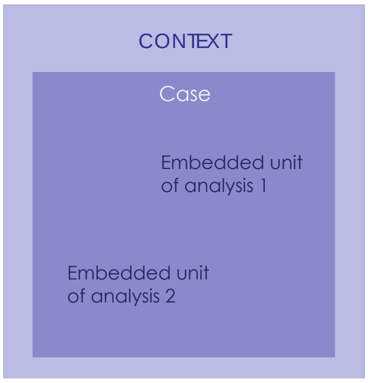

Figure 8. Embedded; multiple units of analysis, Yin (2009), own illustration

Case studies are suitable for investigations on individual organizations, groups or processes (Woodside, 2010). Yin, (2009) explains how case studies with a mixed method design may include several embedded methods to research the one case. The main investigation could for instance rely on a quantitative technique, while the case study approach is further supporting the investigation of the observed phenomena. This study investigated the farm usage process of mulch film, involving six different farms. The approach was made as a case study with six embedded units (farms) of analysis, investigating both quantitative and qualitative data for each unit. The respondents described their mulch film process, and the qualitative data was sorted into phases and activities for this study. Quantitative data from resources, costs, cost drivers and cost objectives was collected and then applied to the identified activities.

3.1.1 A comparative case study

The ambition of a comparative study is to compare several cases of the same phenomenon in order to find and explain differences and similarities occurring (Bryman & Bell, 2014). Though, a relevant factor for such a study is to have a phenomenon of comparable nature (Lijphart, 1971). The mulch film process investigated in this study is analysed with the same method and measurements, making it possible for a comparison. Both types of mulch film require similar resources and activities, with only a few exceptions. Though, the exceptions are part of the differences of interest. Bryman & Bell, (2014) explains how a comparable technique is possible for both quantitative and qualitative studies. The qualitative data in this study will be compared in how decisions was made in the mulch film process and what conditions there are to take into account, and also what activities and resources that is needed to perform the mulch film process.

Case studies are about studying a phenomenon in depth, and could even include or be limited to both quantitative and qualitative data of evidence. Typically used data collection for case studies is a combination of interviews, observations, archives and questionnaires (Eisenhart, 1989), where this study mostly used interviews with farmers, one observation at a study visit and archives (libraries) for the literature review. Yin, (2009) describes there are three types of case study research; explanatory, descriptive and exploratory case studies. From this perspective, this study would be closest to an exploratory case study since the purpose is to illustrate an unclear set of outcomes and situations rather than to explain presumed casual links in a complex real-life intervention or describe such an intervention and the context of its occurrence.

Triangulation is possible with multiple research methods used at several different time periods, (Woodside, 2010). Triangulation usually includes direct observation, examining participants explanations of the case observed to understand operational data and analysis of documents connected to the case environment. For this study's triangulation, one study visit has been made, along with detailed explanations and pictures from the participants, collection of quantitative operational data and a systematic literature review. Instead of data collected from several time periods, data is collected from multiple geographical places in Sweden, with participants using the mulch film for various crops and with various years of mulch film practice. In this way, an embracement of the same phenomenon and context is possible, but with diverse circumstances.

The core criticism for case studies with large samples (defined as $n > 100$) is how such studies fail to assemble details to achieve a deep understanding (Woodside, 2010). This case study is not at the level of criticism; in opposite is using multiple cases for this study an objective to increase the depth, by observing the process of using mulch film from different geographical conditions. Further weaknesses of case studies are subjective preferences (Yin, 2013), premature assumptions (Eisenhardt, 1989) and poor decisions regarding the selection of a suitable framework (Dubois & Gadde, 2002). To avoid these dangers, all respondents were given non-leading questions (appendix 2), the mulch film subject field was thoroughly reviewed and the theory was chosen based on what was to be investigated.

3.2 Systematic Literature Review

This study involves several broad subject fields and to be able to find relevant research studies, a systematic literature review is suitable. A summary of existent research, findings and evidence is essential when creating new academic projects and studies, and literature reviews is one key element for such a search of information (Andreini *et al*, 2017). A literature review was conducted, inspired by the systematic approach. This means that while traditional literature reviews tend to be descriptions and summaries of existing research, a systematic literature review has the advantages that it is replicable and recognizes the author's procedures, steps, strategies and decisions through the literature review (Cook *et al*, 1997). An exclusion or inclusion of research studies must be made clear (Andreini *et al*, 2017), and there should be a logic link to the research questions (Pittaway et al. 2004).

For the search have following databases been used; "Web of science", "Uppsala universitetbibliotek" and "SLU library". The subject areas explored are sustainability, bio-economy, process and cost theories, soil coverage, bio-innovations and economic measurements (table 1).

Table 1. Search words used for this study, different databases, number of articles found.

Database / Search words	Web of science	Uppsala universitetsbibliotek	SLU library
Sustainability	*113 071*	*1 060 537*	*668 431*
Bio economy	*1 396*	*233 319*	*59 436*
Process	*5 274 807*	*21 975 004*	*8 804 847*
Supply chain	*63 099*	*1 331 267*	*363 037*
Value chain	*115 483*	*3 331 005*	*1 352 486*
Total cost of ownership	*1 697*	*580 405*	*140 272*
Activity based costing	*29 738*	*120 830*	*24 146*
Soil Coverage	*4 576*	*191 508*	*101 786*
Bio innovation	*846*	*358 954*	*65 229*
Profitability	*29 418*	*944 503*	*174 391*

All words where aimed at finding "clean" information about a terms or phenomenons, without any application to a certain case. With the most recent research showing on top together with the most popular or relevant ones, studies with only the specific term where further investigated. Definitions, models and assets were in focus for the search, in order to make a fundamental base for the development of different sections in the study. In each subject field was about four or five studies chosen in general. The studies were selected by their abstractness to the fields, for create a neutral ground. In the next search, every research field were given restrictions (see table 2). The further limitations assorted specific topics in every field.

Table 2. Search words used for this study in different databases, number of articles found.

Database / Search words	Web of science	Uppsala universitetsbibliotek	SLU library
Sustainability → agriculture	*7 481*	*305 935*	*125 912*
Bio economy → agriculture	*152*	*99 520*	*21 396*
Process → sustainability	*27 842*	*668 952*	*264 241*
Supply chain → sustainability	*4 193*	*136 580*	*42 991*
Value chain → sustainability	*2 013*	*166 883*	*55 010*
Soil Coverage → agriculture	*265*	*101 965*	*38 683*
Bio innovation → agriculture	*63*	*100 267*	*14 837*

Profitability → agriculture	*1 339*	*106 014*	*38 469*
Activity based costing → agriculture	*386*	*29 047*	*4 158*

Existing research with similar subject combinations or research areas were first selected by title. One consistent term or theme throughout the second search was *bio-economy* or *sustainability*. On the contrary, exceptions were made in the search for soil coverage, bio innovation, profitability and activity based costing. That is because of it being more interesting to discover how these subjects were investigated and discussed when previously applied to agriculture. The most common case found during this search was studies on energy. Approach and case decided whether the articles were excluded or included, i.e. the articles linkage to agriculture or forestry.

Reading the abstracts formed the decision of exclusion or inclusion. Other industries, inoperable cases (techniques for cases, which won't be possible or applicable to this study) and studies not including any economic dimension were excluded. As for the first search was also the second search limited to find four or five relevant studies. The final result of chosen articles had similar approaches of ABC like this study, or had research on sustainability or bio-economy perspectives in agriculture or forestry, or cases of sustainability.

3.3 Data collection and limitations

Multiple sources and various types of data have formed this study's empirical data collection. Yin, (2013) argues for how several sources of data and altered methods for the data collection, supports the assurance and also the consistency of findings. This study's data collection has been made to gain knowledge about relevant activities of the process of mulch film usage, find resources being consumed to perform the mulch film activities, find resource and activity drivers, and lastly qualitative information about the process. Interviews were the most contributing source of information for these questions, with support from literature. The process of the empirical collection was also inspired by Lewis, (1995), by the description of a suitable way to apply the ABC model.

As an interviewer, it is important to be well prepared for the subject (Leech, 2002). To achieve an understanding for mulch film and the process of its usage, a thoroughly systematic literature review was made as an early step in the thesis process. This became very fundamental for several reasons, mainly for the development of the ABC perspective in the thesis, the discovery of what relevant information to include, and the design of the interview material (appendix 2). Another important contribution was the determination of limitations for the thesis. Because of the process perspective, a defined process scope was of great importance (Aouad, G. *et al*, 2008). In this study, the following basic delimitations were made for the process scope; the *cultivation line of the mulch film supply chain*, exclusively a *value chain including vegetable production with one year mulching cycle*, and further the *process of mulch film usage* in the value chain.

Both quantitative and qualitative data has been demanded during the interviews conducted for this study, and for this reason the questions have been both structured and semi-structured. In-depth phone interviews were performed, and the main argument for the method was due to large geographical distances. Phone interviews may produce as good quality as face-to-face interviews (Carr & Worth, 2001), also privacy and anonymity could be attained (Novick, 2008). However, there are a number of disadvantages of phone interviews; the interviewees could be distracted by their surroundings, shorter answers and absence of visual indications regarding context and facial expressions, nervousness and irritation may occur (*ibid*). To increase the quality of the phone interview, the questions were sent out beforehand to the respondents, and a time was decided for the interview with respect to each respondent's schedule. The respondent either answered the questions during the phone interview, or answered by filling out a questionnaire, and added additional information or clarification by e-mail or telephone.

Interviews are an essential part of case study research, especially for the possibility to gain details and explanations of a certain problem (Yin, 2013). The interview guide (appendix 2) was inspired by the value chain perspective, to trace phases generating value (and costs). Documents also give an easy access to data and are relevant to most case studies (Yin, 2013). Monetary data is especially necessary for the ABC theory used in this study. Prices of labor hours and liter fuel were based on general values in Sweden, generated from SCB. During the empirical data collection though, several costs were found to be somewhat unique for the individual case, i.e. shipping, the price for mulch film, indirect material.

The resource costs applied in ABC calculations, are captured in an organization's general ledger system or financial recorded data (Kaplan *et al*, 1998). But for the ABC model used in this thesis, an alternative technique was used. The inspiration is from Tzong-Ru, (2001), who used a simulation technique for the ABC model. That is, instead of applying the whole business recorded data, only the relevant activities for a certain observation are being identified, logged by its actual use of resources and analyzed while it is performing. The simulation technique was chosen for this study for the reasons of the comparative design, several cases, more effective and systematized the focus to only include relevant activities for the mulch film process.

3.3.1 Selection of organisation

Before the interview process started, correspondence was made with the WP4 group responsible for the mulch film research. One meeting was made on skype to get further insight into the demanded research of the group, and a few weeks later a meeting with the responsible person for this thesis was held in Stockholm. An overall understanding of bio-products and the bio-based market was provided, as well as current research and related events. Samples for research with flexible design should be related to main purpose of the study (Robson, 2011). Farmers using mulch film for certain vegetable production were selected due to three motives;

- Mulch film is commonly used within vegetable production (Haapala *et al*, 2014) and is one main group of consumers for the bio-based mulch film (Sarnacke et al, 2008). This was the fundamental limitation for the organizational selection.

