Contribution to Climate Change of a Proposed Horse Manure Composting System

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Bachelor thesis 15 hp in Environmental science

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Degree programme: Ecotechnology 180 hp
Main area: Environmental science
Semester, year: Spring, 2017
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Abstract

Horses produce feces and urine and this mixed with a bedding material such as sawdust or cutterdust gives you horse manure. Hippologum is an equestrian facility in Umeå (county of Västerbotten, Sweden) which produces 20-25 tons of manure per week and when this report was written the facility had some trouble to get rid off the manure. This was in Spring 2016.

The aim of this study is to look into the possible soil improver production as a management strategy for the horse manure produced at Hippologum and the report also looks into which part of this proposed system which has the greatest climate impact. The landfill- and waste center Dåva DAC (also located in the county of Västerbotten, Sweden) is the assumed receiver of the manure, and this is were the manure would be refined (composted). Research based on personal interviews about the manure market in Umeå municipality as well as a short chapter about legal aspects of manure are also included in the report.

According to the screening LCA conducted during this thesis work the greatest impact for 23 tons of horse manure from Hippologum to Dåva DAC is the cultivation of the fodder. The report cannot conclude if there is a manure market in Umeå municipality. Concerning the legal aspects it can be said that the European Union has well developed legislation concerning animal by-products and regulates many aspects of handling and treating of horse manure.

Keywords: Screening LCA, climate change contribution, GWP 100, horse manure

Sammanfattning

Hästar producerar gödsel som är en blandning av avföring, urin och det strömaterial som hästarna står på. Hippologum är en ridanläggning i Umeå (Västerbotten, Sverige) som producerar 20-25 ton gödsel per vecka och när denna rapport skrevs hade anläggningen ingenstans att lagra gödseln. Detta var våren 2016.

Målet med denna studie var att undersöka ett möjligt förvaltning- och komposteringssystem för hästgödsel mellan Hippologum och deponi- och avfallscentret Dåva DAC (som också är beläget i Västerbotten, Sverige) och var systemets största klimatpåverkan finns. En liten marknads-undersökning baserad på personintervjuer och ett kort kapitel om lagaspekter finns också med i rapporten.

Enligt den screening livscykelanalys som genomfördes inom ramen för denna C-uppsats är den största klimatförändrande effekten för 23 ton hästgödsel från Hippologum till Dåva DAC odlingen av fodret. Marknadsundersökningen som utfördes kan inte direkt säga att det finns en marknad i Umeå kommun för komposterad hästgödsel. Gällande den lagliga biten så kan sägas att EU har mycket att säga till om gällande animaliska biprodukter och att den lagliga aspekten tyckts vara väl utvecklad.

Nyckelord: Screening LCA, bidrag till klimatpåverkan, GWP 100, hästgödsel

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1. Introduction

1.1. Horse manure and composting

According to the Swedish Board of Agriculture (SBA) there was an estimated number of 362 700 horses in Sweden in 2010. 74 % of these could be found in a town or the countryside near a town (SBA, 2012a). The number is an increase by 10-20 % compared with 2004, when SBA also made a similar estimate of the number of horses in Sweden (Braam, 2011).

Horses produce manure which is a mixture of feces, urine and a lot of bedding material. A full-sized horse produces about 8-10 tons of manure per year (Hästsverige, 2016). So what do horse owners do with all this manure? In 2010 more than 60 % of the horse keepers in Sweden could spread manure on their own fields, 30 % had agreements with farmers who took care of the manure and the remaining ten percent were letting someone who is not a farmer collect the manure. There were also a few horse owners who were refining and selling the manure (SBA, 2012a).

There are other ways for a horse business to remove the manure from the facility than the ones mentioned above. If no farmer can receive the manure, riding schools can pay to let a company that produces soil improvers or plant soil, burns manure for energy or produces bio-gas collect it. There are also examples where the horse manure is used experimentally in the cleanup of oil-contaminated soil to break down the oil (SBA, 2013d).

Horse manure can become more attractive to plants if it is composted, since this reduces the amount of bedding material which otherwise might take up nitrogen from the soil and leave less for the plant. The most important plant nutrients are nitrogen (N), phosphorus (P) and potassium (K) (Steineck et. al, 2000). A common way to compost waste is in windrows, so called windrow composting (Avfall Sverige, 2015). Horse manure can be composted using this technique, but usually some kind of carbon-rich structuring material like crushed garden waste is added. The windrows are turned occasionally depending on how the compost process is proceeding and how much time the composting is allowed to take[1].

