Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

**Department of Economics**

# An Estimation of Environmental Impacts of Dairy Farming
# - a cost benefit analysis of dairy farming in Sweden

*Mjölkproduktionens miljöpåverkan i Sverige - en kostnads-nyt-toanalys av mjölkproduktion i Sverige*

Hanna Nilsson

Master's thesis • 30 credits
Agricultural programme – Economics and Management
Degree project/SLU, Department of Economics, 1225 • ISSN 1401-4084
Uppsala, Sweden 2019

# An Estimation of Environmental Impacts of Dairy Farming in Sweden – a cost benefit analysis of dairy farming in Sweden

*Mjölkproduktionens miljöpåverkan i Sverige - en kostnads-nyttoanalys av mjölkproduktion i Sverige*

Hanna Nilsson

**Supervisor:** Gordana Manevska Tasevska, Swedish University of Agricultural Sciences, Department of Economics

**Assistant supervisor:** Efthymia Kyriakopoulou, Swedish University of Agricultural Sciences, Department of Economics

**Examiner:** Jens Rommel, Swedish University of Agricultural Sciences, Department of Economics

**Credits:** 30 credits
**Level:** A2E
**Course title:** Master thesis in Economics
**Course code:** EX0907
**Programme/Education:** Agricultural programme – Economics and Management 270,0 hp
**Course coordinating department:** Department of Economics

**Place of publication:** Uppsala
**Year of publication:** 2019
**Cover picture:** Pixabay.com
**Title of series:** Degree project/SLU, Department of Economics
**Part number:** 1225
**ISSN:** 1401-4084
**Online publication:** http://stud.epsilon.slu.se

**Key words:** cost benefit analysis, dairy farming, Sweden, environmental benefits, environmental costs

Swedish University of Agricultural Sciences
Faculty of Natural Resources and Agricultural Sciences
Department of Economics

# Abstract

The production of dairy products has both negative and positive external effects on the environment. Positive and negative external effects can be monetized and defined as environmental benefits and costs. Balancing environmental costs and benefits is crucial to prevent market failures. The aim of this paper was to investigate the balance between the environmental benefits and the environmental costs associated with dairy production in Sweden using cost-benefit analysis (CBA). Five dairy farms were used as case studies to conduct the analysis. Both an economic and a financial CBA was conducted for each farm. The results of the CBAs show that there are generally higher environmental costs than benefits. Three out of five farms have positive net present values in the economic CBAs, implying that these farms should go on with their production. The primary objective of the paper was to investigate whether or not there were differences in the results when analysing organic and conventional production systems and across different farm sizes. It is not possible to claim there are differences between conventional and organic production from the results in this CBA.

# Sammanfattning

Framställningen av mjölk och mjölkprodukter har både positiva och negativa effekter på miljön. Dessa positiva och negativa externaliteter kan värderas i monetära termer och definieras som miljönyttor och miljökostnader. För att undvika marknadsmisslyckande är det önskvärt att sträva efter balans mellan miljönyttor och miljökostnader. Syftet med denna studie var att utreda balansen mellan miljönyttor och miljökostnader som associeras med mjölkproduktion i Sverige genom att använda kostnads-nyttoanalys. Både en samhällsekonomisk och en finansiell kostnads-nyttoanalys utfördes. Resultaten i studien visar att miljökostnaderna är högre än miljönyttorna generellt sett. Tre av fem gårdar i studien har positiva nettonuvärden vilket antyder att dessa bör fortsätta med produktionen. Ett av målen med studien var att undersöka hur produktionssätt (ekologisk eller konventionell) och storlek på gården påverkade resultatet. Ingen skillnad mellan konventionell och ekologisk produktion kunde fastställas utifrån resultaten från kostnads-nyttoanalysen.

# Abbreviations

CBA – Cost Benefit Analysis
SEK – Swedish Krona
USD – American Dollars
WTP – Willingness-to-pay

# Table of Content

# List of tables

# 1 Introduction

The dairy sector stands for the largest portion considering value of production in the Swedish agricultural sector. During the last few years the economic conditions and prices for dairy products have fluctuated, with long periods of low prices, making it difficult for farmers who are sensitive to price changes to survive on the market (Jordbruksverket, 2018). The portion of Swedish produced milk in the production of final goods has decreased by 20 percentage over the last ten years. In the production sector, the general trend moves towards less cattle and fewer but larger farms producing dairy (Zimmermann & Heckelei, 2012). One explanation for the fluctuating prices and changing sector is the removal of milk quotas in EU in 2015 (Jordbruksverket, 2018). This led to lower prices and a tougher market in general. During 2017 the prices stabilized and the demand for milk fat increased. Milk producing cattle has declined which is partly due the steady price of cattle meat which has led to an increase in slaughter of cattle (ibid). Today, when the milk price is rising together with demand, there will be a lag in the production sector since building up the cattle herd is a slow process.

The dairy farms in Sweden are distributed somewhat equally throughout the country, though some patterns can be observed as there are more and larger farms in southern Sweden than in the northern parts (Jordbruksverket, 2018). Most milk farms have between 25-49 cattle and a majority of the milk farms have 74 or fewer cattle in their herd. The trend shows that farms with fewer cattle has decreased most during the last few years, supporting the earlier mentioned trend of fewer but larger farms. This trend can be seen in all of EU. Technological changes within the sector has also affected the general development (ibid). The production is moving from tethered systems to lose housing systems with milking robots. These newer systems require large investments and are more frequently found on larger farms with many cattle. This development has been fuelled by legislative amendments and other improvements such as for example animal health and working environment.

The EU dairy market is a large agent on the world market and a net exporter of milk products (Jordbruksverket, 2018). Despite the last turbulent years with a global dairy crisis and decommissioning of dairy quotas, the EU market has developed positively and is predicted to gain larger demand over the upcoming years until 2026. The embargo against Russia, which used to be the largest export market for EU, has only led to a shift in export to USA and Saudi Arabia instead (ibid). The number of cattle is predicted to decrease, this implies that each cow will produce more milk and that the technology will develop and increase productivity. When considering the world market, the largest producer of dairy is Asia (ibid). Approximately 77% of the total increase in dairy production is predicted to happen in developing countries, especially in India and Pakistan. EU and USA are predicted to keep a steady production level over the next ten year and dairy products will be consumed where they are produced to a greater extent.

The production of dairy products has both negative and positive external effects on the environment (Statistics Sweden, 2014). The positive external effects are for example effects leading to open landscapes, increased biodiversity etc. The negative external effects are emissions of carbon dioxide or leakages of pesticides from arable land into waterways etc. Positive and negative external effects can be monetized and defined as environmental benefits and costs. Environmental benefits of dairy farming, such as open landscapes, have been shaped by agriculture for centuries. Pasture lands, small waterways and ditches are habitats for many different species. The last few years however, the agriculture has developed fast towards a monotonous landscape where ditches, small waterways etc. has disappeared. This has led to a changed habitat for many smaller animals and insects. The trend showed a decreasing usage of pasture lands until the middle of 1990s when it increased due to environmental supports for managing these lands.

Economic supports are paid to framers to incentivise them to, among others, protect a biodiverse landscape, produce environmental goods, make investments and produce food (Government Offices of Sweden, 2018). These economic supports contain for example direct payments such as the single payment scheme which gives the farmer a certain amount per hectare and environmental supports which gives a compensation for services provided by the farmer such as open landscapes and increased biodiversity. There are also supports which are intended to keep production levels stable. In a report from Statistics Sweden (2014), the impacts of the Rural Development Programme 2007-2013 are analysed. The goal achievements of the economic supports and compensations, set in the Rural Development Programme, differ between the different supports mentioned above. The environmental support, which entails the establishment of riparian zones and supports to implement permanent grasslands are among others the supports which achieved their goal in the programme. Other supports such as investment supports and non-productive investments were not as successful, although the overall goal achievement rate was about 80%.

Balancing environmental costs and benefits is essential to prevent market failures and is usually maintained by subsidies or economic supports. The Rural Development Programme aims to develop and preserve a sustainable farmland and reduce the environmental impacts of agriculture (Government Offices of Sweden, 2018). These measures are intended to contribute to reach the national environmental targets. The need for these supports implies there is a market failure present, meaning the supports are needed to stabilize and ensure the future of the dairy sector. Previous studies estimating environmental impacts of dairy farms is limited, e.g. (Baskaran, et al., 2009; de Boer, 2003), since finding appropriate indexes to use on a farm level is difficult. However, this type of analysis is necessary to gain knowledge, since the agricultural policy is shifting towards a more result-oriented approach for support distribution.

## 1.1 Aim, Objective and Limitations

The aim of this paper is to investigate the balance between the environmental benefits and the environmental costs associated with dairy production in Sweden. The primary objective is to investigate whether or not there are differences in the result when analysing organic and conventional production systems and across different farm sizes. These issues will be investigated at farm level using five dairy farms as case studies and applying cost-benefit analysis, henceforth called CBA.

This study will lead to some insight of different production systems and their benefits and disadvantages which will be helpful for decision makers and resource managers when deciding on the levels of support paid to the farmers and optimal levels of production. It may also be used for policy assessment when evaluating what environmental effects may be expected. Gaining an understanding of the environmental impacts of dairy farming on farm level will aid investors', for example banks, regarding decision making when evaluating how sustainable investments in dairy farms are as well as an understanding of to what purpose they loan money. The study is limited to dairy production in Sweden and to the five case-study dairy farms. The geographical limitation is in the two areas Gotland and Uppland.

# 2 Environmental Effects of Dairy Farms

There are both positive and negative effects on the environment of dairy farming. In this chapter these effects are described in more detail.

## 2.1 Environmental Costs of Dairy Farming

The main environmental costs of farming are leakages of fertilizers and pesticides from arable land and greenhouse gas emissions. Leakages of fertilizers and nutrients from arable land contributes to eutrophication of both the Baltic sea and inland lakes and streams. Agriculture constitutes 41% of nitrogen leakages to water (Statistics Sweden, 2014). According to one of the national Environmental Quality Objectives “No eutrophication”, fertilizers should not have a negative impact on human health, biodiversity and the usage of land and water resources. The agricultural sector has a significant liability to reach this goal since large amounts of the nutrient leakages are from this sector. The largest leakages to the sea are from the farms situated on the coastal regions, in these parts the leakage is about 90 % of the nutrients added to the farmland. In other parts on the inland the leakage to the sea is about 10-20 %. Between 1995 and 2009 the leakage declined with about 10 % due to an increased nitrogen efficiency and implementation of more permanent grasslands and less cereal crops. Phosphorous is considered to have a significant role regarding eutrophication of inland lakes and streams, where agriculture answers for 44 % of the total emissions.

The use of pesticides contributes to maintaining food production all over the world. One dollar spent on pesticide control yields 4 dollars in saved crops (Pimentel & Burgess, 2014). In general, if pesticides were forbidden, 10 % of crops would be lost. Even though pesticide use has increased, so has the crop loss due to insects. This is probably partly due to changes in agricultural practices. Crop rotation has decreased in conventional farming which has led to an increased number of insects. While pesticides have increased food supply, there are significant environmental and economic costs which occur with the use of pesticides (ibid). Pesticide use has a negative effect on for example human health, animal poisonings, destruction of natural enemies, pesticide resistance, groundwater contamination and decreased pollination due to destruction of pollinators. According to WHO, the use of pesticides leads to 1 million human poisonings and 20 000 deaths per year in the world. Further, pesticide use leads to a 20 % reduction of honey bees and another 15 % are weakened by the pesticides.