- Secondly, the bio-based mulch film is currently lasting throughout one season (and then tilled into the soil) (Ahokas et al, 2014), which made the choice of including vegetable productions with one-season cycles. Such vegetables are zucchini, onion, salad and squash, to mention a few. Other vegetables with longer cycles, such as strawberries, were excluded.

- Finally, organizations were chosen by their varied geographical locations and one-season crop production, to be able to create a neutralized and rich collection of data.

To find organizations fulfilling the criteria of using mulch film for one-season vegetable production, contacts was provided from Sustainable Innovation as the organization knew about the subject and knew relevant farmers. Then, further phone calls were made to advisors in agriculture, companies and farmers. One study visit was made to at a respondent's farm nearby Uppsala, though the cultivation season had not begun yet. The mulching material was shown and also the greenhouse and the equipment for the mulch film lay out. Because of the small scale, relatively light equipment was used which gave the insight of positive possibilities for small scale farms being able to use mulch films at a low cost.

3.3.2 Selection of respondents

With the identified organization of analysis, the choice of person to be interviewed was decided upon the responsibility for the mulch film process. Either the person performing the whole process or the person responsible for coordinating the activities was decided to be interviewed. Most importantly were answers regarding the quantitative questions i.e. how much resources, what prices and what cost exist, and also further information about the activities. Four of the interviews were made by phone, one face-to-face and one by written answers in the question form (table 3). Follow-up emails were also sent out to have the respondents clarify some points. The collected data was continuously tested in the ABC calculations to make sure all information was gained. The validation was made with the written material sent out by email, also containing additional information about the upcoming process of the empirical data.

Table 3. Interviewed respondents'

Respondent	Mulch film	Type of interview	Validation	Interview date
Respondent 1	Plastic	*Phone*	*2018-05-18*	*2018-04-18*
Respondent 2	Fibre mulch (plastic)	*Phone*	*2018-05-18*	*2018-04-19*
Respondent 3	Bio-based	*Phone*	*2018-04-27*	*2018-04-23*
Respondent 4	Plastic and bio-based	*Phone*	*2018-05-10*	*2018-04-23*
Respondent 5	Bio-based	*Face-to-face*	*2018-05-02*	*2018-04-24*
Respondent 6	Plastic	*Phone*	*2018-05-18*	*2018-05-02*

One aspect of this thesis was to decide how many respondents that would be necessary to include in the empirical collection. Trost, (2010) explains how depth in material and quality is a higher priority than number of respondents. A higher number of respondents would have provided a greater validity and confirmatory to the economic map of the mulch film process. But since a relatively large amount of data and time was required for the ABC calculation, the number of respondents was maintained.

The respondents' farms were situated at various locations in Sweden; Skåne, Halland, Gotland, Västergötland and Uppland. All mentioned landscapes are in the relatively southern parts of Sweden. The farmers were having different vegetable production, including zucchini, lollo rosso, bavaria, squash, onion, cucumber, tomatoes, beetroot and carrots. Tomatoes were cultivated in greenhouse, but the function of the mulch film was the same. The interview guide was continuously revised because of the many new insights occurring during the interview process. The respondents also had altered ways of measuring their costs but calculation was manageable and the respondents had informative answers.

3.4 Quality assurance

In the research process, it is important to achieve both validity and reliability (Robson, 2011). To ensure the quality of case studies is an essential part of the research (Yin, 2013), especially since case studies always have been under great inspection regarding their scientific value (Flyvberg, 2006). Riege, (2003) have amassed literature for techniques to achieve quality assurance in case studies. There are four major quality aspects; construct validity, internal validity, external validity and reliability. The actions described in table 4 provide a high scientific quality to case studies, according to Riege, (2003).

Table 4. Quality assurance, examples and appliance (Riege, (2003); modified by author).

Case study quality aspects	***Examples of techniques and method***	***Applied in this study***
Construct validity	Multiple sources for the data collection	Six structured/Semi-structured interviews, secondary data i.e. documents, reports, statistics
	Have a consistent routine for managing the evidence in the performed data collection	*Interviews*: transcript, tested in ABC calculations, follow-up emails and phone calls and verification. *Secondary data*: reviewed and documented
	Have a third-party review of data	Transcripts were sent to interviewees
Internal validity	Support the analysis of data with illustrations and diagrams	Tables were made for the quantitative data, illustrations of the theoretical framework and methods applied
	Systematically use concepts and findings	The ABC model was consistently applied
External validity	Determine scope and limitations to the applied research design	Described in the *theoretical framework* and *research approach*.
	Find relations between collected data and evidence with existing literature in the data analysis	*Empirical background*: reviewing performed ABC studies, analysed in chapter of *analysis and discussion*
	Give account to ideas and theories	Methods and theories has been the inspiration to the performance of certain parts of this study, *i.e.* data collection, empirical structure and analysis.
	Have links between identified research problems and the	The links is introduced in the problem, aim and method for this study

Reliability	features of selected study design	
	Note observations and activities, record as concrete as possible	Interviews have been noted and transcript, including the respondents description on performed activities
	Mechanically record data	Interviews are transcript directly
	Develop a database for the case study	Collected data has been organized, and all method tools are explained in the method chapter
	Keep findings parallel to multiple data sources	Consistently used theoretical framework and logic throughout the study
	Peer reviewed and examination of the performed case study	Half-time seminar with supervisor, opposition in a full-time seminar

3.4.1 Ethical considerations

Ethical aspects are an important component throughout the whole research process (Guillemin & Gillam, 2004). As for the quality assurance of research, the researcher should also be reflexive on ethics. Ethical considerations for this study are found in two areas. First how the research process was made, and as suggested by Robson (2011), all interviewees had the choice to be interviewed and were informed beforehand about this study's purpose. In addition, the names of the respondents were not considered to contribute to the results of the study and were left anonymous. The farms were only described fundamentally. Secondly is the ethics of the subject area. All sources contributing to this research has been treated respectfully, with references and permissions to use certain materials.

Kvale *et al*, (2014) are specifically mentioning interviews to be influenced by ethical problems. The authors are mentioning the possibility for the interviewee to withdraw participation, and awareness of the consequences having the respondent participating in the research. To take these considerations into account, the interviews were held on the conditions set by the respondent, while informing the respondent's about this research. The respondents' names are not mentioned in the study in order to provide anonymity.

4 Empirical background

In preparation for this thesis empirical collection, relevant subject areas regarding the theme have been overviewed and put together in this empirical background. The subject areas are the following: soil covering and bio-based soil covering, bio-based business and innovation, bio-economy aspects and profitability, and calculation for decision-making.

4.1 Soil coverage

Soil covering has many positive effects for crop production (Benites *et al*, 2005). By covering the soil with mulches, several features are being added by caused organic processes, like the deletion of weed growth and erosion. 1,4 million tons of plastic mulch film is being used globally every year for mulching, whereof 220 000 tons in Europe (BioInnovation, 2018). The type of plastic used for mulch film is polyethylene (Ahokas *et al*, 2014; Shogren, 2000). The polyethylene is made of oil, natural gas or coal (Seymour, 1989). Also petroleum is required for the production of polyethylene, which is strongly related to sustainability issues (Shogren, 2000).The *plastic mulch film* holds many sought characteristics for the agricultural use (Shogren, 2000) and is the most common used mulching material due to its low price and positive impact on the soil (Haapala *et al*, 2014). It sustains three months on the soil (Espi *et al*. 2006) and up to four years (Larsson *et al*. 1996), depending on quality. It will not degrade and the material is relatively strong (Haapala *et al*, 2014). *Ground weave,* made by weaved polyethylene, is breathable and has the feature of letting water through its surface (Jordbruksverket, 2015). *Fibre mulches* made of polypropylene (plastic) are applied to protect the crops from damage and are placed over the crops instead of directly on the ground.

Mulch film could probably be expected to have a growing market share globally because of the possibility to reduce the usage of pesticides (Sarnacke *et al*, 2008). High value crops like strawberries, tomatoes and tobacco are typical crops for the extended usage of mulch films. Concerning bio-based mulch films, changes in external conditions like weather will affect the market since the bio-based product is more sensitive for wet or stormy weather and lasts longer when being dry. At the same time, the disposal of the plastic mulch film appears to be a growing and expensive problem, even though in 2014, the plastic mulch film was still significantly more economical to use than other alternatives.

The mulch film market is dominated by plastic producing companies and there is no commercial production of cellulose-based mulch film (BioInnovation, 2018). The market share of degradable mulch film has increased, but these options are considered to be too expensive by many farmers (BioInnovation, 2018). On the other hand, Sarnacke *et al*, (2008) states that the global demand for a cost-effective biodegradable mulch films would be high within most row crop markets. That is, because it would eliminate the cost and effort of the mulch film disposal. Though the biodegradable mulch films also needs to meet the required performance and at the same time not exceed the alternative disposal cost. Brault *et al* (2004) argues for how aspects like cost and availability will be decisive in the adaption of paper mulch film among farmers.

4.1.1 Bio-based soil coverage

Biodegradable mulch films (figure 9) do exist on the market, with merely a market share of less than 10 percent and has a price which is two or three times higher the price than of plastic mulch film (Ahokas *et al*, 2014). In Europe about 5 percent of used mulch film is degradable (BioInnovation, 2018). The most common used organic mulch film is made of leaves, hay or paper (Shogren, 2000). The bio-based mulch film is mostly used in countries with high landfilling and labour costs, because the plastic mulch film requires more labour and disposal (Ahokas *et al*, 2014). The advantage of biodegradable mulch film however, is that it does not need to be removed and will biodegrade once being tilled into the soil (Ahokas *et al*, 2014; Haapala *et al*, 2014; Jenni *et al*, 2006). That will in turn reduce a considerable cost of usage for the activities such as removal work (Anderson *et al*., 1995) as well as the cost of the often-tedious landfilling practice for used plastic mulch film (Ahokas *et al*, 2014; Shogren, 2000).

Figure 9. Vegetable production with bio-based soil coverage, Source: Respondent 2

Two types of bio-based mulch films are commonly used is:

- **Bio-plastic mulch film**
  Bio-plastic is made of bio-based raw material (Halley *et al*, 2001) and is branded as a degradable plastic or bio-plastic (Zhang *et al*, 2008). Bio-plastic is then classified as either *completely degradable* or *partially degradable*. Completely degradable is a bio-plastic which will be processed to become carbon dioxide and water. Partially degradable is a bio-plastic which will leave desired substances (i.e. nutrients) in the soil (Halley *et al*, 2001).

- **Craft paper**
  Paper mulch films, usually called *craft paper* (Haapala *et al*, 2014) has the capability to prevent weed growth in the soil, sometimes even better than the plastic mulch film, but keeps a lower ground temperature than plastic mulch film.