1 Torbjörn Ånger, Project leader at VafabMiljö, interview by telephone 7th of April 2016.

Horse manure is an animal by-product and therefore there are legal aspects involved, for example according to the EU regulation on animal by products (EU 2011; SBA 2014b) the whole manure mass composted must reach 70 °C during at least one hour or 52 °C during 13 hours to be allowed on the market. This is one reason why the rotary drum compost is used as the composting technique in this study, it is a more controlled way of composting horse manure compared to windrow composting. This study actually uses a rotary drum compost which is approved by the SBA, which means that after the composting process the horse manure is allowed to be sold to wholesalers and consumers. A second reason is that the rotary drum showed promising results in an experiment conducted by Rodhe et. al (2015). In that experiment three percent of the nitrogen left the manure during the composting stages. This can be compared to the fact that in a windrow experiment using straw as bedding 11,2 % of the total nitrogen was lost as ammonia (Steineck et. al, 2001).

1.2. About Hippologum

Hippologum is a non-profit association that manages one of largest equestrian facilities in Sweden (with the same name as the association). The Hippologum facility is located outside the city of Umeå. According to Eva Ranered[2], approximately 120 horses are stabled here. About 75 horses are so called “member horses” owned by private individuals and about 45 horses belong to the riding school. Member horses are mostly full-sized horses, but in terms of the riding school horses half of them are ponies. The horse boxes use mostly sawdust and cutterdust (also called wood shavings or just shavings) as bedding material.

According to Ranered, Hippologum generates 20-25 tons of horse manure per week and the facility has nowhere to store the manure, therefore it is transported two or three times a week to their neighbor Forslundagymnasiet. Forslunda is an agricultural college and is spreading 70 % of the horse manure on their fields, the rest is being windrow composted[3].

1.3. About Dåva DAC

Dåva industrial landfill started in 1974, but the municipal company Dåva DAC (short for Dåva landfill- and waste center) was formed in 2013. Dåva DAC is located outside the city of Umeå.

2 Eva Ranered, Purchaser at Hippologum, interview at study visit 19th of April 2016.
3 Stig Rönnlund, Manager at Forslundagymnasiet, mail conversation started 18th of May 2016

The waste accepted at the center includes waste and biomass ash, contaminated soil, waste products from industry, landfill waste from households and businesses, asbestos and sulphide (Dåva DAC, 2016). Examples of Dåva DAC´s customers are incinerator facilities, municipal recycling centers and recycling companies like Stena, RagnSells and IL. Other possible customers are industries, municipalities and construction companies leaving waste from different remediation projects[4].

1.4. Purpose for this study

The purpose of this study is to look into the possible soil improver production as a management strategy for the horse manure produced at Hippologum. The landfill- and waste center Dåva DAC is the assumed receiver of the manure, and this is were the manure would be refined (composted).

The questions to answer during the study are:

- Which part of the theoretical horse manure composting system has the greatest impact on climate change when it comes to emissions of the green house gases (GHG) carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O)?
- Is there a market for composted manure in Umeå municipality?
- How well developed is the Swedish and European legislation when it comes to composted manure?

The report looks into which part of the proposed which has the greatest climate impact and how this impact can be reduced. This is done using a screening life cycle assessment (LCA). Another purpose for this study is to find out if there really is a market for composted horse manure in Umeå municipality and how the legislation around horse manure is handled, therefore research based on personal interviews about the manure market in Umeå municipality is included as well as a short chapter about legal aspects of manure. The market study is specific for Umeå municipality, the legal chapter is general and aims to just give a hint of how well developed the legislation concerning horse manure is and how much it would take for a company like Dåva DAC to set up a composting system.

4 Gustaf Sjölund, Market director at Dåva DAC, presentation at study visit 23:rd of April 2015.

2. The proposed horse manure composting system for Hippologum

2.1. Fodder cultivation

The hay is bought from two villages in Västerbotten called Estersmark and Vebomark which are located 78 respectively 88 km from Hippologum. The hay is assumed to be cultivated and dried somewhere near these two villages. Silage is also bought from Västerbotten. The silage suppliers are located in Degernäs and Nordmaling, 16 respectively 63 km from Hippologum. The silage is assumed to be cultivated and fermented somewhere near Degernäs and Nordmaling. Hippologum consumes about 2,4 tonnes of hay and 5,6 tonnes of silage per week.