Increased amounts of green-house gases in the atmosphere leads to global warming. Dairy farming mainly causes three different kinds of green-house gas emissions; methane, nitrous oxide and carbon dioxide (Statistics Sweden, 2014). One source of nitrogen emissions is animal droppings, both from dunghills and from cattle grazing grasslands. The nitrogen turns into ammonia and later on acidic rain, having both an acidifying and eutrophicating effect. The ammonia emissions were reduced with 25 % between 1995 and 2009. This reduction is partly due to a decrease in number of animals, but since the consumption of meat has increased, the emissions may just have moved to other countries from which animal products are imported. Methane emissions are mainly from cattle, which has also decreased over time because of the decrease in number of cattle. The carbon dioxide emissions are from the combustion of diesel fuel and oil. Emissions from combustion of fuel and oil are carbon dioxide, methane and nitrous oxide. The amount of emissions has not changed since 1990. The Environmental Quality Objective regarding emissions of green-house gases states that the Swedish emissions year 2020 should be 40% lower than those of year 1990 for activities not included in the trade with emission permits in EU (Ibid). Swedish emissions in other countries are also considered in the Environmental Quality Objectives.

## 2.2 Environmental Benefits of Dairy Farming

When discussing positive environmental effects of dairy farming the concept of ecosystem services emerges. Several reports have been written on the Swedish agricultural sector which identifies and estimates the ecosystem services provided by dairy farms. Generally, when discussing ecosystem services, they are divided into four categories, supplying, regulatory, cultural and supporting values (SP, 2017). Supplying services include the products produced, in this case different kinds of dairy products and biogas. Regulatory services include benefits from regulation of processes in the ecosystem, e.g. pollination and water retention. Cultural services include non-materialistic values such as recreational and aesthetic values and ecotourism etc. The fourth and final value is supporting values which includes services which is necessary for other services to function e.g. soil formation, primary production of biomass and the soil's cycle of nutrients. This classification system will need to be handled with caution since there are some categories which overlap entailing a risk for double counting (SP, 2017).

The most trivial ecosystem service provided by dairy farms is the production of dairy products, meat and in some cases crops such as different cereal (SP, 2017). Some farms contribute with energy production in the form of biomass fuel which is used on the farm or sold. Honeybees and wild pollinators such as bumblebees, hoverflies and solitary bees have a crucial role in the production of crops since some crops are dependent on pollination (ibid). Honey bees cannot pollinate all kinds of crops which reinforces the importance of gaining the wild pollinators. They need habitats and feeding places such as natural pastures, fruit trees and berry bushes. The pollinators are dependent on blooming flower during the whole season. Therefore, choosing crops that bloom at different points during the season is favouring. Other things that gain pollinators are small fields, variation of crops on and in-between fields and planting bushes, trees, pastures in the agricultural landscape. Organic farms which do not use pesticides have a higher biodiversity and more pollinators on their land than conventional farms. Dairy farms contribute with improved habitats for pollinators since they have pasture lands with blooming herbs, mixed grasslands with clover and leguminous plants and crop rotations with grassland which decreases the need for pesticides.

When perennial crops such as grass- and pasturelands are cultivated carbon sequestration increases (SP, 2017). Dairy farms cultivate a lot of grassland which is seldomly tilled or not tilled at all, which contributes to a larger and more stable storage of carbon in the soil. Also, using manure as plant nutrient instead of mineral fertilizer adds more carbon to the soil. Dairy farms contribute to carbon sequestration by; having a lot of lay and pasture lands which are perennial and at least three years old and using manure as fertilizer (ibid). Soil fertility is also increased by these two factors. Farming perennial grass land also reduces the risk of leaching of pollutants. Supporting ecosystem services, in terms of the soil's cycle of nutrients, is improved at a dairy farm by the addition of nutrients in the form of manure, a varying crop rotation with grassland and clover in the lay (ibid). Since a dairy farm has cattle and farms a lot of grassland there is a natural semi-closed cycle of nutrition on the farm.

Cultural and aesthetic values provided by dairy farms are significant and many, but difficult to valuate. There are values such as recreation, ecotourism, education and cultural heritage (SP, 2017). Aesthetic values are subjective to the individual and varies, e.g. a one person may prefer a varied agricultural landscape while someone else prefers wild landscapes with little or no human impact. Dairy farms contribute by farming the farmland and smaller parcels in the woodland, keeping grazing cattle, having accommodation rental business on the farm and arranging events when the cattle are released into the summer pasture.

# 3 Literature Review and Theoretical Framework

In this chapter earlier studies in the subject area are presented. Existing studies using CBA are mainly focused on studying the effectiveness of policies (Eliasson, 2009; Snyder & Kaiser, 2009), or evaluating effects of projects (Perman, et al., 2011). Hence, the literature mentioned below are on the subject of evaluating environmental impacts of dairy farms, however they use other methods.

## 3.1 Previous Literature

Baskaran et al. (2009) estimates values of the environmental impacts of dairy farming in New Zealand. They use a choice modelling method to evaluate the willingness to pay to avoid negative externalities. The focus is on four environmental issues; air pollution, water pollution and depletion and loss of native biodiversity. The results show that higher levels of environmental regulations and environmentally friendly agricultural programmes is supported by the public (Baskaran, et al., 2009). They also demonstrate that the respondents derive utility from reducing the environmental impacts of dairy farming. The estimated values in the study are annual marginal willingness to pay for a five-year period of improvements in the environmental attributes, holding all other attributes not considered in the study constant. The conclusions were that the reason why dairy farming leads to degradation of ecosystem services is that the price paid for dairy products does not reflect the external costs of dairy farming. Water quality and quantity are the highest valued attributes which reflects the importance of these attributes to the respondents.

In another article by de Boer (2003) the environmental impacts of organic and conventional dairy production were compared using life cycle assessment. The aim of the article was to review life cycle assessment as a tool and its ability and constraints to assess the environmental impact of organic and conventional animal production. The results imply that some environmental impacts, such as acidification potential due to evaporation of ammonia, did not improve with an organic production process compared with a conventional. Eutrophication per tonne of milk was decreased with an organic production process due to lower rate of fertilizer application (de Boer, 2003). Gas emissions contributing to global warming were similar in the two production processes although organic production increases the amount of methane gas emissions. The use of pesticides is decreased in organic production, but the land use per tonne of milk is increased. More research is needed to determine major differences in the environmental impact between organic and conventional production.

Using life cycle assessment to analyse this kind of topic is quite common. A study on industrial dairy production compared three different dairy farms and included the consumption and waste management step in the analysis (Høgaas Eide, 2002). Determining the significance of farm size and automatization was the main objective. The agriculture was found to be the main contributor for almost all the environmental impacts. The environmental impact was determined by calculating the energy use in production, use and waste. Smaller dairy farms were found to have larger environmental impacts than the larger farms. This seemed to be due to the internal processing and that the larger farms could benefit from economies of scale.

In the literature, the subject of interest is studied from other perspectives than the economic. Capper et al. (2009) investigate how the environmental impact of dairy production has changed between 1944 and 2007 from the perspective of animal science. To estimate resource inputs and waste outputs per billion kg of milk a deterministic model was used based on cows' metabolism. The findings were that modern dairy farming requires less inputs than in 1944 (Capper, et al., 2009). Only 21% of animals, 23% of feed, 35% of water, and 10% of the land was needed to produce the same amount of milk. Waste outputs were also reduced with the modern system producing only 24% of the manure, 43% of methane and 56% of nitrous oxides. They conclude it is essential to develop management practices and technologies that improves productivity and efficiency in dairy production in order to fulfil the requirements of an increased dairy production.

## 3.2 Contributions to the Literature

Since this study is conducted on a farm level, which to the best of our knowledge has not yet been done before, the results will contribute with insights of the values associated with dairy farming. The results will differ from earlier studies conducted in this subject area. Since the analysis is made on farm level, it will provide new information which may be used both by policy makers, and by other agents in society such as financial institutions wanting to define adequate policy or to evaluate what environmental implications their lent money contributes to. Further on, using CBA to analyse this type of issue will contribute with new insights, since most of the earlier papers have used other methods. The results of this analysis will differ depending on farm size, type of production and location in the country and in that way provide new aspects of the results. Moreover, the study is an attempt and starting point for mapping the environmental impacts of the agricultural sector.

## 3.3 Theoretical Framework

The foundation of cost-benefit analysis is developed from the Kaldor-Hicks compensation criterion which was developed as a part of the pareto efficiency framework of new welfare economics (Wegner & Pascual, 2011). This criterion is based on comparison between individuals' utilities and more specifically the utility losses encountered by some compared to the utility gains encountered by others. Pareto efficiency is achieved when no other allocation of goods can be made so that one individual is better off without making anyone else worse off (Boardman, et al., 2014). This concept of pareto efficiency is the conceptual basis of the CBA. The Kaldor-Hicks criterion is a decision rule for whether or not a policy should be adopted, if those who gain from a policy can fully compensate those who lose and still be better off the policy should be adopted. From the Kaldor-Hicks criterion the pareto efficiency rule was derived (ibid). If a policy has positive net social benefits, there is a possibility to compensate those who are worse off by the policy with payments and still achieve a situation where no one is worse of and at least one is better off. The difference between these two rules are that in the Kaldor-Hicks criterion the transfer payments are only hypothetical while in the pareto efficiency rule the payments are expected to happen (ibid). In reality it is rare to make these kinds of transfer payments and it is not certain that they would be pareto efficient if the wrong individual, for example someone who's situation is unchanged, offers to compensate the ones who are worse off.

Following the Kaldor-Hicks criterion, investments in dairy farms should be made as long as the net benefits are positive and there is a hypothetical scenario where the losers of the investment could be compensated. The policy supports distributed to farmers could be observed as income support, enabling investments and therefore the development of farming. Some agents of the society will be worse off from this investment because of emissions of air and water pollutants from the farms, but some will be better off.

# 4 Method

In this chapter, the method used in the paper will be presented followed by a motivation of why CBA is a useful method. The last part gives an explanation of data and indexes.

## 4.1 Outline of a Cost-Benefit Analysis

One basic concept in economics is that everything people demand can be valued with in monetary terms (Perman, et al., 2011). If this is true it is possible to attach monetary values to public goods such as clean air, forests and biodiversity. CBA is often used as a social appraisal of investment projects, also called economic CBA, although it need not be a typical investment with accumulation of money (ibid). If there are consequences of a decision which will stretch over future time it suffices as a subject for analysis. A social appraisal takes into account not only what yields the largest monetary profit, but also including welfare economics. By including welfare as well as commercial profits and costs, the CBA aims to correct for market failure (ibid). If there is no market failure, the commercial and social costs and benefits will correspond with each other.

The basic steps of a CBA are stated below in table 1 (Boardman, et al., 2014). These steps are general for all CBAs which means some steps, e.g. number 1, will not be relevant for this analysis. The costs and benefits which will be considered in the analysis are the financial and environmental costs and revenues.