There are a few possible compositions of materials for the production of a biodegradable mulch film. Paper film material made of chemical pulp fibers is biodegradable, though it probably has to be developed with a greater decay resistance because of its fast biodegrade, in order to be functional in further areas than just dry regions (Ahokas *et al.*, 2014). Anderson *et al*, (1995) and Shogren, (2000) discovered that paper itself will break and blow away due to biodegradation and will be damaged by water within 2-3 weeks. To increase the durability of biodegradable mulch film, different kinds of coating are essential. An obvious advantage for mulches made of paper, is that removal by the end of the season is not necessary, as it will be degrading into the soil (Ahokas *et al*, 2014; Haapala *et al*, 2014; Jenni *et al*, 2006).

Paper mulches can also be made of mechanical or chemimechanical pulps, which have a higher resistance of biodegradation (Ahokas *et al.*, 2014). This kind of mulch film has the ability to function until the cultivation season is over or remain for two years when not being processed into the field. It has it weakness though in *mechanical stress* like mechanized laying, employees working in the field and wind. For this reason is this bio-based mulch film made of mechanical or chemimechanical pulps, more suitable for a long lasting procedure. Shogren, (2000) found that kraft paper had a significantly higher strength against wetness when impregnated with different extracts of soybean and linseed oils respectively soybean and citric acid. The coated kraft papers maintained for about 8-12 weeks on top of the soil and the uncoated paper lasted for about 8 weeks until being fragmented. The author examined that polymerized oils were the most effective coating to provide disintegration and weed growth.

Ahokas *et al.*, (2014) investigated how the bio-based (paper) mulch film could be developed and produced at a lower cost and at the same time be comparably performed to the plastic mulch film in the field. The research and experiments were performed in farms of Finland, Swaziland, Turkey and Spain. Properties to be included are especially; ease to put it in place, weather resistance which also applies the ability to block sunlight and to have a bio-based mulch film that does not begin to biodegrade until tilled in the soil (*ibid*). The authors explain that different materials of bio-based mulch film, is suitable for different countries and geographic areas.

The crop also has an impact for the most appropriate choice of bio-based mulch film. For example, Spain has a low amount of rainfall, which means that a quickly biodegrade mulch-film is not a severe problem, in contrast to other countries and regions. There are also plants, like melon, which grow fast and are able to “protect” by keeping it in place with branches and leaves. Experiments have shown that the best bio-based mulch film was comparable to both polyethylene and biodegradable plastic mulch film (Ahokas *et al.*, 2014). One of the main problems with paper board mulch sheets however, is their tendency of getting curled up on the soil. Even though paper mulches have a low share on the market, it has potential and farmers are positive towards a low cost biodegradable mulch film.

4.1.2 Economic considerations of soil coverage

There are many expenses related to the mulching process in addition to the price of mulch film (Haapala *et al*, 2014). The transportation cost is dependent on the weight of the mulching material; a heavy load will lead to large expenses. Labor costs connected to laying and removal of the mulch film, make these activities important to keep effective and simple. For non-degradable mulch film, there are also an additional disposal cost to be included. Still, mulching is interesting for farmers since it gives an opportunity to reduce costs for labor and agricultural chemicals. For some cases where biodegradable material film is required, it could be more economical to have mulch made of paper, treated with polymerized vegetable oil (Shogren *et al*, 2006).

Sarnacke *et al*, (2008) investigated the economic position of row crop farming, due to needed equipment such as fertilizers, pesticides and mulch films. The authors argue that the price of this gear have increased, due to the price inflation of natural gas and crude oil. Furthermore, the distinctive costs for mulching have ascended from 130$ to 200$ per acre (325$ to 500$ per hectare) since the beginning of the 21st century - 2008. During the mulching process, there are activities like field collection, trucking and discarding which have been examined to have risen from 50$ per acre to 100$ (125$ per hectare to 250$) (*ibid*). Even the separate cost of removal of the plastic mulch film could by itself have an approximately charge of 250$/hectare, according to Shogren, (2000). A few selected prices for mulch film are being presented in table 5, where it is observable how the polyethylene mulch film tends to be the cheapest alternative.

Table 5. Prices for mulch film 2008, 2009 and 2011.

Prices for mulch film 2008, (Han et al, 2008).	
Biodegradable mulch film:	0,23 EUR – 0,60 EUR /m2
Polyethylene mulch film:	0,05 EUR – 0,08 EUR /m2
Price for mulch film, Finland 2009, (Ylitalo, 2009).	
Paper	0,045 EUR – 0,094 EUR /m2
Price mulch film 2011, (Haapala et al, 2014).	
Retail paper mulch film	0,29 EUR – 1,06 EUR /m2

4.2 Bio-based businesses

The fundamentals of a bio-economy, is the idea of an economy based on renewable biological resources for energy and food security (Ipate, *et al*, 2015). To measure and define bio-economy businesses', Efken *et al*, (2016) suggest having an input oriented calculation. The bio-economy portion of a certain industry is found by the share of biological resources in the input. In the long run, natural resources may not have the potential to fund a strong growth in consumption due to its shortage on bio-product supplies and rising prices on bio-resources (Kotler *et al*, 2010). As a result, the cost burden of having bio-products will increase for customers and companies and only those who can achieve a sustainable supply of natural resources will become strong competitors.

Biomass holds an important role in supplying feedstock with renewable resources (Wyse, 2011). Sugar and starch are readily available resources, but the access to lingo-cellulosic is an important and vital breakthrough. Wyse, (2011) also claims for technology to move closer to the biomass, because of its lower energy density than currently used energy resources as petroleum. Opportunities for the industry are to either integrate waste conversation or focus on the improvement of accessing dedicated energy crops. Sectors having its primary production in bio-based materials are defined as *bio-economy sectors* in the study of Heijman (2016), i.e. aquaculture, fishery, agriculture, and forestry and veterinary services. Sectors using inputs from the bio-based primary production (sector 1) are set as bio-business sectors having secondary bio-production (sector 2). The bio-economy (business) consisted therefore of sector 1 together with a part of sector 2 (figure 10).

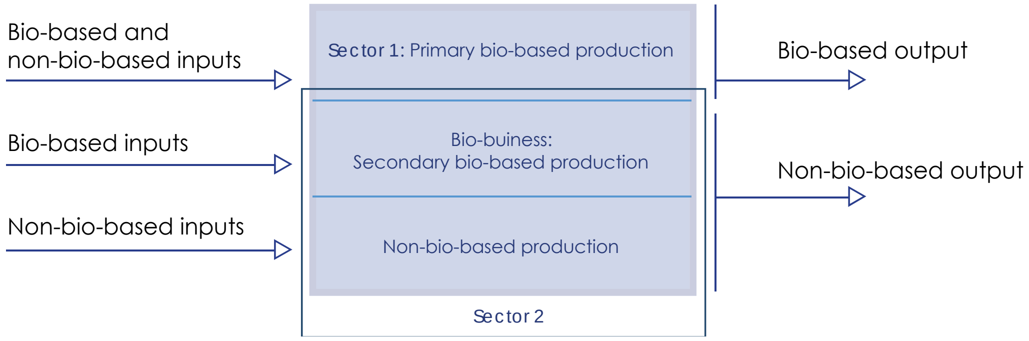

Figure 10. Bio-based and non-bio-based sectors, (Heijman, 2016), own illustration

In Ronzon *et al*, (2017) are bio-economy businesses' either seen as fully or partly bio-economy sectors. Manufactures of food products, wood, paper and beverages were examples of fully bio sectors. Furniture production, rubber and plastic products and other organic basic chemicals, were seen as partly bio-economy sectors. The authors did a study regarding the EU's bio-economy sectors and found forestry, agriculture and fisheries to be the most labor-intensive sectors (figure 11).

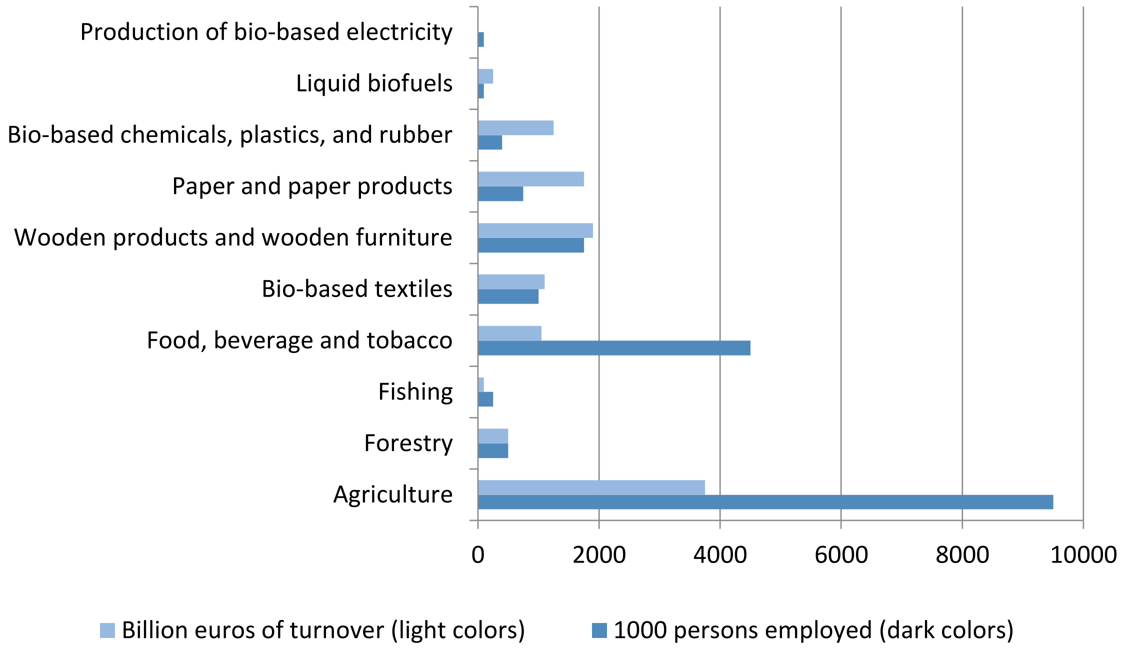

Figure 11. Employment and turnover generated in EU-28 sectors (2014), manufacture (Ronzon et al, 2017), own diagram

Ipate, *et al*, (2015) means the bio-economy management should be designated to optimize the resource allocation between food and fuel. Both the primary sector and the processing sector needs development through innovation and research, to create new business models, industry concepts, markets and jobs. To endeavor energy and food security are two identified main drivers for the emerging bio-economy (Wyse, 2011). Challenges are in the development of technologies that is low-carbon-emitting, through a sustainable manner. Increased productivity by using tools and technologies and improve efficiency is essential, and in order to develop such solutions, innovations are fundamental.