2.2. Sawdust and cutterdust

Sawdust is a by-product in the production of sawn and planed wood at a sawmill in Brattby (Brattby Sågverks AB, 2016) which is located 22 km from Hippologum. The cutterdust is also a by-product, but it is produced in Sävar and Kramfors. Sävar is located 21 km and Kramfors 201 km from Hippologum. Hippologum consumes about 7,7 m^3 sawdust and 38,5 m^3 cutterdust per week. The study allocates the emissions from production of sawdust and cutterdust to the actual products produced by the sawmills.

2.3. Manure production

When the fodder has been brought to Hippologum it will eventually be eaten by a horse, digested and in the end leave the horse as manure. Sooner or later the manure end up at the Hippologum dunghill. Since all manure is assumed to be released in the stables or near the dunghill, spillage is not taken into account. Spillage here meaning manure that is released when the horse owners are out riding or manure that is too contaminated with gravel from the paddocks.

2.4. Composting

After a 14 km transport from Hippologum to Dåva, the manure is assumed to go through the following stages: precomposting, composting in a rotary drum and curing.

2.5. Transports

All fodder and bedding is assumed to be transported the shortest way possible to Hippologum. The same goes for the manure transport from Hippologum to Dåva DAC.

3. Methodology

3.1. Methods used for this study

Life cycle assessment (LCA) is the method used for answering the research questions about the proposed system´s climate impact. Chapter 3.2 below covers the LCA-parts of this study. When it comes to the market study based on Umeå municipality personal interviews through mail conversation and telephone was used. The legal chapter is based on information found mostly on the website for the Swedish Board of Agriculture (SBA).

3.2. Life cycle assessment in general

Life cycle assessment (LCA) is a method used to follow a product from cradle to grave when it comes to parameters like resource use, energy use and emissions. The cradle is usually resource extraction, the grave when the product has served its purpose and is sent to disposal. A product can also be followed from cradle to gate. The gate is often the gates of an industry refining the raw material and even though the product will leave the industrial site no more parameters are added to the product's environmental burden. An LCA usually consists of four parts which are goal and scope definition, inventory analysis, environmental impact assessment and interpretation (Baumann & Tillman, 2004).

3.3. Goal and scope definition for the screening LCA

The goal is to study the potential management and composting system of horse manure between Hippologum and Dåva.

In order to answer the first research question presented under topic 1.4 Purpose for this study a screening LCA was conducted. A complete LCA would have been too time-consuming and voluminous to fit into this thesis work, therefore a screening LCA was conducted. A screening LCA can still identify the most important aspects of the studied system.

3.3.1. Studied function and functional unit

This screening LCA is of the accounting type as well as prospective, because it studies a non-existing system. The functional unit is 23 tons of horse manure. This was the average manure produced per week at Hippologum in Spring 2016 according to Åsa Hagner[5].

This study aims to investigate horse manure from cradle to gate. Cradle was defined as production of bedding and fodder for the horses and gate was defined as composted manure at Dåva DAC. See Figure 1 below for a simplified flow chart over the life cycle modeled. The study not only contains the conducted screening LCA , but also a small market research on composted horse manure in Umeå municipality as well as legal aspects of manure handling and composting. The manure market in Umeå municipality is an interesting part since it might give some clues if there could be a business idea for a company like Dåva DAC to refine and sell some of the weekly tonnes of horse manure. As mentioned previously the laws about selling animal by-products to consumers is quite well regulated, therefore a small chapter on what a company must do to get approval from the SBA is included in this report.

5 Åsa Hagner, Coordinator Institutionen för skoglig resurshushållning SLU, mail contact 20th of April 2016