*Table 1 Major steps in a CBA. Based on Boardman et al. (2014)*

1. Specify the set of alternative projects.
2. Decide whose benefits and costs count.
3. Identify the impact categories, catalogue them, and select measurement indicators.
4. Predict the impacts quantitatively over the life of the project.
5. Monetize (attach dollar values to) all impacts.
6. Discount benefits and costs to obtain present values.
7. Compute the net present value of each alternative.
8. Perform sensitivity analysis.
9. Make a recommendation.

The first step, to specify the set of alternative projects, is often difficult (Boardman, et al., 2014). For some projects the number of alternative projects is infinite, therefore restricting the analysis to a maximum of six alternatives is reasonable. When analysing government policy, the comparison of projects is often with status quo. In this paper, this step will not be relevant since this is not a project appraisal. Although it could be included in further research.

Step number two, deciding whose benefits and costs count, is about who has standing in geographical terms applying a local or global perspective for example. When the analysis includes environmental issues, many critics argue that a global perspective should be applied since the effects are often global (ibid). A global perspective should be applied since the analysis includes environmental effects, but the aim is to investigate the effects on a farm level meaning the perspective of the analysis will be local.

Identifying the physical impact categories, sorting them into benefits or costs and specifying an index for each impact category is step three (Boardman, et al., 2014). The indexes are the values attached to the environmental benefits and costs. The term impacts include both inputs, such as resources, and outputs. For this paper, the impacts will be for example green-house gas emissions, open landscapes and milk produced. In a CBA, the only impacts of interest are those which impact the utility of the individuals with standing. Whether or not an impact is a cost or a benefit may in some cases differ depending on the preferences of the individual. When this issue appears, it is usually possible to divide the impact into two or more categories.

Step four involves quantifying and predicting the impacts in all time periods, because some impacts occur over a time horizon. This step is one of the most important and difficult ones in a CBA. It is especially challenging when the time horizons are long, the project is unique or the relationships between variables are complex. Using previous studies and data from official institutions are helpful in this step.

The next step in the process is to value and monetize all impacts. Valuating environmental impacts is difficult and are often measured in terms of "willingness-to-pay" or WTP (ibid). If there is a well working market for an environmental impact it is possible to determine WTP by a market demand curve. In cases where a market does not exist, WTP is measured in other ways, for example with survey questions. Common practice in CBA is to use indexes of values from previous studies. Only impacts which people are willing to pay for have values in the analysis. In some cases, politicians or other decision makers are unwilling to attach a value to e.g. a statistical life, then a cost effectiveness analysis is applied instead.

The costs and benefits have to be discounted, which is step six. There are two reasons for discounting (Boardman, et al., 2014). The first is because of the opportunity cost attached to the resources in the analysis, meaning there are other investments which could be made instead. Also, people have a time preference where they prefer consumption today rather than later. A cost, C, or benefit, B, which occurs in time t is discounted by dividing it by 1 + s, where s is the social discount rate. The project has a life span of n years. The formulas for discounting benefits and costs are shown in equation 1 and 2 below.

$$PV(B) = \sum_{t=0}^{n} \frac{B_t}{(1+s)^t} \quad (1)$$

$$PV(C) = \sum_{t=0}^{n} \frac{C_t}{(1+s)^t} \quad (2)$$

Choosing an appropriate level of the discount rate is complex and its level will significantly influence the results of the analysis (Boardman, et al., 2014). The theory describing how the discount rate should be defined is quite straightforward. In short, it measures the rate of change in the shadow price. In practice it is not as straight forward, especially when determining the discount rate in projects where the impacts stretch far into the future and where multiple generations are affected or where it concerns mitigations of climate change or other long-term environmental benefits. Since the analysis is sensitive to the level of discount rate, it is a good parameter for sensitivity analysis. This issue will be discussed further on in the paper.

Step seven is to subtract the present value of benefits with costs to receive the net present value:

$$NPV = PV(B) - PV(C) \quad (3)$$

A general rule is to adopt the project if the net present value is positive, that is, if the benefits exceed the costs (Boardman, et al., 2014). There are other decision rules which may also be used in a CBA. Internal rate of return and benefit-cost ratio can both be used, but could lead to misleading and incorrect decisions, which is never the case with the net present value. However, they may give a stronger recommendation. One obvious fault with net present value is that it only considers the alternatives specified in the analysis (ibid). There may be better alternatives, but if they are not included in the analysis they will not be considered. This method will give a recommendation on the more efficient, but not the most efficient alternative.

Next up is performing a sensitivity analysis to check the robustness of the analysis. There are several uncertainties related to both the predicted impacts and the monetary valuation of each impact. Due to these uncertainties, it is necessary to perform a sensitivity analysis. One way is to do the analysis from both a global and local perspective if the analyst is uncertain about the standing (Boardman, et al., 2014). It is also standard practise to do the analysis with different levels of discount rates. Potentially all parameters in a CBA can be varied to check for sensitivity, though this is not feasible. The last step is to make a recommendation. Generally, the project with the highest net present value should be recommended for further implementation, but the sensitivity analysis should be taken into account since net present values are estimated values and the analysis may show that the project with the highest net present value is not the best choice. Lastly, the CBA is not a tool for decision, it is a tool for recommendation.

In some analyses, it is beneficial to conduct a financial CBA to compare with the economic CBA (European Commission, 2015). It is conducted to assess the profitability of the project, verify the financial sustainability and review the cash flows which are a foundation for the economic CBA. In this type of analysis only the financial data is included. The analysis is conducted from the infrastructure owners' perspective. In this paper a financial CBA will be conducted, along with an economic CBA, including the investment- and operating costs and revenues.

## 4.2 Why CBA?

There are several advantages of using a CBA. The results are easily interpreted and can be used by other than economists. From the analysis it is also clear who are the beneficiaries and losers, both in terms of time and place (Boardman, et al., 2014). This information helps to avoid decisions made on the basis of impacts to a single group or goal. For example, it is quite common for decision makers to make decisions based on a few parameters and ignoring other, which could lead to a decreased overall welfare. The result of the analysis will give the decision maker an indication whether anything at all should be done and which outcome is the best, since there is usually a status-quo-option (ibid). Other methods compare different options but not whether doing nothing is more beneficial. A CBA accounts for the time preference and how the future generations are considered, which is done by discounting. It is important to reflect on how impacts in the future are valued versus impacts today and who will have to pay for them.

Furthermore, the CBA addresses the issue of how to allocate resources when there is an unrestricted application, use and number of stakeholders for them (Hanley, et al., 2009). The fact that there is unrestricted applications and stakeholders means the resources are scarce which implies there are more options for application of the resource than amount of resource. There is also an opportunity cost connected to the use of a resource since it cannot be used for something else once it has been used. For example, if a part of the land is used for agriculture it cannot be used for a forest plantation. If the goal is to reduce carbon dioxide, it is useful to know which alternative is most effective. In such cases, where a decision maker is supposed to make such a decision, the CBA provides this information. Further, the general people's preferences are included in the analysis since the economic values depend on what people are willing to pay to have more of a good, what they are willing to accept as a compensation to gain more of what they do not want and what they like (ibid). In this way the CBA is an economic display of democracy since it engages a larger part of the society in policy decisions.

## 4.3 Criticism, Limitations and Alternative Approaches

The biggest advantage mentioned above is also the biggest limitation of CBA. The simplicity of the results does not encourage a reflection of what is optimal since the comparison of projects is only between the ones under consideration (Boardman, et al., 2014). There is a risk of not considering other options since the analysis only can contain a certain number of alternatives. The fundamental utilitarian assumption of CBA states that the sum of individuals' utility should be maximized, meaning one person's losses can be traded of for another person's gains (ibid). Politicians, philosophers and economists among others have directed criticism towards this because they do not agree with the trade-off between individuals.

There is also an issue with disagreements about what impacts will occur over time, how to monetize them and how to value the future (Boardman, et al., 2014). The issue of valuation is closely connected to ethics. For example, the value of a human life could be worth an infinite amount of money or what the individual produces in terms of GDP. Since one individual contributes with such a small portion of the GDP the value of a human life would be next to nothing. In the same way one could argue that there is no finite value to saving an ecosystem or a specific species such as orangutans. Moreover, technical limitations make it impossible to identify and quantify all impacts (ibid). This makes the CBA very complex and difficult. These main issues make CBA net benefit criterion unsuitable as a decision rule for public policy. Instead the criterion should be used as a guide and a mapping of the effects of different kind of options. It is thereafter up to decision makers to handle the ethical and distributional dilemmas.

Other approaches which could be used when CBA does not do a great job are cost-effectiveness analysis and multi-goal analysis (Boardman, et al., 2014). The cost-effectiveness analysis compares alternatives by the ratio of the costs and a quantified effectiveness measure. This is useful when analysists are unwilling to, or if it is too difficult to monetize an impact. For example, when considering a road policy which will save lives the cost-effectiveness analysis will give a result in terms of cost per life saved. The multi-goal analysis compares policy alternatives in terms of relevant goals, which is also helpful when monetization of certain effects is difficult of unwanted.

## 4.4 Data and Indexes

The data needed for the CBA was collected by interviews performed on five case study dairy farms. The interviews were conducted by phone which was chosen since it was most convenient to the farmers. The questions asked are a mixture of open- and close ended since the data needed is digits describing their production and their farm. The data consists mainly of values concerning for example; amount of fertilizer used, area of arable and pasture land, structure of crop production, amount of milk produced, livestock units etc. The data was later transferred into the same units to allow for analysis and comparison. There were no major treatments, such as no exclusion of outliers, applied to the data. Indexes of environmental benefits and costs was transferred from other studies and from reports of official institutions such as the EU or the Swedish Government.

### 4.4.1 Benefit Transfer

Benefit transfer implies using research results from one situation and deduce them to another, new, but similar situation (Johnston, et al., 2015). The aim is to use empirical estimates when funding, time or scope of the research does not include assembling the estimates and data from primary studies. The method is commonly used in applied economics, more specifically in environmental economics. Benefit transfer is pleasant since it requires less effort and money than assembling data in primary research. It is often simpler and more straightforward than conducting primary research (ibid). However, there is an issue of validity and accuracy which rely on several criteria. Ideally, all characteristics of the sites should be identical. In reality this is hardly ever the case. There appears to be a disparity between the best practices and what is actually used in for example policy analysis.

Another issue is the lack of procedure protocols when one criterion is not fully fulfilled. This leads informal and sometimes uninformed decisions about the applicability and importance of different recommended transfer practices (Johnston, et al., 2015). One common finding is that transfers of benefit functions are better than fixed unit values of benefits. Despite this, fixed unit transfer is commonly used with the argument that it is “good enough”, which clearly violates the earlier mentioned criteria. But since almost all benefit transfers violate these criteria to different extents, and the need for accuracy varies among projects it is difficult to determine and discourage the projects which uses this argument.

# 5 Empirical Case Study of Dairy Farms

In this chapter the process of performing the CBA on the five different dairy farms will be described together with a description of the five case study farms and the index values.