4.2.1 Bio-based innovations

Bio-products are often produced with less energy and at a lower cost than non-bio products (Liebert, 2013). In Esposti (2012) innovation is described as a science-based phenomenon, with solutions going downstream to the agriculture sector. Process innovations have enabled an increase yield in general. New chemical fertilizers, agricultural machinery, crop varieties generating higher yields and resistance respectively in addition to new active components used for weed control are examples of innovations within the agriculture sector. However, there is a dependency of appropriate norms, regulations and incentives, which lead to a rather institutional process for such technological innovations.

There is also a possibility for policy and financial innovations, achieved by concrete and consistent policies on governmental level (Liebert, 2013). Though, socio-economic research for a transition to a bio-economy remains rare (Lancker *et al*, 2016). Concepts for managing technology and innovation are crucial for the bio-economy development, but are specifically limited. The authors found three key issues regarding innovation of bio-economy processes: The fundamental stakeholder groups having importance for the continuing innovations of bio-economy, an innovation network, and features considered as obligatory in organizations involved in collaborative innovation.

4.3 Bio-economy aspects and profitability

The bio-economy is regarded as an alternative economic model, with a bio-based concept to generate profit (Sillanpää *et al*, 2017). One main goal in implementing a bio-economy is to find profitability opportunities of sustainable economic models. Although initial costs may be high to reach sustainable developments, Krykavskyy *et al*, (2016) states the importance of reviewing the whole life cycle of services and products to find their true impact on the environment. Sustainable supply chains are required, and to support them it is essential to apply processes and use equipment with low environmental impact.

The definition of profitability in general is usually explained as the relation between profit and capital (Olhager, 2015). When a decision is made, a valuation should be prepared from how this decision will affect the company's economical profitability (Eklund, 2007). If the decision makes the total utility (income) larger than the total cost of the effort, the decision should be made. Also Porter (2004) argues that firms are profitable once the commanded value (measured as total revenue) of a product surpasses the costs involved for the construction of the product. Changes in costs and capital do affect the outcome results and to create a long-range profitability for a company, there are four strategic disciplines to observe and develop (Olhager, 2015);

- Quality
- Delivery capacity
- Cost effectiveness
- Flexibility

Each discipline may have different importance and weight depending on product or service (*ibid.*). The meaning of *quality* has been investigated and is often seen as subjective, but *product quality* usually means a products ability to fulfill a customer's expectation. With correct quality, a higher income can be generated as well as poor quality may cause both direct and indirect costs for the company, for example by rejects. Delivery capacity could be summed up as the customer's expectation for the time of service as well as time for arrival of the product. There is an endeavor for short-limited and assured time of delivery, which is defined as *delivery rate* and *delivery precision*.

The idea of cost effectiveness is multidimensional and could be viewed from different perspectives and measurements (*ibid.*). One measurement is the relation of output to input, or more precisely, *productivity*. Output is described as amount of provided products and input as one or many efforts to produce the output. The final discipline, flexibility, is also about the time rate. But in this case, it's all about adapting quickly to changes and trends in society and to new conditions. In the long-range, that is possible by developing new products, systems and processes while in the short-term adjust the production volume to a given demand and product mix. To gain flexibility, the company should also have short conversion time limits for adjusting tools, machines and routines when making alterations of production inputs.

Profitability is the base when forming business calculations (Eklund, 2007). However one discipline is rarely included in those calculations despite its “cost” for being used; that is *effects on the environment*. If the marginal cost for the environmental impact were to be added as a marginal cost to the business calculations, the decision for a planned investment may be revised. To be able to use the fundamental rule for profit, *marginal cost = marginal income*, it is necessary to put a price on the effects on the environment.

4.4 Performed ABC calculation

The ambition with product calculation is to present a high causality between costs and manufactured products (Andersson, 2009). It is about making an appropriate calculation for a given company’s business, by selecting sincere and customized distribution keys. The most used approach of traditional calculation is said to be the top-down perspective, where common resources are distributed thoroughgoing cost centers and cost carriers to each calculation object (Andersson, 2009). In contrast, the activity perspective has a bottom-up view with the principle of having a calculation object causing resource consumption. This means the company uses its business as foundation for designing the calculation model.

In an article by Korpunen *et al*, (2010) ABC was used as method for a case study of sawmilling. The authors identified processes in the production and analyzed their cost structures in detail. Subsequently resources, activities and cost drivers for the processes defined. The authors discussed how different technical solutions for a certain production process may alter its cost structure. Depending on how a resource was delivered to the production, the supply could be either included or excluded to the cost analysis. As an example, heat energy production was outsourced and therefore not included. There is also a possibility to take opportunity cost into account with the ABC model (*ibid*). A significant difference in costs between two products was found, and the authors conclude that ABC in general enables an insightful analysis of a production.

Tzong-Ru, (2001) made a case study about a certain fish market in Taiwan, using ABC in combination with a simulation technique. The study had the objective to observe the cost for a fish market practice. The aim with the simulation technique was to design a system close to reality, and it was achieved by collecting data of operational time and number of resources used. The author argues how a simulation technique generates more accurate results to the ABC model, regarding the allocation of resource costs. An arbitrary allocation is thereby reduced. After identifying the activities, resources were allocated by direct charging and estimation respectively. Resources and resource drivers were determined, and with the simulation technique, every recognized resource was calculated by its actual consumed time or volume for the certain activity. The activity cost was then defined with number of performances (cost driver) and then calculated to the cost objective, which was constituted as kg fish. In conclusion, Tzong-Ru (2001) encourages the simulation technique when using the ABC model in future research of agriculture systems.

5 Empirical collection

In this chapter, the study's result is being presented. The first section presents all phases and activities in the soil covering process. The information is both gathered from literature sources and from respondents using different kinds of mulch film. Cost drivers and resources are described and explained, based on the ABC framework. In the following section quantitative indirect and direct costs are presented.

5.1 Phases and activities of soil covering

In the thesis by Paulsson, (2016) several steps (phases) were identified during the process of soil covering. In this study, the following phases have been identified as cost-activities; *purchase, storage, lay out, maintenance service, end of season, and final management.* The phases are described below with their corresponding activities.

Phase: Purchase. All respondents were familiar with soil covering and knew by previous experience what kind of mulch film to purchase. That's why the *search to find information about different types of mulch film* turned out to be an insignificant activity to include in the ABC model. The decision of which mulch film to order was simply made by browsing a catalogue, calling the retailer by phone or lay a few minutes on the retailer's website. At the most, about one hour was set on the purchase. At the same time, to gain and develop knowledge about a suitable mulch film for the certain vegetable production, had for some respondents taken several years. That includes both plastic and bio-based mulch film, where thickness (plastic and bio-based) and material (bio-based) had been altered. Both Swedish and international retailers of mulch film were mentioned, and how the purchase price varied due to the exchange rate and quantity of mulch film rolls purchased (discounts). The mulch film is thin, and the delivery cost was dependent on how many other products that were ordered and delivered at the same time. The order arrived by truck.
Activities: Delivery material

Phase: Storage. The delivered mulch film material was in general kept in a storage area. One respondent having plastic mulch film kept the material outside on the courtyard until usage, because the weather does not make any harm. Another aspect mentioned about the plastic mulch film, was that it is perishable and needs to be used in the near future. Most respondents purchased the mulch film a few weeks before the upcoming season. The activity cost consists by a fictive cost of storage.
Activities: Stock-keeping

Phase: Lay out. For the phase of *lay out*, one activity was identified as *setup of machines* for the mulch film laying. The respondents had a special equipped machine for the laying, which was either bought complete or built manually by the respondent. The machine was held ready by the time the lay out was going to start, and the setup was found to be lasting for a couple of minutes up to mostly one hour. The cost of labour was calculated for the activity when it was lasting for ten minutes or more. To put the mulch film in place, the respondents were using different routines and a tractor, machine or other lay out equipment that was always supporting the process. The layout was either made solo or by multiple employees, partly manually or with machines only. Tube for drip irrigation (indirect material) was used by two respondents who combined the lay out with the mulch film. Seeding/planting was also made at the same time. Cost for the activities was labour, fuel, indirect material (if any) and depreciation (if any). The activities of *placing* and *cultivation/collection* have been seen as the central activities of the

whole mulch film process and have therefore been connected with *direct labour of manufacturing* for regular employees.
Activities: Setup machine, Placing

Phase: Maintenance service. When the respondents were asked about contingently maintenance service no respondent was recognizing such an event as too common. The weather turned out to be the dependent factor, especially stormy weather. One respondent mentioned how the method for placement could support the securing of the mulch film, *i.e.* the size of plant holes in the mulch and the fastening in the soil (dirt being put on the mulch film edges). Also the aspect of soil type was mentioned to be important for mulching conditions. If the mulch film loosened, it was manually fastened again. In the empirical background damage of the mulch film was found to be a common problem, but this cost was excluded from the ABC calculation due to its insignificance in this study. For the non-woven fibre though, the service of lifting the fibre to use pesticide on the crop was necessary. This cost was decided to be included due to its connection to the non-woven fibre and for being relatively time consuming.
Activities: Servicing the mulch film

Phase: End of season. After the season, the bio-based mulch film is tilled into the soil or the plastic mulch film is being collected. For the ABC calculation, the cultivation process was only included when it was specifically made because of the mulch film, and excluded if the cultivation was made independent if mulch film had been used or not. The plastic mulch film was mostly being picked up manually with the support of custom made equipment (by the farmer). The mulch film was in general rolled up on rolls, to ease recycling or storage (non-woven fabric). Though, one respondent had support from neighbours regarding the cultivation, as part of a cooperation. Only the labour hours were therefore included in that case. Costs occurring during the activities were identified as labour and fuel. Labour cost has been calculated as *direct labour of manufacturing* together with labour cost from the placing activity.
Activities: Cultivation or Collection

Phase: Final management. Since the bio-based mulch film already has been tilled down as final management, this phase only includes the plastic mulch film. The recycling routine appeared different between the respondents. The plastic mulch film was either transported to a recycling station or was recycled on the farm. The non-woven fabric in usable shape was stored until next season. Two respondents paid a fee for the recycling and one respondent recycled for free. The relevant cost for the recycling activity was the recycling fee.
Activities: Recycling

5.2 Resources used for soil covering activities

Consumed resources for the soil covering (indirect) activities could be summed up as shipping, storage, diesel, labor, depreciation, indirect material and recycling cost. The costs of resources was first calculated for the individual resource, and then multiplied with a resource driver. The resource cost of shipping, storage, depreciation, indirect material was obtained from the respondents. For diesel and labor, general costs/prices in Sweden were applied. The TCO perspective limited the amount of resources to only include the most significant ones, excluding negligible resource costs (i.e. phone costs for new mulch film orders).

Resource: Shipping. The respondents were asked to do an estimation of the mulch film share of the freight (resource cost), since the mulch film usually was shipped together with other products like seeds or agricultural equipment. This way, the freight cost could be considered as close to reality. The number of deliveries was the resource driver.