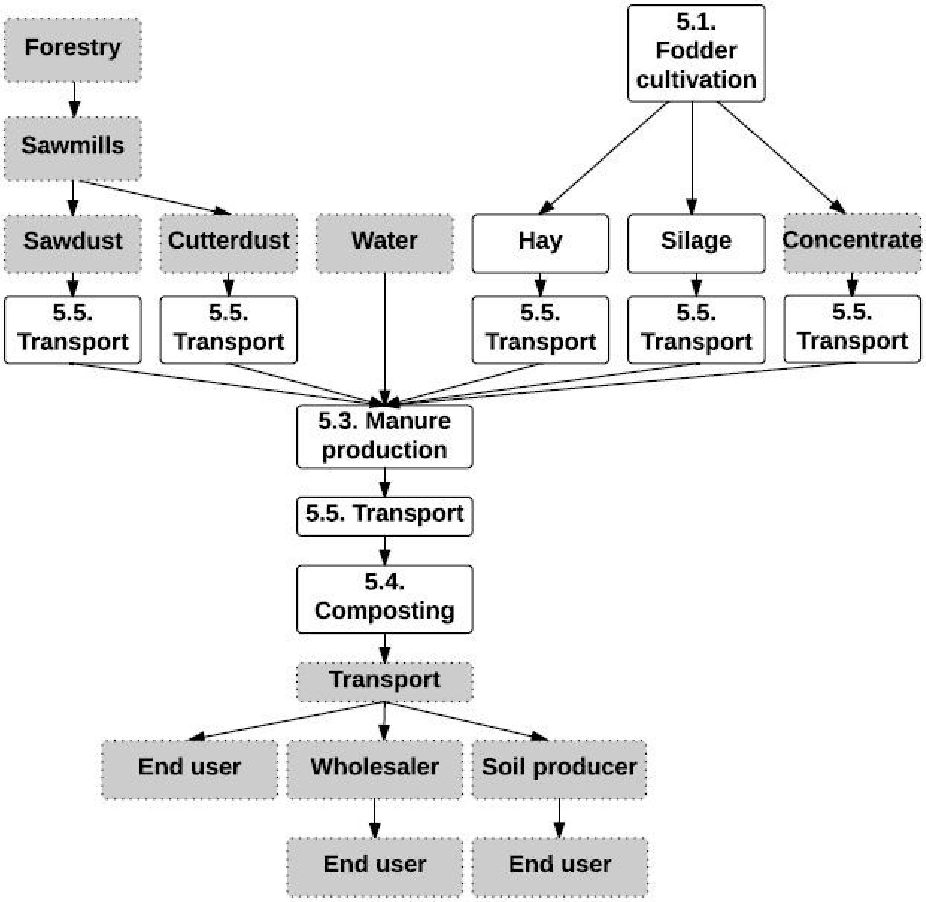

Figure 1. A simplified flowchart of the life cycle of horse manure from cradle to gate. Grey boxes are products or activities not included in this study. The numbers infront of some boxes are references to chapter 5 "Life cycle inventory of the proposed system".

3.3.2. System boundaries

The geographical boundaries are set to the north of Sweden. Only activities from the counties of Gävleborg, Jämtland, Västernorrland, Västerbotten and Norrbotten are included. According to Cederberg et. al (2007) most of the grain and sugar beets used in cow concentrate fodder are produced in the southeastern part of Sweden. In this study it is assumed that this is also true for horse concentrate fodder, corn and oats. Therefore this production is not included, only the transport of it. Fodder in the form of hay and ensilage is included, since this production takes place in the north of Sweden.

Hippologum is using about 1,3 ton of a special compacted sawdust per month as bedding material but only the standard sawdust is included in the study. Water needs to be added to the special compacted sawdust before it can be used. Other excluded activities are water use, production of bedding, plastic around fodder, buildings, farming machines used at Hippologum for manure handling, emissions from fodder digestion and the vegetable waste that is assumed to be mixed with the horse manure in the rotary drum compost.

Information about Hippologum is mostly from year 2015 to 2016, so the theoretical system should not be too far ahead in time since things might change when it comes to the amount of manure generated. 2018 as a start year for the composting is therefore assumed.

3.3.3. Data

The quality of the information on the location of fodder suppliers, bedding suppliers and manure production per week at Hippologum is considered good. The sources are two women (Åsa Hagner and Eva Ranered) who know the Hippologum organization very well.

The data used in this report comes from various sources. Emissions from fodder cultivation (Flysjö et. al, 2008) are considered to be the most reliable sources for this study of a theoretical system since it is actually called a LCA database and the data is based on more horse farms compared to the data used in the study by Hushållningssällskapet Halland (2011). But since the study by Hushållningssällskapet Halland was based on Swedish horse farms it was used as a data source. When it comes to the data on rotary drum composting the data. There are two large assumptions that has been made during this thesis work which will affect the result a great deal in bringing along much uncertainty. The first one is that silage and hay have the same dry weight, see calculations in Table 2. The second one is for the composting in the rotary drum compost, a 50% reduction of the material is assumed.only contains measurements from two different rotary drum composting systems. Only data from Wiggeby farm was used since this farm used 90 % horse manure in their compost, the other farm in the experiment conducted by Rodhe. et al (2015) only used 60 % horse manure. The remaining percentage was cattle and pig manure. It can be argued that the data quality would have been better if the data had been on more farm experiments, but for this report it is good enough.