## 5.1 The Farms

An overview of the farms can be found in Table 1. Farm number one is a conventional farm in Uppland and has 238 hectares including both forest and pasturelands. There are 217 livestock units in total of which 140 are milk cows. The milking system is a milk pit and the cows live in a loose housing solution; 1 300 000 kg milk is produced each year. Farm number two is an organic milk farm in Uppland. It farms 95 hectares of land, including forests and pasturelands as well as arable land. There are 51 livestock units of which 30 are milk cows and they are held in a tethered stable. Some of the milk is sold in an automat at the farm, the rest is sold to a dairy and the meat is sold directly to the consumer. The farm produces 225 000 kg milk per year.

The following three farms are all situated on Gotland. Farm number three is an organic farm with around 400 ha of land of which 350 ha are grasslands producing hay and the rest is pastureland. There are 865 livestock units of which 550 are milk cows who are held in a loose housing system. The milking system is a carousel and they produce 4,1 million tons of milk every year. Farm number four is a conventional farm with 195 ha of which 15 ha are pasture lands and 50 ha are forest. There are 155 livestock units on the farm, of which 150 are milk cows which are held in a loose housing system and milked by robots. 1 400 000 kg of milk is produced every year at the farm and about 50 livestock are sold for meat. Farm number five is a conventional farm with 130 hectares of arable land. There are 65 livestock units on the farm of which 42 are milk cows which are held in a tethered stable. 400 000 kg of milk is produced each year and about 15 cattle are sold for meat each year.

*Table 2 An overview of the farms.*

| | Type of production | Hectares | Livestock units | Livestock units/ha | Production (kg) |
|---|---|---|---|---|---|
| **Farm 1** | Conventional | 238 | 217 | 1,29 | 1 300 000 |
| **Farm 2** | Organic | 95 | 51 | 0,78 | 225 000 |
| **Farm 3** | Organic | 400 | 865 | 2,17 | 4 100 000 |
| **Farm 4** | Conventional | 195 | 155 | 1,07 | 1 400 000 |
| **Farm 5** | Conventional | 130 | 65 | 0,5 | 400 000 |

## 5.3 The Environmental Benefits

In this chapter the estimation process of the environmental benefits in the CBA will be described. The benefits not included in the analysis will also be discussed.

### 5.3.1 Pollination and Beehives

A third of the food production in the world is dependent on pollinators such as honey bees which perform 85% of the pollination (Jordbruksverket, 2018). The total economic value of the pollination of crops in Sweden is 189-325 million SEK. According to an estimation made by Jordbruksverket in 2016 there were 174 000 beehives in Sweden. The environmental value is estimated from the average annual total value of pollination, which is 260 million SEK (with 2009 as a base year) (ibid). This value divided by the number of beehives and transformed into 2018 SEK, gives a value of 1637 SEK/beehive. Full calculations can be found in appendix 1.

### 5.3.2 Linear Field Elements

Stone walls, alleys and open ditches on arable land are examples of eligible linear field elements (Hasund, et al., 2011). These elements are important for biodiversity as well as cultural heritage and aesthetic features. In a study made by Hasund et al. (2011) a valuation of different linear field elements in arable land was made using a contingent valuation method. In the price database of socioeconomic standard values (Naturvårdsverket & Jordbruksverket, 2016) made by Jordbruksverket and to Naturvårdsverket the results from the study written by Hasund et al. (2011) are summarized and transformed to SEK/meter or SEK/unit All index values for stone walls, alleys, open ditches, roads without gravel or asphalt, old cattle paths used in the CBA is collected from this price database. These values are converted SEK with 2018 as a base year.

### 5.3.3 Grassland Field Elements

Cultivation stone cairns, ancient monument sites, building ruins, solitary trees, ponds, field islets and traditional buildings are all different grassland field elements (Hasund, et al., 2011). They are, as well as the linear field elements, important for biodiversity, cultural heritage and aesthetic features. Hasund et al. (2011) estimates the values of these elements with a contingent valuation method. These values are used by Jordbruksverket and Naturvårdsverket in their price database for socioeconomic standard values where they have transformed some of the values in other units (Naturvårdsverket & Jordbruksverket, 2016). The values for these elements are converted into SEK with 2018 as a base year and used in the CBA.

### 5.3.4 Grassland

Grazing grasslands contribute to biodiversity, recreational accessibility and aesthetic features by maintaining an open landscape (Hasund, et al., 2011). There are different kinds of grassland. Cultivated grasslands are fertilized or sprayed with pesticides which reduces the positive impacts on biodiversity etc., usually the farmers take hay from this land. There are also semi-natural pastures which are not fertilized with other than the animals' manure when they graze the land. This type of grassland contributes more to the aspects mentioned above. Hasund et al. (2011) estimate values for these different types of grasslands which are used in the CBA. The values are converted to SEK, with 2018 as a base year.

## 5.2 The environmental costs

This chapter describes how the identified environmental costs are estimated together with a motivation for including these costs in the CBA. Costs excluded from the analysis will also be discussed.

### 5.2.1 Diesel Fuel Emissions

All farmers use diesel as fuel for all their vehicles used in the production. There are three different ways of measuring the emissions of fuel, well-to-wheel, well-to-pump and tank-to-wheel (Eriksson & Ahlgren, 2013). In this CBA, the value for tank-to-wheel will be used since the intention is to include the use of diesel fuel and its environmental impact. In a report by Eriksson & Ahlgren (2013), which is a literature review, different life cycle analyses on petrol and diesel fuel are summarized. The emissions of diesel in $CO_2$ equivalents in Sweden is 75,5 g/MJ according to this report. Trafikverket wrote a report in which they estimate the cost of emissions from $CO_2$ equivalents to be 1,14 SEK/kg (The Swedish Transport Administration, 2018). These values are used in order to calculate the cost of emissions from the diesel fuel used on the farms. Full calculations can be found in appendix 1.

### 5.2.2 Methane Emissions

Methane emissions from cows account for about 15% of global emissions and is a highly potential green-house gas, having many times the global warming potential of carbon dioxide (Grainger, et al., 2007). In a study made by Grainger et al. (2007) methane emissions from dairy cows were estimated by placing the cows in special chambers with measures of gas flow and composition. The result was that on average 322 g methane per cow and day. This value is transformed into $CO_2$ equivalents. One tonne of methane equals 21 tonne $CO_2$ (Jordbruksverket, 2010). The cost of $CO_2$ emissions is estimated to be 1,14 SEK/kg (The Swedish Transport Administration, 2018).

### 5.2.3 Pesticide Use

The use of pesticides has positive effects, such as an increased yield of crops, and negative effects, such as contamination of products, poisoning of bees, health impacts resistance etc. (Pimentel & Burgess, 2014). In the paper written by Pimentel & Burgess (2014) the negative effects of the total use of pesticides are estimated in monetary terms for the US. The aspects included are public health impacts, domestic animal deaths and contamination, loss of natural enemies, cost of pesticide resistance, honeybee and pollination losses, crop losses, fishery losses, bird losses, groundwater contamination, government regulations to prevent damage. In the CBA, the value is divided by the total consumption of pesticides in the US, transferred to SEK with 1992 as a base year and then transferred into SEK with 218 as a base year to get the value in SEK/kg/year.

### 5.2.4 Nitrogen Leakage

Eutrophication of the Baltic sea is a serious environmental issue (Naturvårdsverket, 2002). All of the farms included in the CBA are situated on the east coast of Sweden and runs a risk of contributing to eutrophication of the Baltic Sea though emissions of nitrogen. In a report by Naturvårdsverket (2002) nitrogen leakages from farmland is estimated. These estimates are used together with a valuation of abatement of nitrogen leakages to calculate the cost of nitrogen leakages per hectare for different crops in different regions in Sweden (Gren, et al., 2018). The cost of nitrogen leakages is measured in terms of abatement costs. Full calculations can be found in appendix 1.

*Table 3 An overview of the index values for the environmental benefits and costs. All values show the current prices in SEK, with 2018 as a base year.*

| | Value | Unit | Source |
|---|---|---|---|
| **Benefits:** | | | |
| Pollination | 1637 | SEK/st/year | (Jordbruksverket, 2018) |
| Field islets | 216 | SEK/st/year | (Hasund, et al., 2011) |
| Traditional building | 216 | SEK/st/year | (Hasund, et al., 2011) |
| Small arable field with irregular shape | 216 | SEK/st/year | (Hasund, et al., 2011) |
| Wetlands or ponds | 216 | SEK/st/year | (Hasund, et al., 2011) |
| Solitary tree | 189 | SEK/st/year | (Hasund, et al., 2011) |
| Avenue trees | 162 | SEK/st/year | (Hasund, et al., 2011) |
| Building ruin | 162 | SEK/st/year | (Hasund, et al., 2011) |
| Ancient monument site | 433 | SEK/st/year | (Hasund, et al., 2011) |
| Clearance cairn | 195 | SEK/st/year | (Hasund, et al., 2011) |
| Old cattle path | 8,7 | SEK/m/year | (Hasund, et al., 2011) |
| Stone wall | 3,2 | SEK/m/year | (Hasund, et al., 2011) |
| Old road without gravel or asphalt | 1,6 | SEK/m/year | (Hasund, et al., 2011) |
| Open ditch | 1,6 | SEK/m/year | (Hasund, et al., 2011) |
| Semi-natural pastures | 2504 | SEK/ha/year | (Hasund, et al., 2011) (Drake, 1992) |
| Cultivated grassland | 2261 | SEK/ha/year | (Hasund, et al., 2011) (Drake, 1992) |
| **Costs:** | | | |
| Diesel fuel | 3,03 | SEK/L | (Eriksson & Ahlgren, 2013) (The Swedish Transport Administration, 2018) |
| Methane | 2948 | SEK/cow/year | (Grainger, et al., 2007) (Frankhauser, 1994) (The Swedish Transport Administration, 2018) |
| Pesticides | 132 | SEK/kg/year | (Pimentel & Burgess, 2014) |
| Nitrogen Corn Gotland | 1557 | SEK/ha/year | (Gren, et al., 2018) (Naturvårdsverket, 2002) |
| Nitrogen Cereals Gotland | 1742 | SEK/ha/year | (Gren, et al., 2018) (Naturvårdsverket, 2002) |
| Nitrogen Grassland Gotland | 430 | SEK/ha/year | (Gren, et al., 2018) (Naturvårdsverket, 2002) |
| Nitrogen Corn Uppland | 767 | SEK/ha/year | (Gren, et al., 2018) (Naturvårdsverket, 2002) |
| Nitrogen Cereals Uppland | 790 | SEK/ha/year | (Gren, et al., 2018) (Naturvårdsverket, 2002) |
| Nitrogen Grassland Uppland | 105 | SEK/ha/year | (Gren, et al., 2018) (Naturvårdsverket, 2002) |

## 5.4 The Choice of Discount Rate

The social discount rate is used in economic CBA. The reason for implementing it in the analysis is to enable comparison between costs and benefits that occur in the future and costs and benefits that occur today (Boardman, et al., 2014). This is essential to obtain a single value for the project, called net present value. Discounting incorporates the fact that one dollar today is worth more than one dollar at a future time. There are two reasons for this. The first is that by investing a sum of money today, it will grow to a greater amount in the future and the fact that people are impatient and prefer to consume a given amount now rather than in the future, is the second reason. The optimal social discount rate should answer the following question, what should the consumers be compensated with, if they postpone the consumption to the future, so that the overall utility is the same (OECD, 2018)? The answer is derived from the Ramsey Rule and illustrated by the following equation (Ramsey, 1928);

$$i = \delta + \eta g$$

Where $\delta$ is the utility discount rate which is a reflection of the time preference discussed earlier, $\eta$ is the elasticity of marginal utility and g is the growth rate of per capita consumption over time. The social discount rate is later used to calculate the social discount factor, $W_t$, which is calculated as follows;

$$W_t = \frac{1}{(1+i)^t}$$

The social discount rate is the same in all time periods but the social discount factor, $W_t$, will diminish over time (Boardman, et al., 2014). To receive the net present value the net value is multiplied with the social discount factor.