Resource: Stock-keeping. The stock-keeping cost was calculated by a commonly used stock-keeping cost equation (resource cost), described in Ohlager, (2015). It is calculated with the base of the article value, and then a stock-keeping cost interest rate was decided (figure 12).

$$H = r * V$$

H = stock-keeping cost
r = stock-keeping cost interest rate
V = article value

Figure 12. Stock-keeping cost equation, (Ohlager, 2015).

Ohlager, (2015) described that the stock-keeping cost interest rate, should be decided by the article's (i.e. materials) difficulty of usage, the amount of space being occupied and by the desired storage balance in the company. Within the context of this study, the main purpose of the stock-keeping cost was to imitate and measure the occurrence in reality. Bio-based mulch film has a need of storage holding, and storage cost was therefore seen as a relevant value to include. Although, since the mulch film was kept in storage for barely a month (resource driver), is essential for the production and did not fill a major space (according to the respondents), the stock-keeping cost interest rate was kept at two percent a month in this study.

Resource: Diesel. Fuel consumed by the mulch film activities required data regarding how many liters of diesel that was being consumed (resource driver). The respondents were asked about the consumption estimated for the activities, or brought leading to make a self-calculation of the amount. The price for one liter diesel (resource cost) was gained from the report of agricultural statistics by Jordbruksverket, (2017).

Resource: Indirect labor. Indirect labor cost was calculated as labor hours consumed by the indirect activities (resource driver), including additional employees working only during the central *placing* and *cultivation/collection*. The respondents were asked about the duration of all activities (requiring employees) and how many employees supporting in the activities. The price/cost for one labor hour was gained from the report of agricultural statistics by Jordbruksverket, (2017). The same cost for one labor hour was used for both indirect labor hours and direct manufacturing labor (regular employees).

Resource: Depreciation. Each respondent were asked about the depreciation for the tractor and machine used for mulch film management. First, the yearly depreciation for the tractor and machine were asked about (resource cost), and then the estimated percentage of usage for the mulch film, relatively the whole year usage (resource driver). The data was measured by spent hours. This way, solely the mulch film share of the depreciation cost was given. The respondents' depreciation cost was dependent on the price for the purchased tractor and machine, in combination with years of usage.

Resource: Indirect material. The resource cost of indirect material did only occur for respondents having additional material, such as the drip irrigation tube or other material (resource cost), and depending on the mulch film usage. A few respondents used the same method for irrigation, regardless of having mulch film placed on the soil. In these cases the irrigation equipment was excluded from the ABC calculations, since the cost would have been incurred either way. The cost was calculated with a suitable unit measure, like *meters* in the case of the drip irrigation tube (resource driver).

Resource: Recycling cost. When asking the respondents about the cost of recycling, two respondents were found to have a fee paid for the service. The transportation to the recycle station appeared to only take a few minutes for all respondents (if any) and was therefore seen as insignificant to the resource cost of recycling. It was judged as fairly representative in the ABC calculations to only include the recycling fee. Other respondents recycled by their own effort or for free at the recycling station.

5.3 Activity costs and cost drivers for soil covering

When the resources have been identified, the next step is to determine how much of the resources are being spent on each activity (Kaplan *et al*, 1998). In other words, what resource/resources are required to perform the activity? As described in the theory chapter, to make the resource allocation to activities, one could either apply *direct charging*, (direct allocations of resource costs to activities), *estimation*, (resource allocation using cost drivers) or *arbitrary allocation*, (casual allocation of the resources to activities) be used (Ostrenga, 1990).

Activity: Delivery material. For this activity, the resource cost of *shipping* was required and is recognized as a *direct charging* resource. The respondents' further effort of transporting the material from the courtyard to the storage area was made in a couple of minutes with a truck or tractor. The data for this part of the performance was difficult to make any sense of, and only includes the indirect labor resource cost if lasting longer than ten minutes, to the ABC calculations. The cost driver was determined as the number of seasons, which for all respondents was held as one season.

Activity: Stock-keeping. To calculate this activity only the stock-keeping cost was included, and that is only for the farms having the mulch film in a storage area. Direct charging also occurs for this resource cost, since it only appears during this activity. No other resources were consumed during this activity performance. Similar to the previous activity, the cost driver for stock-keeping was identified as number of seasons, which was limited to one season for all respondents.

Activity: Setup machine. To setup the machine, indirect labor cost was required. The resource was allocated by *estimation* to all activities requiring indirect labor (administrative tasks, extra personnel). Still, a few respondents didn't consume any time for the setup since the equipment already was prepared to process. The resource cost only includes respondents consuming time for setup the machines. The activity cost driver was set as number of layouts during a season, which for all respondents was held as one.

Activity: Placing. Resources required for this activity were diesel, indirect labor cost, depreciation and generally consumed indirect material. *Estimation* was made for the resource allocation of all indirect resources except for indirect material, which was made by *direct charging*. The respondents' resource cost was dependent on extra personnel, if depreciation still was made and if any indirect material such as irrigation drip tube was used. Number of layouts was defined as the activity cost driver.

Activity: Servicing the mulch film. This activity only regards the non-woven fabric and consists of indirect labor. The resource allocation was made by *estimation* and the activity cost driver as number of performances during a season.

Activity: Cultivation. The cultivation activity is only required for respondents using the bio-based mulch film, as opposed to the usage of plastic mulch film. Even if cultivation often is a part within crop production, it becomes the *final management* for bio-based mulch film since its being tilled down, which is to be compared to the plastic mulch film final management and therefore needs to be calculated for. Resources used were indirect labor, depreciation and diesel, which were all allocated by *estimation*. The activity cost driver was set as number of cultivations per season (one for all respondents).

Activity: Collection. The collection of mulch film only concerns the plastic mulch film users, because it needs to be removed from the soil by the end of the season. Indirect labor for extra personnel is the resource consumed for the activity and was allocated by *estimation*. The activity cost driver was determined as number of times the plastic mulch film was to be collected, which is one per season.

Activity: Recycling. This activity also only concerns the plastic mulch film users. The recycling fee is the main consumed resource cost and was made by *direct charging* to the activity. Indirect labor, fuel and depreciation would have been relevant to include as well, but the transport of the used plastic mulch film turned out to be lasting for about five minutes and sometimes also made in combination with another errand. It was complicated to find a proper resource cost regarding this matter, and was hence excluded from the ABC calculations. The activity cost driver was number of times recycling's' per season, which was set as one time.

5.4 Direct costs and cost objects

Direct costs are allocated directly to the cost objects (Lewis, 1995; Kaplan *et al*, 1998). That is costs directly connected to the manufacturing process, as material and labor. In this study's ABC calculations, direct material is defined as amount of mulch film rolls consumed, multiplied by the price for each roll of mulch film. This data was gained from all the respondents. To identify direct labor hours, regular employees working hours during the *placing* and *cultivation/collection* activities were calculated. The distinction between indirect labor and direct labor resource cost turned out to be displaying clear variations to the numbers in the ABC calculations. Albeit, the method and distinction was held consistent through all respondents' cases and was regardless to be accumulated in the result.

One step of creating the ABC calculations requires the identification of cost objects in the organization (Kaplan *et al*, 1998). Because of the comparative design of this study, as well as the economic mapping purpose, *hectares* was identified to be the most suitable cost object for this performed ABC calculates. The respondents were asked about their numbers of hectares used for mulching, to be able to apply the correct area for the ABC calculations.

5.5 Structure of the ABC calculations, the mulch film process

The ABC calculations made for this study was inspired by Korpunen *et al*, (2010), for support on how to structure the equations. The equations down below were customised for this specific case and have been used for all the respondents' farms. First, each identified activity cost was calculated by their consumed resources, either by direct charging or estimation. Since the activity costs were calculated for one year (one season), the cost driver is already within the equations because of most activities only occurring once during the season. The activity costs were then aggregated and divided by number of (mulched) hectares, to find the total cost for mulch film per hectare.

5.5.1 Indirect costs, ABC calculations

Equation (1) displays the cost for delivery of the mulch film material. Only deliveries with mulch film were calculated for, and were gained as the estimated cost for the mulch film share only.

$$ACM_{Delivery\ Material} = S_n \cdot SC \tag{1}$$

$$\begin{aligned} ACM_{Delivery\ Material} &= Annual\ Cost\ of\ Delivery\ Material, for\ the\ Mulch\ film\ process \\ S_n &= Number\ of\ shipments \\ SC &= Shipment\ cost \end{aligned}$$

Equation (2) calculates the stock-keeping cost. This cost is only fictive, meaning it does not really exist in reality. It was included though, for the bio-based mulch film requirement of being kept in storage before usage (when not used directly).

$$ACM_{Stock-keeping} = M_n \cdot P_m \cdot SK_r \cdot MO_n \tag{2}$$

$$\begin{aligned} ACM_{Stock-keeping} &= Annual\ Cost\ of\ Stock-keeping, for\ the\ Mulch\ film\ process \\ M_n &= Number\ of\ Mulch\ film\ rolls \\ P_m &= Price\ per\ mulch\ film\ roll \\ SK_r &= Stock-keeping\ rate \\ MO_n &= Months\ in\ storage \end{aligned}$$

Equation (3) displays the setup cost for the machine, where only working hours were consumed. Most respondents did not have a significant duration for the activity, and was in some cases excluded.

$$ACM_{Setup\ machine} = \left((IWH_{tot} \cdot WC_h) \cdot \frac{IWH_{Setup\ machine}}{IWH_{tot}} \right) \tag{3}$$

$$\begin{aligned} ACM_{Setup\ machine} &= Annual\ Cost\ of\ Setup\ machine, for\ the\ Mulch\ film\ process \\ IWH_{tot} &= Indirect\ Working\ Hours\ in\ total, the\ mulch\ film\ process \\ WC_h &= Wage\ Cost\ per\ hour \\ IWH_{Setup\ machine} &= Indirect\ Working\ Hours\ to\ Setup\ the\ machine \end{aligned}$$

The placement calculation shown in equation (4) consumed the resources diesel, indirect working hours (if extra personnel were supporting), a percent share of the depreciation cost for the tractor (based on the same percent as for diesel used) and equipment and possible indirect (extra) material.

$$ACM_{Placement} = \left(\frac{D_{Placement}}{D_{tot}} \cdot P_D \cdot D_{tot}\right) + \left((IWH_{tot} \cdot WC_h) \cdot \frac{IWH_{Placement}}{IWH_{tot}}\right) + \left(ACM_{Depreciation} \cdot \frac{D_{Placement}}{D_{tot}}\right) + IM_{Cost} \quad (4)$$

$$\begin{aligned}
ACM_{Placement} &= \text{Annual Cost of Placement, for the Mulch film process} \\
D_{Placement} &= \text{Litre Diesel consumed for the placement of the mulch film} \\
D_{tot} &= \text{Litre Diesel in total for the mulch film process} \\
P_D &= \text{Price per litre Diesel} \\
IWH_{tot} &= \text{Indirect Working Hours in total, the mulch film process} \\
WC_h &= \text{Wage Cost per hour} \\
IWH_{Placement} &= \text{Indirect Working Hours for the placement of the mulch film} \\
ACM_{Depreciation} &= \text{Annual Cost of Depreciation, equipment for the mulch film process} \\
IM_{Cost} &= \text{Cost of Indirect Material}
\end{aligned}$$