There are two large assumptions that has been made during this thesis work which will affect the result a great deal in bringing along much uncertainty. The first one is that silage and hay have the same dry weight, see calculations in Table 2. The second one is for the composting in the rotary drum compost, a 50% reduction of the material is assumed.

3.3.4. Characterization methods

This study uses Global Warming Potential over a 100 year time horizon (GWP 100). The greenhouse gases studied are carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). In order to compare the different gases, they were characterized so that all were measured in gram or kilograms CO_2-equivalents (CO_2-eq).

GWP is how much infrared absorption a gas causes in the atmosphere measured in comparison to carbon dioxide. One kilogram carbon dioxide therefore have a GWP of one. Methane on the other hand has a GWP of 25, which means that releasing one kilogram of methane has the same effect on global warming as 25 kilograms of carbon dioxide. In other words, it is a measure of how much the gases can absorb infrared radiation and heat the atmosphere (Baumann & Tillman, 2004).

3.3.5. Allocation

All climate impacts studied are allocated to the final soil improver product which is composted horse manure. This study does not take into account that the horses are held for business or recreational purposes, they are seen as manure producers and nothing else.

The study also allocates the emissions from production of sawdust and cutterdust to the actual products produced by the sawmills. Therefore only transport of the bedding material is taken into account.

4. Results

4.1. Screening LCA climate impacts

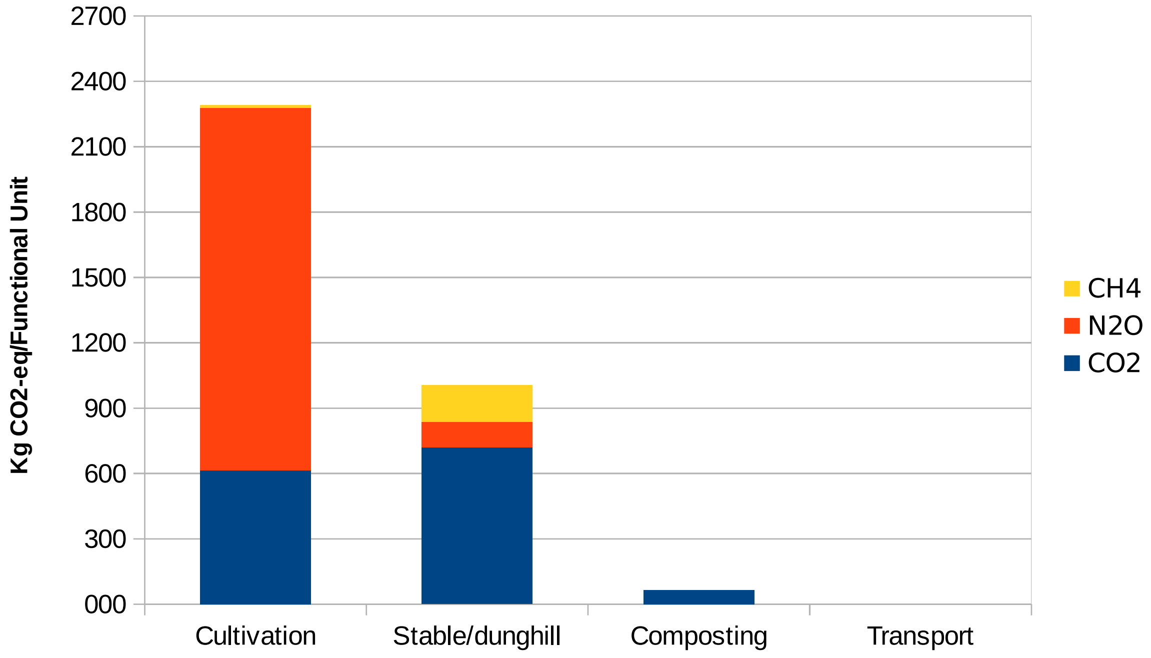

Figure 2. Emissions contributing to climate change in kilograms CO_2-eq per functional unit (FU). The functional unit was 23 tons of horse manure.

As can be seen in Figure 2 above and Table 1 below the greatest impact for 23 tons of horse manure from Hippologum to Dåva DAC is the cultivation of the fodder. About 2 300 kilograms CO_2-eq is estimated to be released to the air as the weekly fodder for Hippologum is produced. Silage on its own stands for about 1 600 kilograms CO_2-eq and hay stands for 600 kilograms CO_2-eq, this can be seen in Table 2 as well.

Table 1. Data used to create Figure 2.