In reality, the official recommendations, made by for example EU or OECD, regarding the level of discount rate has declined in general (Groom & Hepburn, 2017). In the United Kingdom for example the recommended discount rate has declined from 6% to 3,5%. A recommendation of the social discount rate from the European Commission in European member states is 3% (European Commission, 2015). However, in this CBA, a social discount rate of 2 % is chosen since the consequences of the emissions of carbon dioxide and methane are realized far in the future, which makes the future consequences more important. Further, the true effects of the emissions are uncertain.

In the financial CBA, the discount rate is a reflection of the opportunity cost of capital (European Commission, 2015). The European Commission recommend a 4 % discount rate for financial appraisal.

### 5.4.1 Sensitivity Analysis

Since the CBA contains several assumptions, it is necessary to check how robust the results are if the parameters are changed (Boardman, et al., 2014). If the net present value does not change sign, positive or negative, the result is considered robust. Since the analysis usually contains many different assumptions it is impossible to check all different combinations in a sensitivity analysis. Boardman et al. (2014) mention three approaches for sensitivity analysis which are more reasonable; partial sensitivity analysis, worst- and best-case analysis and Monte Carlo sensitivity analysis. Partial sensitivity analysis is performed by changing one variable, while holding all others constant, and this is the approach chosen in this paper. Usually the variables chosen for the analysis are those which are believed to be the most important and uncertain variables. A common variable to choose is the discount rate since it usually affects the result of the CBA considerably. If the net present value does not change sign in the sensitivity analysis, the result is robust.

## 5.5 The Conduction of the CBA

To perform the CBA data had to be collected from the five case study farms. The financial data was collected from the annual accounts report. To minimize the risk of valuating some items twice, the environmental support the farmers receive was subtracted from revenues. The farmers receive economic supports from the EU CAP programme and the national rural development programme. Some of these supports are payments directed towards production. The single payment scheme is a support primarily paid to increase competitiveness and stabilize and ensure production (Government Offices of Sweden, 2018). This support is based on acreage and not level of production. To receive this support, the farmers must diversify crops, preserve permanent grasslands and promote areas with organic focus. About 30 % of the amount payed is reserved for these three tasks. It is not possible to separate the part regarding grassland from the total amount, hence there is a small possibility of double counting. Another support is the compensatory allowance which is paid to compensate for inferior farming conditions. It should promote a continued use of the land, upkeep of rural areas and sustainable farming. The support is based on a calculation of additional costs and production loss for an area with inferior production possibilities. Supports for conversion to organic production or organic production are intended to increase the organic production and increase competitiveness and can be received both for plant-based production and animal production (ibid). There is also a support paid for raising dairy cows for production which intended to ensure and stabilize dairy production. All these supports are included in the economic CBA. There are some supports which are directed for environmental and cultural services provided by farmers. The environmental support is intended to increase environmental goods in the landscape such as biodiversity etc. Since including the environmental support in the economic CBA would result in some environmental benefits being accounted for twice, this support was removed from the analysis. In the financial CBA, all of the supports were included. The spreadsheets for each farm's calculations are found in Appendix 3.

Data on the environmental attributes was assembled during telephone interviews where the farmers stated the values. The interview questions can be found in Appendix 2. When the interviews had been conducted all values were transformed and calculated using Excel. The installation cost in the analysis includes the cost of building the stable and installing all the equipment needed for a milk stable. Since the CBA does not include transactions between stakeholders in the society, neither depreciation of the buildings or inventory, nor interest paid, is taken into account in the analysis. For the CBA, for each farm, data for the environmental benefits were multiplied with the index values described earlier in this chapter. All values were transferred in current prices in SEK, with 2018 as a base year. Lastly, the sensitivity analysis was performed with discount rates of 1 % and 3 %. All results are summarized in tables in the following chapter and the spreadsheets of the CBAs can be found in Appendix 3.

# 6 Results

The results of the CBAs are presented in Table 3 below. The net present values for the financial CBAs are higher than the ones for the economic CBAs. In all cases, the environmental costs are higher than the environmental benefits. Farms one, two and four have positive results for the CBA no matter the discount rate, meaning the sensitivity analysis was successful since the decision of going forward with the investment would not change if the discount rate changes. Farm three and farm five have negative net present values for all discount rates in the economic CBA. In this case the sensitivity analysis was also successful as the decision of investing or not would not change with the discount rate in this case either. All farms have positive net present values in the financial CBA no matter the discount rate except farm number five which has a negative net present value for a discount rate of six percent. The spreadsheets with each farms CBA can be found in Appendix 3. The financial information is removed in the spreadsheets since it is sensitive information.

In conclusion, almost all results are robust. The two farms situated in Uppland have similar results while the three farms situated on Gotland vary in the results. Two of the three farms have a negative net present value in the economic CBA, the third one has a positive value. The two organic farms in the analysis, number two and three, have different results.

*Table 4 Results of the CBA with different discount rates. All values are in SEK.*

| | **Farm 1** | **Farm 2** | **Farm 3** | **Farm 4** | **Farm 5** |
|---|---|---|---|---|---|
| Economic CBA 1% | 22 656 339 | 12 827 669 | - 11 647 611 | 4 589 673 | - 612 872 |
| **Economic CBA 2%** | **19 684 436** | **10 690 668** | **- 10 893 087** | **2 797 531** | **- 1 110 825** |
| Economic CBA 3% | 17 098 751 | 8 886 558 | - 10 256 099 | 1 238 289 | - 1 531 210 |
| Financial CBA 2% | 30 421 213 | 11 689 052 | 26 749 572 | 9 716 797 | 2 550 534 |
| **Financial CBA 4%** | **23 764 537** | **8 154 245** | **20 405 032** | **5 627 534** | **1 041 694** |
| Financial CBA 6% | 18 652 512 | 5 582 245 | 15 788 614 | 2 487 167 | - 56 168 |

The net benefits were normalized to receive a net benefit value per hectare. This value was used to calculate a net present value for each farm. The results of sensitivity analysis and the signs are the same as above. Values are expressed in SEK/ha and can be seen in the table below.

*Table 5 Results of the CBA net benefits per hectare SEK/ha.*

| | **Farm 1** | **Farm 2** | **Farm 3** | **Farm 4** | **Farm 5** |
|---|---|---|---|---|---|
| Economic CBA 1% | 134 859 | 197 349 | - 29 192 | 31 653 | - 3 006 |
| **Economic CBA 2%** | **117 169** | **164 472** | **- 27 301** | **19 293** | **- 4 714** |
| Economic CBA 3% | 101 778 | 136 716 | - 25 705 | 8 540 | - 11 779 |
| Financial CBA 2% | 181 079 | 179 832 | 67 042 | 67 012 | 19 619 |
| **Financial CBA 4%** | **141 456** | **125 450** | **51 140** | **38 811** | **8 013** |
| Financial CBA 6% | 111 027 | 85 881 | 39 570 | 17 153 | - 432 |

To determine how the agricultural policy supports the farmers receive influence the results, a CBA without all these payments was conducted. The results are found in table 5. Farms one and two are not affected by the absence of policy support. However, farm three, four and five are dependent on supports since neither the economic nor the financial CBA gives a positive net present value.

*Table 6 Results of the CBA without the agricultural policy supports. All values are in SEK per year*

| | **Farm 1** | **Farm 2** | **Farm 3** | **Farm 4** | **Farm 5** |
|---|---|---|---|---|---|
| Economic CBA 1% | 12 406 988 | 7 385 616 | - 53 392 745 | - 12 558 655 | - 10 076 707 |
| **Economic CBA 2%** | **10 397 296** | **5 866 305** | **- 47 900 013** | **- 12 740 909** | **- 9 500 484** |
| Economic CBA 3% | 8 648 776 | 4 583 665 | - 43 262 912 | - 12 899 478 | - 9 014 023 |
| Financial CBA 2% | 19 139 787 | 6 650 185 | - 11 424 896 | - 7 129 902 | - 6 229 808 |
| **Financial CBA 4%** | **14 388 095** | **4 122 295** | **- 10 141 008** | **- 8 374 419** | **- 5 984 055** |
| Financial CBA 6% | 10 739 012 | 2 282 950 | - 9 206 824 | - 9 330 151 | - 5 805 240 |

# 7 Analysis & Discussion

The results of the CBAs differ between the farms in several aspects. There seems to be a difference in the results depending on where in Sweden the farm is located. Farms number one and two who are situated in Uppland have positive net present values for both the economic and the financial CBAs. The three farms situated on Gotland has inferior results in general. Only one of the farms has a positive net present value in the economic CBA. The negative net present value in the economic CBA for farm number three is probably due to the high number of livestock units which yields a high cost for methane emissions. The total cost of methane emissions is 2,5 million SEK per year. Farm number five has relatively large installation costs which gives a negative net present value even though the net benefits for each year are positive.

No differences between organic and conventional production were observed. The environmental benefits and costs included in the analysis are all relevant for both types of production except for the cost of pesticide use since it is forbidden in organic production. If other costs and benefits would have been included such as the environmental costs of production and transport of animal feed and phosphorous emissions, there may have been a difference in the results. There is a slight pattern in the results regarding livestock units per hectare. The farms with a high ratio have larger environmental costs and therefore a lower net present value. This could be interpreted as; a more highly intensive production is less profitable in environmental terms although the financial profit is larger. This is especially observed in the results for farm number three.

Comparing the results of the CBAs with the agricultural policy support included and the one where they are excluded, tables 3 and 5, show that without these supports farms three to five would not make a financial profit if these supports were eliminated. This shows the situation some farmers in Sweden are facing; the need for policy support in order to make a financial profit. The three farms which do not make a financial profit without policy supports are all situated on Gotland whereas the other two farms are situated in Uppland. This shows that there are probably regional differences in the prerequisites for the dairy farms. The Swedish government have decided to equalize the direct payments the farmers receive throughout the whole country (Landsbygdsdepartementet, 2014). Previously the direct payment has been different between regions in Sweden. The results of this, relatively small, investigation suggests that there are different needs for supports depending where in the country the farm is situated.