Equation (5) accounts for if any maintenance service is performed and is limited to only including possible occurring indirect working hours.

$$ACM_{Maintenance} = (IWH_{tot} \cdot WC_h) \cdot \frac{IWH_{Maintenance}}{IWH_{tot}} \quad (5)$$

$$\begin{aligned}
ACM_{Maintenance} &= \text{Annual Cost of Maintenance service, for the Mulch film process} \\
IWH_{tot} &= \text{Indirect Working Hours in total, the mulch film process} \\
WC_h &= \text{Wage Cost per hour} \\
IWH_{Maintenance} &= \text{Indirect Working Hours for maintenance service}
\end{aligned}$$

As displayed in equation (6), cultivation is an activity for the bio-based mulch film. The consumed resources for the activity were diesel, indirect working hours (if extra personnel were supporting), a percent share of the depreciation cost for the tractor (based on the same percent as for diesel used).

$$\begin{aligned}
ACM_{Cultivation} &= \left(\frac{D_{Cultivation}}{D_{tot}} \cdot P_D \cdot P_{tot}\right) \\
&+ \left(IWH_{tot} \cdot WC_h \cdot \frac{IWH_{Cultivation}}{IWH_{tot}}\right) \\
&+ ACM_{Depreciation} \cdot \frac{D_{Cultivation}}{D_{tot}}
\end{aligned} \quad (6)$$

$$ACM_{Cultivation} = \text{Annual Cost of Cultivation, for the Mulch film process}$$

$$WC_h = Wage\ Cost\ per\ hour$$
$$IWH_{Cultivation} = Indirect\ Working\ Hours\ for\ the\ placement\ of\ the\ mulch\ film$$
$$ACM_{Depreciation} = Annual\ Cost\ of\ Depreciation, equipment\ for\ the\ mulch\ film\ process$$

The plastic mulch film requires collection and the calculation for the activity is displayed in equation (7), which only consumed working hours according to the respondents. Additionally, since it is an indirect cost, only indirect working hours of extra personnel are to be included.

$$ACM_{Collection} = \left((IWH_{tot} \cdot WC_h) \cdot \frac{IWH_{Collection}}{IWH_{tot}} \right) \tag{7}$$

$$ACM_{Collection} = Annual\ Cost\ of\ Collection, for\ the\ Mulch\ film\ process$$
$$IWH_{tot} = Indirect\ Working\ Hours\ in\ total, the\ mulch\ film\ process$$
$$WC_h = Wage\ Cost\ per\ hour$$
$$IWH_{Collection} = Indirect\ Working\ Hours, Collection\ of\ the\ mulch\ film$$

The plastic mulch film also requires recycling after being used, and was set as the price for recycling, or the recycling fee, in equation (8)

$$ACM_{Recycling} = P_{Recycling} \tag{8}$$

$$ACM_{Recycling} = Annual\ Cost\ of\ Recycling, for\ the\ Mulch\ film\ process$$
$$P_{Recycling} = Price\ for\ recycling\ (the\ recycling\ fee)$$

5.5.2 Direct costs, ABC calculations

There are two direct costs for these ABC calculations; direct material and direct manufacturing labor. Direct material shown in equation (9), consists of the mulch film material and is calculated as number of mulch film rolls multiplied with the price per mulch film.

$$ACM_{Direct\ material} = M_n \cdot P_M \tag{9}$$

$$ACM_{Direct\ material} = Annual\ Cost\ of\ Direct\ material, for\ the\ Mulch\ film\ process$$
$$M_n = Number\ of\ Mulch\ film\ rolls$$
$$P_M = Price\ per\ mulch\ film\ roll$$

Direct manufacturing labor in equation (10) represent the working hours consumed by the regular personnel for the mulch film process.

$$ACM_{Direct\ manufacturing\ labor} = DWH \cdot WC_h \tag{10}$$

$$ACM_{Direct\ manufactoring\ labor} = Annual\ Cost\ of\ Direct\ labor,\ the\ Mulch\ film\ process$$
$$DWH = Direct\ Working\ Hours$$
$$WC_h = Wage\ Cost\ per\ hour$$

5.5.3 Total cost per hectare, ABC calculations

In this final section, the total cost per hectare calculation is presented. The aggregated cost consists of all the activity costs, and is then divided on the number of hectares mulched. The calculation differs depending on the usage of the bio-based or plastic mulch film.

Total cost per hectare for the bio-based mulch film is presented in equation (11).

$$ACM_{Hectare} = \frac{\begin{pmatrix} ACM_{Delivery\ material} + ACM_{Stock-keeping} + ACM_{Setup\ machine} + ACM_{Placing} + ACM_{Maintenance\ service} \\ +ACM_{Cultivation} + ACM_{Direct\ material} + ACM_{Direct\ manufacturing\ labor} \end{pmatrix}}{Hectares_n} \tag{11}$$

$$\begin{aligned} ACM_{Hectare} &= \ Annual\ Cost\ per\ Hectare, the\ Mulch\ film\ process \\ ACM_{Delivery\ Material} &= Annual\ Cost\ of\ Delivery\ Material, for\ the\ Mulch\ film\ process \\ ACM_{Stock-keeping} &= \ Annual\ Cost\ of\ Stock - keeping, for\ the\ Mulch\ film\ process \\ ACM_{Setup\ machine} &= \ Annual\ Cost\ of\ Setup\ machine, for\ the\ Mulch\ film\ process \\ ACM_{Placement} &= \ Annual\ Cost\ of\ Placement, for\ the\ Mulch\ film\ process \\ ACM_{Maintenance} &= \ Annual\ Cost\ of\ Maintenance\ service, for\ the\ Mulch\ film\ process \\ ACM_{Cultivation} &= \ Annual\ Cost\ of\ Cultivation, for\ the\ Mulch\ film\ process \\ ACM_{Direct\ material} &= \ Annual\ Cost\ of\ Direct\ material, for\ the\ Mulch\ film\ process \\ ACM_{Direct\ manufactoring\ labor} &= \ Annual\ Cost\ of\ Direct\ labor,\ \ the\ Mulch\ film\ process \\ Hectares_n &= Number\ of\ hectares\ with\ mulch\ film \end{aligned}$$

Total cost per hectare for the plastic mulch film is presented in equation (12).

$$ACM_{Hectare} = \frac{\begin{pmatrix} ACM_{Delivery\ material} + ACM_{Stock-keeping} + ACM_{Setup\ machine} + ACM_{Placing} + ACM_{Maintenance\ service} \\ +ACM_{Collection} + ACM_{Recycling} + ACM_{Direct\ material} + ACM_{Direct\ manufacturing\ labor} \end{pmatrix}}{Hectares_n} \tag{12}$$

$$\begin{aligned} ACM_{Hectare} &= \ Annual\ Cost\ of\ Hectare, the\ Mulch\ film\ process \\ ACM_{Delivery\ Material} &= Annual\ Cost\ of\ Delivery\ Material, for\ the\ Mulch\ film\ process \\ ACM_{Stock-keeping} &= \ Annual\ Cost\ of\ Stock - keeping, for\ the\ Mulch\ film\ process \\ ACM_{Setup\ machine} &= \ Annual\ Cost\ of\ Setup\ machine, for\ the\ Mulch\ film\ process \\ ACM_{Placement} &= \ Annual\ Cost\ of\ Placement, for\ the\ Mulch\ film\ process \\ ACM_{Maintenance} &= \ Annual\ Cost\ of\ Maintenance\ service, for\ the\ Mulch\ film\ process \\ ACM_{Collection} &= \ Annual\ Cost\ of\ Collection, for\ the\ Mulch\ film\ process \\ ACM_{Recycling} &= \ Annual\ Cost\ of\ Recycling, for\ the\ Mulch\ film\ process \\ ACM_{Direct\ material} &= \ Annual\ Cost\ of\ Direct\ material, for\ the\ Mulch\ film\ process \\ ACM_{Direct\ manufactoring\ labor} &= \ Annual\ Cost\ of\ Direct\ labor,\ \ the\ Mulch\ film\ process \\ Hectares_n &= Number\ of\ hectares\ with\ mulch\ film \end{aligned}$$

6 Results

In this chapter, the results of the empirical survey are presented when ABC has been applied.

6.1 Data of soil covering, indirect costs

In this section, indirect costs connected to the mulch film process are presented. All resources that are indirectly connected to the mulch film process, i.e. all resources that are not direct labour (manufacturing) or direct material (price for mulch film), are included. Tables of content present the quantitative empirical data and overhead titles describe costs calculated. The structure of the tables is arranged as total area of soil covering, with the lowest to highest area. This arrangement is then categorized for the bio-based mulch film, the plastic mulch film and the non-woven fabric. The tables present indirect resource costs and activity costs.

The first presented data is the calculated resource cost for the indirect activities (table 7). The calculation is based on the resource cost and resource driver described in previous sections of this chapter. An aspect to be noted is that certain costs only incurred for some of the farms. When not occurring, the box is left empty in the table.

Table 6. Respondents' indirect resource costs for the mulch film process, per hectare.

Mulch film / Resources	Bio-based	Bio-based	Bio-based	Plastic	Plastic	Plastic	Nonwoven fabric
Respondent	*1*	*2*	*3*	*4*	*5*	*3*	*6*
Hectares	*0,5ha*	*6ha*	*27ha*	*2,5ha*	*5ha*	*27ha*	*8ha*
Shipping, SEK	300	200	39	800	100	47	125
Stock-keeping, SEK	72	158	197		96	94	474
Diesel, SEK	38	417	1103	2596	278	552	
Indirect labour, SEK	2590	1090	89		37	90	1156
Depreciation, SEK		525	618	180	802	607	4
Indirect material, SEK	1560			600	5100		
Recycling cost, SEK					84		

The indirect costs were calculated with a consistent method. However the result was based on the individual farms' methods and routines, which made the outcome varied. For example, respondent 4 did not keep the plastic mulch film in a storage area, and therefore no stock-keeping cost occurred. Respondent 6 using the non-woven fibre did the activities only by hand (and supporting equipment) and had no expenses for fuel for the mulch film process. Depreciation was dependent on when the tractor used for the mulch film activities was bought, and for which price. The depreciation resource was also allocated by the percentage of usage throughout the year. Indirect material was identified as irrigation tubes, even though depending on the specific farm, irrigation systems not correlated to mulch films were also in use. The recycling fee only appeared for one farmer, the alternative was recycling on the farm or for free.

The second table holds the calculated activity cost based on the indirect resource costs (see table 8). As for the resources, only certain activities incurred for each farm. An important distinction between indirect and direct costs is that indirect labour (for example) concern indirect activities and "extra" employees, supporting the mulch film process.

Table 7. Calculated activity costs, per hectare.