	Cultivation	*Stable/dunghill*	*Composting*	*Transport*
CO2	613,86		720,00	64,34
N2O	1 663,89	116,56		
CH4	13,23	167,60		
Sum each activity	*2 290,98*	*284,16*	*720,00*	*64,34*
Total sum all activities	*3 359,48*			

All activities of the manure composting system stand for about 3 360 kilograms CO_2-eq all together. Subtracting the emissions from cultivation gives that the other activities contributes with 1 068 kilograms CO_2-eq.

4.2. Research on the manure market

In order to start a manure composting system like the proposed one described in this study there must be a market for the final product. The main issue with horse manure and the reason for the low interest for non-treated horse manure is the high bedding content (SBA, 2013d). But is there a market for composted horse manure in Umeå municipality?

Rönnlund[6] and Holmström[7] think that if horse manure was treated in some way (composted for example) to make it less filled with bedding there could possibly be a market for it. Rönnlund also thinks that if the price is right it does not really matter to the customer if the product is composted manure or a ready-made soil mixed with horse manure. An example of this can be seen in Vetlanda[8], here 100-120 tons of horse manure is composted together with crushed garden waste and given away to the municipal inhabitants for free. It is very popular and simple for people who visit the recycling center to throw away large items and later use their trailers to pick up some kilograms of compost on their way out. It can be assumed that if the composted horse manure was given away for free (the only cost for the customers would be to collect it at Dåva DAC) it would find its way to the gardens of Umeå 's inhabitants.

According to Rönnlund, Forslundagymnasiet in Umeå produced 3 000 tons of soil in 2015, in which horse manure was a component, and Umeå municipality actually received some of it. The municipality have asked for more soil to use in their parks and outdoor areas. But the questions remain of how much more soil is needed and if Forslundagymnasiet can produce more due to legal issues (see topic 4.3 Legal aspects of manure).

6 Stig Rönnlund, Manager at Forslundagymnasiet, mail conversation started 18th of May 2016
7 Micael Holmström, Park manager at Umeå municipality, interview by telephone 26th of April 2016
8 Mats Fasth, Vetab, mail contact 31st of March, interview by telephone 15th of April 2016

4.3. Legal aspects of manure

Since horse manure is an animal by-product there are some legal aspects involved. This last part of the study will answer the question how Hippologum and Dåva DAC must work to be allowed to sell the composted manure on the market. First of all, it should be clarified that it is fully legal to receive manure from a horse owner and spread it in your own garden or fields. The manure is then counted as “untreated”, but if Dåva DAC want to sell it to a wholesaler or a private person the manure must be treated and here is where the legal aspects enter the arena.

When it comes to manure, it is the legislation on animal by-products (ABP) that has to be followed (European Union 2009; European Union 2011). Among other things these regulations state that the material must be hygienized. All material must reach 70 °C in at least one hour so that pathogens are killed. Facilities handling and treating ABP must be approved by SBA. SBA will then check the whole process of the manure from handling to treatment and to a market-ready product.

After manure has been collected there are requirements on the storage area, for example it must be located on a safe distance from larger roads and other facilities. This is because no contamination is allowed to occur. The storage area must also be easy to clean, disinfect and have proper protection against pests (birds, insects, rodents). The vehicles transporting the manure might also need cleaning and disinfection (SBA, 2014b).

Organic fertilizers like composted manure and soil improvers, in which manure can be a part, must be stored or transported in a bulk and under appropriate conditions to prevent contamination. It must also be packaged or put in big bags if the purpose is to sell it to end users (SBA, 2014b).

5. Life cycle inventory of the proposed system

Here follows a life cycle inventory on the emissions of CO_2, N_2O and CH_4 from the theoretical horse manure composting system. The same subtopics as in chapter 2 “The proposed horse manure composting system for Hippologum” are used.

5.1. Fodder cultivation

Data on conventional grassland farming was collected from Flysjö et. al (2008). This LCA database assumes that the grassland farming looks the same for hay and silage. The grass studied in this database is 100 % grass, a three year ley, harvested twice per year and is located in the western parts of Sweden (Västra Götaland). The calculations in this database are done using guidelines from IPCC (IPCC, 2006). Emissions from direct energy use from farm machines, drying and handling of the grass, application of fertilizers and cattle manure are included.

Table 2. Conventional cultivation emissions from hay and silage in gram CO_2-eq. Collected from Flysjö et. al (2008).