In all CBAs the environmental costs are higher than the environmental benefits. This does not necessary imply that it is the entire truth in reality. In general, the environmental costs are higher valued which might be due to the fact that the consequences of methane and carbon dioxide emissions or pesticide use are connected to human health. The valuation also depends on what approach and costs are included, if only the national effects are included instead of global effects etc. When human life and health issues are involved, the costs rise (Boardman, et al., 2014). Valuation of environmental benefits has other issues. Since the effects of for example biodiversity or pollination loss does not seem as acute as human health issues and does not affect us directly, it tends to be undervalued in comparison to the environmental costs. The effects of these kinds of losses are difficult to predict and more research in this area is needed.

The financial CBA shows that three of the farms would not be profitable without the policy support they receive from the direct payments and the rural development program. This might imply there is a market failure apparent in the sector and the policy support should correct for this failure. There is an ongoing discussion within EU about the level and the form of the policy support. Given the result that the market does not pay the full price of the produce (because of the low consumer prices), a reduction or elimination of the supports would be problematic to the Swedish market, which has been found to be highly dependent on subsidies (European Commission, 2018). Moreover, the Swedish government has a long-term food strategy for Sweden which includes a goal for self-sufficiency of food production (Ministry of Enterprise and Innovation, 2017). Reducing the supports would probably reduce the self-sufficiency level in Sweden.

The index values included in the analysis are all acquired from studies conducted in Sweden except for the one regarding cost of pesticide use which is from a study conducted in the USA. Since valuation of environmental costs are different among countries this implies a weakness for this study. It would have been ideal to use a value which was acquired from a study conducted in Sweden because there would not be a need for transforming the value into SEK from USD. Almost all indexes for the environmental benefits were obtained from Hasund et al. (2011), who used contingent valuation method to calculate a WTP for different elements in the Swedish agricultural landscape. There are values which are not included in this study. Some recreational values are not included such as the value of being able to visit the farm and enjoying the view of grazing cows. There is an existence value of dairy farms which is not included, the value of knowing there are Swedish dairy farms. Furthermore, the farms contribute largely to food security and self-sufficiency in Sweden which could also be valued.

There are several weaknesses in this study and the largest one is probably the index values used for the environmental costs and benefits. The environmental benefits were valued in terms of WTP using a contingent valuation method (Hasund, et al., 2011). There are uncertainties with WTP studies since they are conducted based on a hypothetical scenario which may invite individuals to over- or underestimate their WTP (Perman, et al., 2011). The respondents of the survey have to truly understand the impact of these environmental benefits to make a reasonable estimation of their WTP, unfortunately this is not often the case. However, this is a common way of valuating environmental goods since there are few methods which are better. The index values for the environmental costs may be more accurate and reliable since there is more research and literature in this area and the value for carbon dioxide emissions is assembled from the Swedish Transport Administration.

Previous literature uses other methods to estimate the environmental impacts of dairy farming. The methods which could have been used instead of the CBA are lifecycle assessment or a cost effectiveness analysis. However, the analysis would differ using these methods instead since the results would focus on other aspects. The results from earlier studies are not directly comparable with the results received in this study. However, they do show a positive WTP to improve the environmental attributes such as water quality and quantity (Baskaran, et al., 2009). They also conclude that the external costs of dairy farming are not reflected in the market price paid for the dairy products. More research on valuation of environmental goods provided by agriculture is needed to make certain statements regarding environmental impacts of dairy farming.

# 8 Conclusion

The aim of this paper was to investigate the balance between the environmental benefits and the environmental costs associated with dairy production in Sweden. The results of the CBAs show that there are generally higher environmental costs than benefits. Three out of five farms have positive net present values in the economic CBAs. Following the instructions for CBAs this implies the three farms should go on with their production. However, there are uncertainties with these results and issues with the valuations of environmental costs and benefits as mentioned in the two previous chapters. The primary objective of the paper was to investigate whether or not there were differences in the results when analysing organic and conventional production systems and across different farm sizes. It is not possible to claim there are differences between conventional and organic production from the results in this CBA. More extensive research with several more case study farms is needed to make certain conclusions. When comparing the results of the CBA with the farms ratio of livestock units per hectare there may be a connection with high environmental costs and a high ratio of livestock units (livestock density) per hectare.

Since the scope of this research is rather small, the recommendation regarding whether or not to undertake the investment, which is usually made in a CBA, is not fully possible. There is a need for more research and a larger study including more farms to make recommendations regarding dairy farming in Sweden. The results of this study are a starting point for continued research on the subject of environmental impact valuation of agriculture. They can be used to gain some insight of different production systems and their benefits and disadvantages which can be helpful for decision makers and resource managers when deciding on the levels of support paid to the farmers and optimal levels of production. The results also make a contribution to the discussion of the economic supports paid to farmers. Gaining an understanding of the environmental impacts of dairy farming on farm level will aid investors', for example banks, regarding decision making when evaluating how sustainable investments in dairy farms are as well as an understanding of to what purpose they loan money.

# References


Baskaran, R., Cullen, R. & Colombo, S., 2009. Estimating values of environmental impacts of dairy farming in New Zealand. *New Zealand Journal of Agricultural Research,* December, 52(4), pp. 377-389.

Boardman, A. E., Greenberg, D. H., Vining, A. R. & Weimer, D. L., 2014. *Cost-Benefit Analysis - Concepts and Practice.* 4th ed ed. Essex: Pearson Education Limited.

Capper, J. L., Cady, R. A. & Bauman, D. E., 2009. The environmental impact of dairy production: 1944 compared with 2007. *Journal of Animal Science,* 87(6), p. 2160–2167.

de Boer, I. J., 2003. Environmental impact assessment of conventional and organic milk production. *Livestock Production Science,* Volume 80, pp. 69-77.

Drake, L., 1992. The non-market value of the Swedish agricultural landscape. *European Review of Agricultural Economics,* 19(3), pp. 351-364.

Eliasson, J., 2009. A cost–benefit analysis of the Stockholm congestion charging system. *Transportation Research Part A: Policy and Practice,* 43(4), pp. 468-480.

Eriksson, M. & Ahlgren, S., 2013. *LCAs of Petrol and Diesel: a literature review,* Uppsala: SLU, Swedish University of Agricultural Science .

European Commission, 2015. *Guide to Cost-Benefit Analysis of Investment Projects,* Brussels: European Union.

European Commission, 2018. *Agricultural and farm income,* s.l.: European Union.

Frankhauser, S., 1994. The Social Costs of Greenhouse Gas Emissions: An Expected Value Approach. *The Energy Journal,* 15(2), pp. 157-184.

Government Offices of Sweden, 2018. *Sweden - Rural Development Programme,* Sweden: Government Offices of Sweden.

Grainger, C. et al., 2007. Methane Emissions from Dairy Cows Measured Using the Sulfur Hexafluoride (SF6) Tracer and Chamber Techniques. *Journal of Dairy Science,* June, 90(6), pp. 755-2766.

Gren, I.-M., Säll, S., Zeleke Aklilu, A. & Tirkaso, W., 2018. Does Mussel Farming Promote Cost Savings and Equity in Reaching Nutrient Targets for the Baltic Sea?. *Water,* 10(11).

Groom, B. & Hepburn, C., 2017. Looking Back at Social Discount Rates: The Influence of Papers, Presentations, Political Preconditions and Personalities on Policy. *Review of Environmental Economics and Policy,* 11(2), pp. 336-356.

Høgaas Eide, M., 2002. Life Cycle Assessment (LCA) of Industrial Milk Production. *The International Journal of Life Cycle Assessment,* 7(2), pp. 115-126.

Hanley, N., Barbier, E. B. & Barbier, E., 2009. *Pricing Nature: Cost-benefit Analysis and Environmental Policy.* s.l.:Edward Elgar Publishing.

Hasund, K. P., Kataria, M. & Lagerkvist, C. J., 2011. Valuing public goods of the agricultural landscape: a choice experiment using reference points to capture observable heterogeneity. *Journal of Environmental Planning and Management,* 54(1), pp. 31-53.

Johnston, R. J., Rolfe , J., Rosenberger, R. S. & Brouwer , R., 2015. *Benefit Transfer of Environmental and Resource Values - A Guide for Researchers and Practitioners.* 1 ed. New York: Springer.

Jordbruksverket, 2010. *Minskade växtnäringsförluster och växthusgasutsläpp till 2016 – förslag till handlingsprogram för jordbruket,* s.l.: Jordbruksverket.

Jordbruksverket, 2018. *Jordbruksverket.* [Online]
Available at:
http://www.jordbruksverket.se/amnesomraden/djur/olikaslagsdjur/binochhumlor/biodlingensroll.4.1a4c164c11dcdaebe12800044.html
[Accessed 04 2019].

Jordbruksverket, 2018. *Marknadsrapport - mjölk och mejeriprodukter,* u.o.: u.n.

Jordbruksverket, 2018. *Modulbyggt stall för mjölkkor* , s.l.: Jordbruksverket.

Landsbygdsdepartementet, 2014. *Gårdsstödet 2015–2020 – förslag till svenskt genomförande.* Stockholm: Elanders Sverige AB.

Ministry of Enterprise and Innovation, 2017. *En livsmedelsstrategi för Sverige − fler jobb och hållbar tillväxt i hela landet,* Stockholm: Elanders.

Naturvårdsverket, 2002. *Kväveläckage från svensk åkermark Beräkningar av normalutlakning för 1995 och 1999,* Stockholm: Naturvårdsverket.

Naturvårdsverket, 2014. *Småvatten och våtmark i jordbruksmark,* Stockholm: Naturvårdsverket.

Naturvårdsverket & Jordbruksverket, 2016. *Prisdatabas Samhällsekonomiska Schablonvärden.* s.l.:https://www.naturvardsverket.se/upload/stod-i-miljoarbetet/vagledning/samhallsekonomisk-analys/Prisdatabas-samhallsekonomiska-schablonvarden-2016-06-19.xlsx.

OECD, 2018. *Cost-Benefit Analysis and the Environment: Further Development and Policy Use.* Paris: OECD Publishing.

Perman, R., Ma, Y., McGilvray, J. & Common, M., 2011. *Natural Resource and Environmental Economics.* 4th ed ed. Edinburgh: Pearson Education.

Pimentel, D. & Burgess, M., 2014. Environmental and Economic Costs of the Application of Pesticides Primarily in the United States.. In: D. Pimentel & M. Burgess, eds. *Integrated Pest Management.* Dordrecht: Springer, pp. 47-71.

Ramsey, F. P., 1928. A Mathematical Theory of Saving. *The Economic Journal,* 32(152), pp. 543-559.

Snyder, B. & Kaiser, M. J., 2009. Ecological and economic cost-benefit analysis of offshore wind energy. *Renewable Energy,* 34(6), pp. 1567-1578.

SP, Technical Research Institute of Sweden, 2017. *Ekosystemtjänster på mjölkgårdar: Förekomst, indikatorer och åtgärder,* Borås: SP Technical Research Institute of Sweden.

Statistics Sweden, 2014. *Yearbook of Agricultural Statistics.* Örebro, Sweden: Statistics Sweden, Agriculture Statistics Unit.

The Swedish Transport Administration, 2018. *Analysmetod och samhällsekonomiska kalkylvärden för transportsektorn,* Stockholm: Trafikverket.

Wegner, G. & Pascual, U., 2011. Cost-benefit analysis in the context of ecosystem services for human well-being: A multidisciplinary critique. *Global Environmental Change,* 21(2), pp. 492-504.