Mulch film / **Activities**	**Bio-based**	**Bio-based**	**Bio-based**	**Plastic**	**Plastic**	**Plastic**	**Nonwoven fabric**
Respondent	*1*	*2*	*3*	*4*	*5*	*3*	*6*
Hectares	0,5ha	6ha	27ha	2,5ha	5ha	27ha	8ha
Delivery material, SEK	300	200	39	800	100	47	125
Stock-keeping, SEK	72	158	197		97	83	474
Setup machine, SEK		19			37		
Placing, SEK	3828	1487	1258	2776	6181	1248	4
Maintenance service, SEK							2313
Cultivation, SEK	362	377	562				
Collection, SEK						254	
Recycling, SEK					84		

During the interview of the indirect activities for the mulch film, only the significant activities and costs were included. Still, a few activities were significant for the individual farm, as for respondent 6 regarding the maintenance service by the use of pesticides. The non-woven fiber lies upon the vegetables instead of being put directly on the soil. Indirect cost for cultivation only occurred for one farm having extra personnel in the activity.

6.2 Data of soil covering, direct costs

The final table presents the respondents direct costs (see table 9). Direct costs are directly related to the mulch film process and consist of the direct material, or the price (cost) in this case, for the mulch film and direct labor connected to the mulch film process.

Table 8. Direct costs of the mulch film process, per hectare.

Mulch film / **Direct costs**	**Bio-based**	**Bio-based**	**Bio-based**	**Plastic**	**Plastic**	**Plastic**	**Nonwoven fabric**
Respondents	*1*	*2*	*3*	*4*	*5*	*3*	*6*
Hectares	0,5ha	6ha	27ha	2,5ha	5ha	27ha	8ha
Direct material, SEK	3584	10547	9852	6000	4825	4722	3605
Direct manufacturing labour, SEK	370	1480	216	1258	6290	384	5318

The direct material was calculated as number of mulch film rolls multiplied with the price. In the accounting, the number of used mulch film rolls used for one-season was included, except from the respondent having the non-woven fabric, who could re-use half of the material every season. Only the cost for the new purchased non-woven fiber was included.

6.3 Total result, costs for the mulch film process

The final result of the empirical collection is being presented in table 10 below. For the purpose of establishing an economic map for the mulch film usage, this final table of quantitative data has been provided. The result is made from the empirical data and tables described in earlier sections. All costs in the table boxes are shown as cost per hectare.

Table 9. Total result, costs for mulch film per hectare

Mulch film	**Bio-based**	**Bio-based**	**Bio-based**	**Plastic**	**Plastic**	**Plastic**	**Nonwoven fabric**
Respondent	*1*	*2*	*3*	*4*	*5*	*3*	*6*
Hectares	0,5ha	6ha	27ha	2,5ha	5ha	27ha	8ha
Direct costs							
Direct material, SEK	3584	10547	9852	6000	4825	4722	3605
Direct manufacturing labour, SEK	370	1480	216	1258	6290	384	5318
Total direct costs per hectare, SEK	5064	12027	10068	7258	11115	5106	8924
Indirect costs							
Delivery material, SEK	300	200	39	800	100	47	125
Stock-keeping, SEK	72	158	197		97	83	474
Setup machine, SEK		19			37		
Placing, SEK	3828	1487	1258	2776	6181	1248	4
Maintenance service, SEK							2313
Cultivation, SEK	362	377	562				
Collection, SEK						254	
Recycling, SEK					84		
Total indirect costs per hectare, SEK	4562	2241	2056	3576	6499	1632	2916
Total costs per hectare, SEK	9626	14268	12124	10834	17614	6738	11840

The empirical collected data has been structured and sorted into the table by their direct and indirect appearance. A sum of the total costs for each category (direct and indirect costs) is found in the end of each section, and then combined into total costs per hectare in the final row of the table. As for the empirical chapter, if no cost appeared for the respondent during a certain activity the box was left empty. To remember is that activity boxes left empty means the activity did not cause any *indirect* costs. The activities exist, but only required direct labour and material.

It becomes clear how plastic material for the mulch film tends to be less expensive than the bio-based mulch film. One exception is respondent 1, who had a relatively small amount of mulch film. An important detail between the direct and indirect costs, was labour. This cost turned out very differently between the respondents. One respondent only had extra personnel for the mulch film process. One respondent managed the mulch film process as a part of their regular work and did not have extra personnel. Four respondents had both regular and extra personnel supporting the process. This affects the data in the final table 9, especially the placing activity when being a part of indirect costs.

Delivery material was dependent on how many rolls (weight) and other products that were ordered and shipped. Stock-keeping cost was linked to how many rolls, and the price for the rolls which were kept in the storage area, if not at all as for respondent 4. Setup machine was included when required noticeable time, and not “ready to use” equipment. Placing was the activity consuming most indirect costs. Maintenance service was merely necessary for the non-woven material. Cultivation was an indirect cost for all bio-based mulch films due to depreciation, fuel and extra personnel. Cultivation is not required for the plastic mulch film process, and “regular” cultivation (end of season, weather mulch film was used or not) was not included.

Collection of the plastic mulch film required extra personnel for one respondent and the activity was otherwise included in the direct labour cost. One respondent paid a recycling fee for the plastic mulch film. The last row of table 9 displays the truest cost of the mulch film process, regardless if the cost was direct or indirect. The bio-based had a lower total cost from this ABC perspective, together with respondent 3. But in contrast to respondent 3’s bio-based mulch film process, the cost of the plastic mulch film process only consumed half of the costs.

7 Analysis and discussion

The analysis and discussion focus on the study's outcomes, impacts, causes and limitations. Also the ABC is being investigated regarding the result and limitations.

7.1 The empirical result

The value/cost activities identified in this study were merely included when having a significant purpose or measurable cost during the mulch film usage process. This means there are other activities and costs dependent on the mulch film usage that is not being included in this study's calculations. As Aouad, et al, (2008) claims, a defined process scope is required to conceptualize a new process, and for this study certain decisions regarding the application of the scope and the level of details have been made. The aim has, however, been focused to reveal as many actual costs in the mulch film process as possible. Another aspect to keep in mind is that this empirical result is connected to one of many processes made at the farms. When doing the ABC calculations based on the whole company's financial costs and activities, the outcome may look different due to considered connections among the activities, higher level of details included and also broader and more precise data.

Still, within the frame of this study, main differences could be analyzed. One finding was that for one-season vegetables no disposal does occur for the plastic mulch film, or even a recycling fee. The plastic was only used for one season, except from the non-woven fabric, but the disposal was held on the own farm and the expense over the year was outside the out of the season time limit for this study. In the article of Haapala et al (2014), the disposal costs was one argument for not using the plastic mulch film, but for one-season vegetables it doesn't occur. But for longer use of the same plastic mulch film, that is crops with longer cycles, it may appear. This could also vary for cases situated in other countries but Sweden, and also the recycling fee may appear different. Haapala et al, (2014) also mentions how laying and removal of mulch film needs to be kept effective to minimize labor costs. In this study, these two activities were found to be consuming the majority of needed labor hours for the process (except for the non-woven fabric), and could be seen as strategic to develop. Since the respondents had been using mulch film for several years, they seemed to have also found suitable equipment, routines and techniques adapted for the mulching process.

Differences and similarities of the bio-based and plastic mulch film are apparently depending on various factors. In general the bio-based mulch film material is more expensive than the plastic material (covering the same number of hectares). Anderson et al., (1995) point out the one dissimilarity of cost is made by no removal work needed for the degradable mulch film. The advantage of biodegradable mulch film is often said to be that it does not need to be removed and will biodegrade once being tilled into the soil (Ahokas *et al*, 2014; Haapala *et al*, 2014; Jenni *et al*, 2006). Nonetheless, there is a problem of the bio-based mulch film being too slow in the degrade process, in addition to pieces of mulch film that may be flying around the area. The respondents argued that it makes the landscape look untidy, and is one main incitement for not using the bio-based mulch film. Additionally, in this study the cost of tilling is significant and requires diesel, labor and depreciation, which in the end was higher than the collecting activity (noticeable for one respondent having tried both types of mulch film). The process scope though, does not account for any tilling after using the plastic mulch film. If it had been included in the plastic process scope, the plastic mulch film would probably turn out to be more expensive to use than the bio-based mulch film. The respondent described on the other hand, that in their own made calculations the outcome for both mulch films was somewhat similar in the end. This aspect may question the reliability of this study's result, but to remember is that only certain activities were included in this study, and the income from sold crops is not calculated for. Another finding of this matter is that no activity seemed to be superfluous to the mulch process. All activities were needed in order to perform the process, instead the methods of carry out the activities were more or less effective (according to the respondent' having tried various methods). Although, one respondent having the bio-based mulch film had found it being more profitable, than to use the plastic mulch film. The type of mulch film being more profitable may just be proven only to the individual farm.

The boundary between activities and costs in this study's ABC calculations has been custom made for this specific research. Stock-keeping cost is a fictional cost not causing any real cost to pay (Ohlager, 2015). Then there are *alternative costs*, which could be investigated from many directions. Pesticides and irrigation cost is an alternative to the use of mulch film in general (except for the non-woven fiber, which doesn't protect from weed growth). That is why mulch film is common among organic farmers, states one respondent. Also, only using the mulch film for greenhouse cultivation (figure 13) may give a different result. One of the respondents having a few rows of plants in a greenhouse, had tried to have the mulch film on the soil and found that the bio-based mulch film was lasting longer due to being kept dry. There is also a thought about the impact of the farms conditions and productions. Hobby cultivation or large scale, equipment being more expensive and efficient but also used in several of the farms production areas, years of experience, type of crop and farm collaborations.

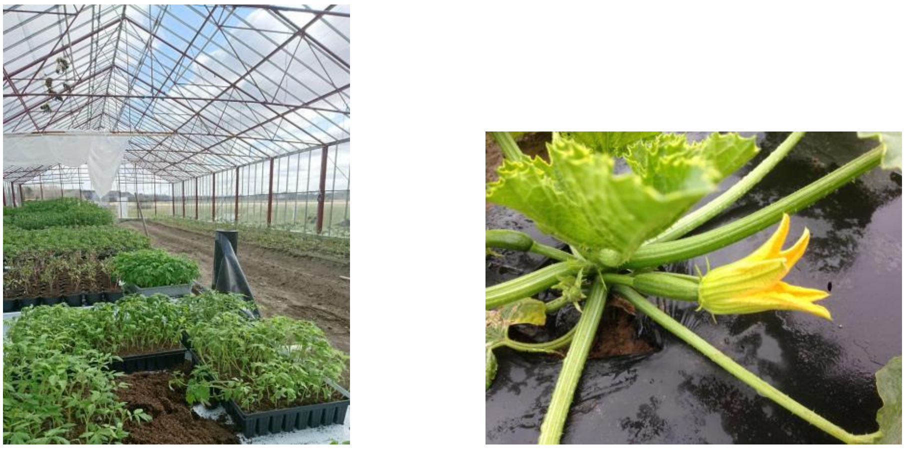

Figure 13, Bio-based mulch film; in greenhouse (rows to the right), Source: Respondent;

The cost of the environment is not calculated for in this study's ABC calculations. De Wrachien., (2003) argues that *sustainable land* is essential within agriculture. The respondents using plastic mulch film mentioned how perhaps a few pieces of plastic could remain in the soil after the collecting, but other properties weights higher. The respondents using plastic mulch film are yet interested in a bio-based mulch film, but of higher quality than the current ones. It needs to be less sheer for the placing, withstand sun and rain, and be able to degrade fast or slow, depending on production. This gives the finding that the placing cost is somewhat similar for both types of mulch film, and there is a higher dependency of quality and final management. Though, one respondent using the bio-based mulch film cultivated the mulch and did not recognize any problem after the season (flying pieces). The method, in all activities may be decisive for how well the mulch can be utilized.