Hay	**Kg/week**	**Kg in DM (0.8)**	**g CO2-eq/kg DM**	**g CO2-eq**
CO2	2 423,08	1 938,46	74,60	144 609,23
N2O	2 423,08	1 938,46	258,25	500 598,00
CH4	2 423,08	1 938,46	1,83	3 547,38
Sum hay			*334,68*	*648 754,62*
Silage	**Kg/week**	**Kg in DM (0.8)**	**g CO2-eq/kg DM**	**g CO2-eq**
CO2	5 634,62	4 507,69	104,10	469 250,77
N2O	5 634,62	4 507,69	258,07	1 163 291,59
CH4	5 634,62	4 507,69	2,15	9 682,52
Sum silage			*364,32*	*1 642 224,88*
Sum hay+silage g CO2-eq				*2 290 979,50*
Sum kg CO2-eq				*2 290,98*

The database Flysjö et. al (2008) was used for the calculations in Table 2. The database showed emissions in gram CO_2-eq/kilogram dry matter (DM) for two types of ley. Type one was 100 % grass and type two 75 % grass + 25 % clover. Type one (100% grass) was used for the calculations in this study. Data on the yearly hay and silage consumption at Hippologum was provided by Eva

Ranered[9] and can be found in Appendix A. The yearly average was divided by 52 to get the weekly average.

As seen in Table 2 conventional cultivation of one week´s hay consumption at Hippologum will emit about 649 kilograms CO_2-eq. The weekly silage consumption will emit about 1 642 kilograms CO_2-eq. The total sum is about 2 291 kilograms CO_2-eq.

<u>Example: Calculation on N_2O for hay cultivation</u>

Hippologum consumes 2 423,08 kg of hay per week. 2 423,08 kg multiplied with 0,8 equals 1 938,46 dry matter hay per week. 1 938,46 kilograms dry matter multiplied by 258,25 g CO_2-eq/kg DM equals 500 608,33 g CO_2-eq per week (about 501 kg CO_2-eq). Note that more decimals have been used than can be seen in Table 1, therefore this calculation example differs a bit from the table above.

The database also showed emissions for one way of handling/drying hay and three different ways of making silage (as round bale, in silo and in tower silo). For hay emissions, 100 % grass plus handling/drying were added together, see Appendix A and Table B for specific numbers. This emission value was then multiplied with 1 938,46 kilograms. 1 938,46 is the amount of hay in kilograms dry matter Hippologum consumes per week. More about calculations on dry matter will follow. The same goes for silage emissions, 100 % grass plus round bale were added together.

Flysjö et. al (2008) has performed calculations so that it is assumed the hay/silage is 100 % dry matter, but hay and silage is not 100 % dry matter in reality. Therefore to find out how much dry matter Hippologums fodder contains, the weekly hay/silage consumption in kilograms was multiplied with the average dry matter content of 0.8 for hay (Hästsverige, 2015). Dry matter 0.8 means that 80 % of the hay is dry matter and 20 % is water. The same was assumed for silage and this assumption will affect the end result when it comes to uncertainty.

5.2. Sawdust and cutterdust

Sawdust and cutterdust are considered to be by-products of different sawmills. Therefore, only transport emissions from sawmills to Hippologum are allocated to sawdust and cutterdust.

9 Eva Ranered, Purchaser at Hippologum, interview at study visit 19th of April 2016.

5.3. Manure production

Data on methane and nitrous oxide emissions from the manure when it has left the horse and been put on a dunghill was collected from Hushållningssällskapet Halland (2011). This data should be used carefully since it is based on a small number of horse farms. The amount of methane that manure releases to the air depends on the storage time and how the manure is composed. Hushållningssällskapet Halland have based their calculations on the guidelines provided by the IPCC (IPCC, 2006) and a stable manure database created by SBA.

Table 3. Calculations on emissions from stable and dunghill from the estimated number of horses at Hippologum. Data collected from Hushållningssällskapet Halland (2011).

Kg gas/horse and year			
Horse type	***CH4***	***N2O***	***Average horse weight***
Riding school (RS) horse	3,7	0,22	500-550 kg
Pony	2	0,11	300 kg
Private horse	2,9	0,17	500 kg
Per horse, kg emission/week			
Horse type	***CH4***	***N2O***	
RS horse	0,0712	0,0042	
Pony	0,0385	0,0021	
Private horse	0,0558	0,0033	
Total kg emission/week			
Horse type	***CH4***	***N2O***	
23 RS horses	1,64	0,10	
23 ponies	0,88	0,05	
75 private horses	4,18	0,25	
Sum emissions in kg	*6,70*	*0,39*	
Total kg CO2-eq/week			
	CH4	***N2O***	***Sum kg CO2-eq***
Sum emissions in kg	*6,70*	*0,39*	
GWP 100	*25,00*	*298,00*	
kg CO2-eq	*167,60*	*116,56*	*284,16*

Emissions are depending on the weight and work load of the horse and, as seen in Table 3, a riding school horse is assumed to emit almost the double amount of methane compared to a pony.