Zimmermann, A. & Heckelei, T., 2012. Structural Change of European Dairy Farms – A Cross-Regional Analysis. *Journal of Agricultural Economics*, 63(3), p. 576–603.

# Acknowledgements

First of all, I want to thank my supervisors Gordana Manevska Tasevska and Efthymia Kyriakopoulou who has helped me throughout the process of writing this paper. Secondly, I want to thank Torbjörn Alness and Markus Forsbäck for supplying me with my case study farms and helping me improve the paper.

# Appendix 1: Calculations of index values

## 1.1 Calculation of the environmental benefits of beehives

Total economic value of pollination in Sweden is estimated to 189-325 million SEK (with 2009 as base year). Calculating an average annual value:

$$\frac{189 + 325}{2} \approx 260\ million$$

SEK/beehive, with 2009 as a base year:

$$\frac{260000000}{174\ 000} \approx 1494$$

Transforming to SEK/beehive, with 2018 as a base year:

$$1494 \times 1{,}0959 = 1637\ SEK/beehive/year$$

## 1.2 Calculations of the cost of diesel emissions

75,5 kg $CO_2$/MJ diesel fuel

42 MJ/kg diesel fuel

0,8 kg diesel/L

1,14 2014 SEK/kg $CO_2$ = 1,19 2018 SEK/kg $CO_2$

$$0{,}8 \times 42 = 33{,}6\ MJ/L$$

$$33{,}6 \times 0{,}0755 = 2{,}5368\ Kg\ CO_2/L$$

$$2{,}5368 \times 1{,}19 = 3{,}0296\ SEK/L$$

## 1.3 Calculations of the cost of methane emissions

322 g methane/cow/day
1 kg methane = 21 kg $CO_2$
1,14 2014 SEK/kg $CO_2$ = 1,19 2018 SEK/kg $CO_2$

$$\frac{322 \times 365}{1000} = 117{,}53\ Kg\ methane/cow/year$$

$$117{,}53 \times 21 = 2468{,}13\ Kg\ CO_2/cow/year$$

$$2468{,}13 \times 1{,}19 = 2947{,}6\ SEK/cow/year$$

## 1.4 Calculations of nitrogen emissions

| Gotland | mg N/L surface water | mm surface water | L surface water/ha | mg N/ha | kg N/ha |
|---|---|---|---|---|---|
| Corn | 16,6 | 217 | 2170000 | 36022000 | 36,022 |
| Cereals | 17,6 | 229 | 290000 | 40304000 | 40,304 |
| Grassland | 6,1 | 163 | 21630000 | 9943000 | 9,943 |

| Uppland | mg N/L surface water | mm surface water | L surface water/ha | mg N/ha | kg N/ha |
|---|---|---|---|---|---|
| Corn | 6,9 | 257 | 2570000 | 17733000 | 17,733 |
| Cereals | 7 | 261 | 2610000 | 18270000 | 18,27 |
| Grassland | 1,3 | 187 | 1870000 | 2431000 | 2,431 |

# Appendix 2: Interview Questions

- How many hectares do you farm?
    - Pastureland:
    - Arable land:
    - Forest land:
    - Other:

- What crops do you farm on the arable land, including grass?

    - Approximately how much of each crop?

- How many cattle do you have of different categories?

    - Cows:
    - Calves:
    - Younglings:
    - Other:

- What is produced on the farm for resale?

- What kind of production system do you have? How long is the lifespan of that system?

- What is the investment cost of that system?

- How much do you produce of:
    - Milk:
    - Hay:
    - Other:

- Do you buy any feed? If yes what kind of feed and how much approximately?

- What kind of fertilizers do you use and how much of each?

- How much fuel do you use during a year?
    - Diesel:
    - Gas:
    - Other:

- Is there any water close to the farm, far away is the nearest lake/watercourse?

- Do you have an avenue of at least 7 trees?

    - How many and how many trees are there in each?

- Do you have any beehives?
    - If yes: How many?
- Do you have any roads without asphalt and oil gravel only used for transport within the farm?
    - If yes: how many and how long is it?
- Do you have any non-arable outcrop?
    - If yes: how many?
- Do you have any old building formations? A house or ruin without a functioning roof that belongs to the original farm?
    - If yes how many? Is it situated on a non-arable outcrop?
- Do you have any ancient monument sites?
    - If yes: how many? Is it situated on a non-arable outcrop?
- Do you have any clearance cairns?
    - If yes: how many? Is it situated on a non-arable outcrop?
- Do you have any stone walls?
    - If yes: how many and how long is it?
- Do you have any old cattle paths? A path on which cattle were herded that is surrounded by stone walls or old wooden fences?
    - If yes: how many and how long is it?
- Do you have any open ditches? A built ditch used for drainage of the arable land. Water should flow in it during some season of the year and it should be beside arable land.
    - If yes: how many and how long is it?
- Do you have any land that is managed to gain a higher biodiversity?
    - If yes: what and how many hectares?
- Do you have any small arable field with irregular shape (max 0,3 ha)? The field should be permanently restricted by forest, waterways, pastureland etc.
    - If yes: how many?

- Do you have any old traditional buildings? A building connected to the original farm with a functioning roof and a relatively preserved outside.
    - If yes: how many? Is it situated on a non-arable outcrop?
- Do you have any wetlands or ponds (max 0,1 ha on water surface)?
    - If yes: how many?
- Do you have any solitary trees? A tree surrounded by arable land.
    - If yes: how many?

# Appendix 3: CBA spreadsheets

## Economic CBA Farm 1

| Year | 0 | 1 | 2 | 3 | … | 20 |
|---|---|---|---|---|---|---|
| Revenue | - kr | xxx kr | xxx kr | xxx kr | … | xxx kr |
| Operating cost | - kr | xxx kr | xxx kr | xxx kr | … | xxx kr |
| Installation cost | - 9 000 000,00 kr | - kr | - kr | - kr | … | - kr |
| Tot. Cost | - 9 000 000,00 kr | xxx kr | xxx kr | xxx kr | … | xxx kr |
| Diesel fuel | - kr | - 63 622 kr | - 63 622 kr | - 63 622 kr | … | - 63 622 kr |
| Methane | - kr | - 639 629 kr | - 639 629 kr | - 639 629 kr | … | - 639 629 kr |
| Pesticides | - kr | - 6 597 kr | - 6 597 kr | - 6 597 kr | … | - 6 597 kr |
| Nitrogen Corn Uppland | - kr | - 16 874 kr | - 16 874 kr | - 16 874 kr | … | - 16 874 kr |
| Nitrogen Cereals Uppland | - kr | - 27 650 kr | - 27 650 kr | - 27 650 kr | … | - 27 650 kr |
| Nitrogen Grassland Uppland | - kr | - 9 135 kr | - 9 135 kr | - 9 135 kr | … | - 9 135 kr |
| Tot. environmental cost | - kr | - 763 506 kr | - 763 506 kr | - 763 506 kr | … | - 763 506 kr |
| Bee hives | - kr | - kr | - kr | - kr | … | - kr |
| Field islets | - kr | 1 082 kr | 1 082 kr | 1 082 kr | … | 1 082 kr |
| Traditional building | - kr | 216 kr | 216 kr | 216 kr | … | 216 kr |
| Small arable field with irregular shape | - kr | - kr | - kr | - kr | … | - kr |
| Wetlands or ponds | - kr | - kr | - kr | - kr | … | - kr |
| Solitary tree | - kr | - kr | - kr | - kr | … | - kr |
| Avenue trees | - kr | - kr | - kr | - kr | … | - kr |
| Building ruin | - kr | 649 kr | 649 kr | 649 kr | … | 649 kr |
| Ancient monument site | - kr | 1 299 kr | 1 299 kr | 1 299 kr | … | 1 299 kr |
| Clearance cairn | - kr | - kr | - kr | - kr | … | - kr |
| Old cattle path | - kr | - kr | - kr | - kr | … | - kr |
| Stone wall | - kr | 260 kr | 260 kr | 260 kr | … | 260 kr |
| Old roads without gravel and asphalt | - kr | 1 620 kr | 1 620 kr | 1 620 kr | … | 1 620 kr |
| Open ditch | - kr | 810 kr | 810 kr | 810 kr | … | 810 kr |
| Semi-natural pastures | - kr | 60 096 kr | 60 096 kr | 60 096 kr | … | 60 096 kr |
| Cultivated grassland | - kr | 162 812 kr | 162 812 kr | 162 812 kr | … | 162 812 kr |
| Tot. Environmental benefit | - kr | 228 844 kr | 228 844 kr | 228 844 kr | … | 228 844 kr |
| Net Benefits | - 9 000 000 kr | 1 754 246 kr | 1 754 246 kr | 1 754 246 kr | … | 1 754 246 kr |
| Net Benefits per ha | - 53 571 kr | 10 442 kr | 10 442 kr | 10 442 kr | … | 10 442 kr |

# Economic CBA Farm 2

| Year | 0 | 1 | 2 | 3 | … | 25 |
|---|---|---|---|---|---|---|
| Revenue | - kr | xxx kr | xxx kr | xxx kr | … | xxx kr |
| Operating cost | - kr | xxx kr | xxx kr | xxx kr | … | xxx kr |
| Installation cost | - 6 000 000 kr | - kr | - kr | - kr | … | - kr |
| Tot. Cost | - 6 000 000 kr | xxx kr | xxx kr | xxx kr | … | xxx kr |
| Diesel fuel | - kr | - 18 178 kr | - 18 178 kr | - 18 178 kr | … | - 18 178 kr |
| Methane | - kr | - 150 328 kr | - 150 328 kr | - 150 328 kr | … | - 150 328 kr |
| Pesticides | - kr | - kr | - kr | - kr | … | - kr |
| Nitrogen Corn Uppland | - kr | - kr | - kr | - kr | … | - kr |
| Nitrogen Cereals Uppland | - kr | - 6 320 kr | - 6 320 kr | - 6 320 kr | … | - 6 320 kr |
| Nitrogen Grassland Uppland | - kr | - 4 935 kr | - 4 935 kr | - 4 935 kr | … | - 4 935 kr |
| Tot. environmental cost | - kr | - 179 760 kr | - 179 760 kr | - 179 760 kr | … | - 179 760 kr |
| Bee hives | - kr | 29 466 kr | 29 466 kr | 29 466 kr | … | 29 466 kr |
| Field islets | - kr | 1 082 kr | 1 082 kr | 1 082 kr | … | 1 082 kr |
| Traditional building | - kr | 433 kr | 433 kr | 433 kr | … | 433 kr |
| Small arable field with irregular shape | - kr | - kr | - kr | - kr | … | - kr |
| Wetlands or ponds | - kr | - kr | - kr | - kr | … | - kr |
| Solitary tree | - kr | 379 kr | 379 kr | 379 kr | … | 379 kr |
| Avenue trees | - kr | - kr | - kr | - kr | … | - kr |
| Building ruin | - kr | - kr | - kr | - kr | … | - kr |
| Ancient monument site | - kr | 433 kr | 433 kr | 433 kr | … | 433 kr |
| Clearance cairn | - kr | 1 169 kr | 1 169 kr | 1 169 kr | … | 1 169 kr |
| Old cattle path | - kr | - kr | - kr | - kr | … | - kr |
| Stone wall | - kr | - kr | - kr | - kr | … | - kr |
| Old roads without gravel and asphalt | - kr | 4 050 kr | 4 050 kr | 4 050 kr | … | 4 050 kr |
| Open ditch | - kr | 9 720 kr | 9 720 kr | 9 720 kr | … | 9 720 kr |
| Semi-natural pastures | - kr | 25 040 kr | 25 040 kr | 25 040 kr | … | 25 040 kr |
| Cultivated grassland | - kr | 67 838 kr | 67 838 kr | 67 838 kr | … | 67 838 kr |
| Tot. Environmental benefit | - kr | 139 610 kr | 139 610 kr | 139 610 kr | … | 139 610 kr |
| Net Benefits | - 6 000 000 kr | 854 903 kr | 854 903 kr | 854 903 kr | … | 854 903 kr |
| Net Benefits per ha | - 92 308 kr | 13 152 kr | 13 152 kr | 13 152 kr | … | 13 152 kr |