Several insights were gained during this study's research, and as Ahokas *et al*, (2014), Shogren, (2000) and Happala *et al*, (2014) implies, mulch film does have many sought features. The fruits become cleaner, delivery to customers is further assured, it is preventing weed growth, holds the soil temperature and moisture (is being pulled upwards into the ground due to the mulch film). Yet, one respondent explained that the harvest remains the same with mulch film, as well as without but the mulched crops get a higher quality. But then again, there are alternative costs, products and activities required when not using mulch film on the soil.

Another practicable aspect is whether or not to include the potential income from using the bio-based mulch film, in relation to the fossil-based mulch film. This kind of investigation requires a lot of data over many years and a special composition of theoretical framework, which is too time consuming and complex to handle with the current available knowledge. Also studying the whole supply chain (identified in this study's theoretical framework) would be a complex task, but would probably generate further information about the mulch films cost impact. It is a limitation to this study though, which only includes one supplier (the farmer).

7.2 The ABC method

The ABC model used for this study provided and displayed information regarding the activities occurring during the mulch film process in vegetable farming. With the activity level applied, even comparison was possible. Still, no earlier ABC studies with comparative objectives were found, and the method may have errors. One difficulty was to make distinctions to the activities, and have the respondents' answers held with the same parameters of measurements.

Johnson, (1992) conveyed certain limitations of ABC systems, and especially argued for the ABC system of not being a tool to achieve long-term competitiveness and profitability among companies. The purpose of this study has been to provide an economic map, to gain information and draw conclusions. This purpose is closer to the ABC model being a tool for management planning, control systems and budgeting (Lewis, 1995). Further limitations of the ABC model, is that of not being supporting companies to improve globally competitive operations, neither change previous management behaviour or fundamental views of organizational work or customer satisfaction (Johnson, 1992).

In the article of Noreen (1991), the author identifies a limitation with cost objects. ABC theory is constructed to always have activities as a cause of a cost object. This means if the cost object, for example a product, is stopped to be processed; the activities connected to the certain product should also stop to exist. This limitation is questioning this study's process scope, since the cultivation made for the bio-based mulch film probably would occur even if not having used a mulch film. The cost was calculated for the bio-based mulch film due to the dependency of being tilled down. The cultivation may be performed when having a plastic mulch film as well, after being collected.

Another limitation to the ABC model is the complexity of only observing one specific process. Wennberg (1997) criticizes the ABC theory for not taking the costs connections into account, which is also experienced during this study's investigation. The shipping cost does not only concern the mulch film rolls, but also other products as well. The percentage share of the mulch film rolls of the freight was asked for during the interviews, to be able to adjust and lower the risk for misjudging. The mulch film process impact on sold harvest or other impacts where not included either, which is also an essential limitation to this study's empirical result.

8 Conclusions

The aim of this study was to identify value/cost activities within the usage of bio-based and plastic mulch films respectively, and explore consumed resources and find differences and similarities between the two types of mulch film. In this final chapter, the aim is being reconnected and the established key findings are summarized. Last, a section regarding method reflection and future research is provided.

8.1 Mulch film usage

Six respondents using bio-based, plastic or non-woven fiber mulch film have been interviewed, and have delivered data for this study. The first aim was to identify cost/value activities in the process of mulch film usage. Activities performed for the mulch film process in general, were identified as material delivery, stock-keeping, machine setup, placing, maintenance service, cultivation, collection and recycling. The cultivation activity was strongly connected to the bio-based mulch film while the collection and recycling activity was connected to the plastic mulch film. The next aim was to identify which resources were being consumed to perform the activities. Indirect resources were identified as shipping, stock-keeping cost, diesel, indirect labor, depreciation, indirect material and recycling fee. Direct resources were direct material (the mulch film) and direct manufacturing labor. Resources consumed to perform the activities were highly dependent on the equipment, routines and methods used, which was one essential finding of this study.

The third aim was to find differences and similarities between each type of mulch film investigated. The activities and resources turned out similar for all types of mulch film, with the exception for the cost of direct material, cultivation and collection, which held the most apparent differences. The impact on direct material was due to the price of mulch film, where the bio-based mulch film was higher than for the plastic mulch film. For the final cost calculation, which is cost per hectare, no clear connection appeared exclusively with regards to which type of mulch film being used. As for direct costs, the plastic mulch film held a lower cost per hectare, except from the one respondent having 0,5 hectare. For the cultivation and collecting activities, the costs were derived from various amounts of resources. The cultivation activity required diesel, labor and depreciation, while the collecting activity needed relatively extra labor hours.

The economic map of mulch film usage may be rather individual to the farm, and the marginal cost reductions are probably found in other aspects than the price of mulch film. Still, the bio-based mulch film, which is a part of the bio-economy, needs to be further developed and also gain higher quality, in order to proceed successfully on the market. As other studies have found, the main restriction of using the bio-based mulch film is not the aspect of costs.

8.2 Methodological reflection and future research

Activity based costing is a tool to provide information and economic aspects to an organization's business. This study applied the ABC method to find such information among several agricultural farms for a comparative purpose and it should be noted that the result and conclusion of this study is based on merely this comparative case study. With extended scope and higher amount of activities, further information and connections could be discovered. This research was meant as a contribution to the analysis of the bio-based mulch film market, and it has hopefully revealed interesting and useful aspects.

Using the ABC method for a comparative purpose provided a rather functional structure to the empirical data collected, but at the same time a lot of data was required. Moreover distinctions, restrictions and limitations of high importance had to be made in order to keep the collected data consequent and also necessary to conceptualize the ABC calculations. The process perspective recommendations in combination with the simulation technique, were therefore efficient factors, contributing to only gathering relevant data for this study. The theoretical contribution of this study is aimed at the process perspective. By analyzing the phenomena as a process, several conclusions and insights were found and especially as earlier studies of mulch film argued for certain advantages in activities for both types of mulch films. This way, the alternative process to one another could be displayed. In conclusion, other information than merely costs was found, which made the data contribute to richer and deeper data to the study.

One dimension in future research of sustainable development is the further investigation of new and current processes and resources. To have a process perspective, as well as applicable process theories as TCO or ABC to analyze a bio-economy case, could probably reveal many interesting aspects and areas of the bio-economy and also the future of sustainable development.

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Appendix 1, The BioInnovation Organization

BioInnovation is an innovation project involving 60 different stakeholders including companies, universities, organisations and institutions (www, Wargön Innovation, 1, 2018). The BioInnovation project is formed as industry collaboration. The project exists to promote and develop competitive and innovative bio-based products, materials and services. The vision of the BioInnovation project is to have Sweden transformed into a bio-based economy by the year of 2050. The BioInnovation project itself, involves projects where different stakeholders contribute during the project process. In October 2015, a BioInnovation project called "*Etablera närodlad textil i Sverige*" (Establish locally produced textile in Sweden) was made. The project will last until August 2018 and investigates conditions to produce a sustainable production of textiles with the base of forestry products and recycled bio-based textile.

The BioInnovation project is also divided into five different work packages (WP) and this study is a part of Work Package 4 (WP4), which is called "*Jordbruk volymprodukter*" (Agricultural volume products) (www, Wargön Innovation, 1, 2018). The main goal of WP4 is to introduce new products on the market, create supplier collaborations, product development and a market driven innovation process. The purpose of WP4 is therefore to apply these main goals and develop and introduce functional soil mulch films, made by cellulose structures in order to replace fossil based mulch films.

The purpose of the whole project WP4 is to find pathways to implement a more sustainable mulch film, in vegetable and other relevant farming (www, Wargön Innovation, 1, 2018). This requires gain and collects of knowledge about the market for bio-based mulch film by investigating certain market areas, find and discover advantages of the bio-based mulch film in relation to the fossil-based mulch film and characteristics of the usage.

Appendix 2, The interview material

Translated to English from Swedish

Interview

Thank you for participating in my master thesis with the subject of mulch films!

The questions have mixed characters and are structured as qualitative questions with a quantitative content. Though, aspects regarding decisions and methods for performing the activities are welcome. If you don't know the specific value for the quantitative questions, you may answer approximately.

You will have the made calculates for your farm when the thesis is ready, your data will be presented anonymously.

Plastic/Bio-based mulch film

Fundamental data
Number of hectares mulched:
Hectares mulched per corp:
Number of ordinary employees working with the mulch film:
Number of extra employees working with the mulch film:
Depreciation per year, tractor:
Depreciation per year, other machine/equipment:

Question 1. The process needed to go through, is from when you order the mulch film until the final management. Down below is the identified activities which may support the completion, remember to only observe the mulch film process (= the scope of the thesis)!

Activities

Information search and purchase (to find a suitable mulch film for the cultivation)

- Mulch film material and measuers:
- How was the information search made and how much time was needed?:
- Number of mulch film rolls per season:
- Price per mulch film roll:
- Is irrigation tube used? Price per meter:
- Is there any other material consumed by the mulching? Price:

Delivery material

- Price for shipping, new mulch film rolls:
- Number of shipping per season:

Move the mulch film to the storage area

- How was the rolls delivered and what do you do with them?

Stock-keeping

- How many rolls are kept in stock and for how long?

Machine service

- How long time is consumed to prepare the tractor/machines?

Lay out

- How many rows are being mulched?
- Length per row (in general):
- How many litre fuel is consumed per row/hour?:
- How long time to lay out the mulch film?
- How many employees are managing the mulch film?

Maintenance service

- Is any maintenance service needed for the mulch film?
- If yes, what is performed and how long time?

Tilling or collection (final managament)

- What is done with the mulch film after the final harvest by the end of the season?
- What resources are consumed and how much time is needed?

Question 2. To put the process of mulch film in relation the other tasks, the following information is needed:

- How many days in total is consumed for the mulch film management, ordinary personnel:

- How many days in total is consumed for the mulch film management, extra personnel:

- How much are the tractor used for the mulch film in relation to other tasks during the year?

- If you collect the mulch film (final management), are there any plastic pieces left in the soil?

- Other comments:

Question 3. How much harvest for the whole season of each mulched crop was made? Kg or other measurable value.