# Economic CBA Farm 3

| Year | 0 | 1 | 2 | 3 | … | 25 |
|---|---|---|---|---|---|---|
| Revenue | - kr | xxx kr | xxx kr | xxx kr | … | xxx kr |
| Operating cost | - kr | xxx kr | xxx kr | xxx kr | … | xxx kr |
| Installation cost | - 5 000 000 kr | - kr | - kr | - kr | … | - kr |
| Tot. Cost | - 5 000 000 kr | xxx kr | xxx kr | xxx kr | … | xxx kr |
| Diesel fuel | - kr | - 90 888 kr | - 90 888 kr | - 90 888 kr | … | - 90 888 kr |
| Methane | - kr | - 2 549 674 kr | - 2 549 674 kr | - 2 549 674 kr | … | - 2 549 674 kr |
| Pesticides | - kr | - kr | - kr | - kr | … | - kr |
| Nitrogen Corn Gotland | - kr | - kr | - kr | - kr | … | - kr |
| Nitrogen Cereals Gotland | - kr | - kr | - kr | - kr | … | - kr |
| Nitrogen Grassland Gotland | - kr | - 150 500 kr | - 150 500 kr | - 150 500 kr | … | - 150 500 kr |
| Tot. environmental cost | - kr | - 2 791 062 kr | - 2 791 062 kr | - 2 791 062 kr | … | - 2 791 062 kr |
| Bee hives | - kr | - kr | - kr | - kr | … | - kr |
| Field islets | - kr | - kr | - kr | - kr | … | - kr |
| Traditional building | - kr | - kr | - kr | - kr | … | - kr |
| Small arable field with irregular shape | - kr | - kr | - kr | - kr | … | - kr |
| Wetlands or ponds | - kr | 216 kr | 216 kr | 216 kr | … | 216 kr |
| Solitary tree | - kr | - kr | - kr | - kr | … | - kr |
| Avenue trees | - kr | 2 435 kr | 2 435 kr | 2 435 kr | … | 2 435 kr |
| Building ruin | - kr | - kr | - kr | - kr | … | - kr |
| Ancient monument site | - kr | - kr | - kr | - kr | … | - kr |
| Clearance cairn | - kr | - kr | - kr | - kr | … | - kr |
| Old cattle path | - kr | - kr | - kr | - kr | … | - kr |
| Stone wall | - kr | 325 kr | 325 kr | 325 kr | … | 325 kr |
| Old roads without gravel and asphalt | - kr | 3 240 kr | 3 240 kr | 3 240 kr | … | 3 240 kr |
| Open ditch | - kr | 2 430 kr | 2 430 kr | 2 430 kr | … | 2 430 kr |
| Semi-natural pastures | - kr | 122 696 kr | 122 696 kr | 122 696 kr | … | 122 696 kr |
| Cultivated grassland | - kr | 791 448 kr | 791 448 kr | 791 448 kr | … | 791 448 kr |
| Tot. Environmental benefit | - kr | 922 790 kr | 922 790 kr | 922 790 kr | … | 922 790 kr |
| Net Benefits | - 5 000 000 kr | - 301 847 kr | - 301 847 kr | - 301 847 kr | … | - 301 847 kr |
| Net Benefits per ha | - 12 531 kr | - 757 kr | - 757 kr | - 757 kr | … | - 757 kr |

# Economic CBA Farm 4

| Year | 0 | 1 | 2 | 3 | … | 20 |
|---|---|---|---|---|---|---|
| Revenue | - kr | xxx kr | xxx kr | xxx kr | … | xxx kr |
| Operating cost | - kr | xxx kr | xxx kr | xxx kr | … | xxx kr |
| Installation cost | - 14 500 000 kr | - kr | - kr | - kr | … | - kr |
| Tot. Cost | - 14 500 000 kr | xxx kr | xxx kr | xxx kr | … | xxx kr |
| Diesel fuel | - kr | - 60 592,18 kr | - 60 592,18 kr | - 60 592,18 kr | … | - 60 592,18 kr |
| Methane | - kr | - 456 878,00 kr | - 456 878,00 kr | - 456 878,00 kr | … | - 456 878,00 kr |
| Pesticides | - kr | - 2 639 kr | - 2 639 kr | - 2 639 kr | … | - 2 639 kr |
| Nitrogen Corn Gotland | - kr | - 34 254 kr | - 34 254 kr | - 34 254 kr | … | - 34 254 kr |
| Nitrogen Cereals Gotland | - kr | - 31 356 kr | - 31 356 kr | - 31 356 kr | … | - 31 356 kr |
| Nitrogen Grassland Gotland | - kr | - 38 700 kr | - 38 700 kr | - 38 700 kr | … | - 38 700 kr |
| Tot. environmental cost | - kr | - 624 419 kr | - 624 419 kr | - 624 419 kr | … | - 624 419 kr |
| Bee hives | - kr | 16 370 kr | 16 370 kr | 16 370 kr | … | 16 370 kr |
| Field islets | - kr | - kr | - kr | - kr | … | - kr |
| Traditional building | - kr | - kr | - kr | - kr | … | - kr |
| Small arable field with irregular shape | - kr | - kr | - kr | - kr | … | - kr |
| Wetlands or ponds | - kr | - kr | - kr | - kr | … | - kr |
| Solitary tree | - kr | - kr | - kr | - kr | … | - kr |
| Avenue trees | - kr | - kr | - kr | - kr | … | - kr |
| Building ruin | - kr | - kr | - kr | - kr | … | - kr |
| Ancient monument site | - kr | - kr | - kr | - kr | … | - kr |
| Clearance cairn | - kr | 1 948 kr | 1 948 kr | 1 948 kr | … | 1 948 kr |
| Old cattle path | - kr | - kr | - kr | - kr | … | - kr |
| Stone wall | - kr | 1 625 kr | 1 625 kr | 1 625 kr | … | 1 625 kr |
| Old roads without gravel and asphalt | - kr | 5 670 kr | 5 670 kr | 5 670 kr | … | 5 670 kr |
| Open ditch | - kr | 14 580 kr | 14 580 kr | 14 580 kr | … | 14 580 kr |
| Semi-natural pastures | - kr | 37 560 kr | 37 560 kr | 37 560 kr | … | 37 560 kr |
| Cultivated grassland | - kr | 203 515 kr | 203 515 kr | 203 515 kr | … | 203 515 kr |
| Tot. Environmental benefit | - kr | 281 268 kr | 281 268 kr | 281 268 kr | … | 281 268 kr |
| Net Benefits | - 14 500 000 kr | 1 057 860 kr | 1 057 860 kr | 1 057 860 kr | … | 1 057 860 kr |
| Net Benefits per ha | - 100 000 kr | 7 296 kr | 7 296 kr | 7 296 kr | … | 7 296 kr |

# Economic CBA Farm 5

| Year | 0 | 1 | 2 | 3 | … | 4 |
|---|---|---|---|---|---|---|
| Revenue | - kr | xxx kr | xxx kr | xxx kr | … | xxx kr |
| Operating cost | - kr | xxx kr | xxx kr | xxx kr | … | xxx kr |
| Installation cost | - 5 000 000 kr | - kr | - kr | - kr | … | - kr |
| Tot. Cost | - 5 000 000 kr | xxx kr | xxx kr | xxx kr | … | xxx kr |
| Diesel fuel | - kr | - 30 296 kr | - 30 296 kr | - 30 296 kr | … | - 30 296 kr |
| Methane | - kr | - 191 594 kr | - 191 594 kr | - 191 594 kr | … | - 191 594 kr |
| Pesticides | - kr | - 6 597 kr | - 6 597 kr | - 6 597 kr | … | - 6 597 kr |
| Nitrogen Corn Gotland | - kr | - 4 671 kr | - 4 671 kr | - 4 671 kr | … | - 4 671 kr |
| Nitrogen Cereals Gotland | - kr | - 54 495 kr | - 54 495 kr | - 54 495 kr | … | - 54 495 kr |
| Nitrogen Grassland Gotland | - kr | - 108 990 kr | - 108 990 kr | - 108 990 kr | … | - 108 990 kr |
| Tot. environmental cost | - kr | - 396 643 kr | - 396 643 kr | - 396 643 kr | … | - 396 643 kr |
| Bee hives | - kr | - kr | - kr | - kr | … | - kr |
| Field islets | - kr | 433 kr | 433 kr | 433 kr | … | 433 kr |
| Traditional building | - kr | - kr | - kr | - kr | … | - kr |
| Small arable field with irregular shape | - kr | 649 kr | 649 kr | 649 kr | … | 649 kr |
| Wetlands or ponds | - kr | 649 kr | 649 kr | 649 kr | … | 649 kr |
| Solitary tree | - kr | 189 kr | 189 kr | 189 kr | … | 189 kr |
| Avenue trees | - kr | - kr | - kr | - kr | … | - kr |
| Building ruin | - kr | 162 kr | 162 kr | 162 kr | … | 162 kr |
| Ancient monument site | - kr | 433 kr | 433 kr | 433 kr | … | 433 kr |
| Clearance cairn | - kr | 779 kr | 779 kr | 779 kr | … | 779 kr |
| Old cattle path | - kr | - kr | - kr | - kr | … | - kr |
| Stone wall | - kr | 813 kr | 813 kr | 813 kr | … | 813 kr |
| Old roads without gravel and asphalt | - kr | 4 860 kr | 4 860 kr | 4 860 kr | … | 4 860 kr |
| Open ditch | - kr | 24 300 kr | 24 300 kr | 24 300 kr | … | 24 300 kr |
| Semi-natural pastures | - kr | 37 560 kr | 37 560 kr | 37 560 kr | … | 37 560 kr |
| Cultivated grassland | - kr | 158 290 kr | 158 290 kr | 158 290 kr | … | 158 290 kr |
| Tot. Environmental benefit | - kr | 229 117 kr | 229 117 kr | 229 117 kr | … | 229 117 kr |
| Net Benefits | - 5 000 000 kr | 199 205 kr | 199 205 kr | 199 205 kr | … | 199 205 kr |
| Net Benefits per ha | - 38 462 kr | 1 532 kr | 1 532 kr | 1 532 kr | … | 1 532 kr |