First, the yearly emissions were divided by 52 to get the weekly average. Then the number of riding school horses, private horses and ponies was multiplied with the weekly average and that gave a kilogram/week value for methane and nitrous oxide from the manure released by the horses and when it is lying on the dunghill. These numbers were multiplied with the GWP 100 for methane and nitrous oxide, giving a value in kilograms CO_2-eq per week. In this case the number was that about 284 kilograms CO_2-eq per week.

5.4. Composting

The emissions from the composting experiment conducted by Rodhe et. al in 2015 were used to calculate what the theoretical manure system would release when it comes to gases contributing to climate change. A simplification was made in assuming that the time for pre composting, the rotary drum composting and the curing would be just like in the experiment. The waste mix was also assumed to be the same, 90 % horse manure and 10 % vegetable waste.

For the composting, a reduction of 50 % from the original weight was assumed. 23 tons divided by two equals about 12 tons. Rodhe et. al (2015) found that 60 kilograms CO_2-eq per tonne compost was released if they had a combined heat exchanger and ammonia trap before (or after) the measuring point. 12 ton composted manure times 60 kilograms CO_2-eq equals 720 kilograms CO_2-eq during all composting stages. 60 kilograms CO_2-eq per tonne compost is one of two results from the study by Rodhe et. al (2015) and it is the larger one. It was used for the calculations on the theoretical system because it was, like already mentioned, larger and because it measured emissions from the curing after several more days. The other result (which was not used in this study) measured emissions after fewer days.

5.5. Transport

The distances used in the calculations in Table 4 are the shortest distances showed on Google Maps. The information about the distances to all the different suppliers were collected from Eva Ranered[10] through personal contact. For transport emissions data from Nätverket för Transporter och Miljön (NTM) through Baumann & Tillman (2004) was used. A truck with a semi-trailer of environmental class Euro 2 emits about 52 g/tkm (gram per tonne kilometer) CO_2.

10 Eva Ranered, Purchaser at Hippologum, interview at study visit 19th of April 2016.

Table 4. Transport emissions. Data used for calculation climate change contribution when it comes to transports per week.

	Km	Ton	Tkm	g CO2/tkm	g CO2
Fodder (start location)					
CO2 (Estersmark)	78,00	0,31	24,00	52,00	1 248,00
CO2 (Vebomark)	88,00	2,12	186,15	52,00	9 680,00
CO2 (Degernäs)	16,00	0,92	14,77	52,00	768,00
CO2 (Nordmaling)	63,00	4,71	296,83	52,00	15 435,00
CO2 (Holmsund)	27,00	0,52	14,02	52,00	729,00
Sum fodder	*272,00*	*8,58*	*2 332,92*		*27 860,00*
Bedding (start location)	**Km**	**Ton**	**Tkm**	**g CO2/tkm**	**g CO2**
CO2 (Brattby)	22,00	1,08	23,69	52,00	1 232,00
CO2 (Kramfors)	201,00	1,35	270,58	52,00	14 070,00
CO2 (Sävar)	21,00	4,04	84,81	52,00	4 410,00
Sum bedding	*244,00*	*6,46*	*379,08*		*19 712,00*
Manure (start location)					
CO2 (Umeå)	14,00	23,00	322,00	52,00	16 744,00
Sum manure	*14,00*	*23,00*	*322,00*	*52,00*	*16 744,00*
Sum all transports in g CO2					*64 316,00*
Sum in kg CO2					*64,316*

Using information about how many tonnes of bedding and fodder Hippologum are purchasing per year the average tonne per week was calculated. Basic fodder like hay and silage from different suppliers was calculated separately since it was known from which village they came. Fodder like corn, oats and concentrate fodder comes from a wholesaler in Holmsund, therefore all tonnes were added together.

The total tonnage of bedding and fodder that Hippologum per week plus the tonnage of manure generated (in this case 38,04 tonnes) were multiplied with the total kilometers that the products were assumed to be transported in the theoretical system. This gave a value in tonne-kilometer. After that data (see Table 4 above) on emissions per gram CO_2/tonne-kilometer for a truck with a semi-trailer of environmental class Euro 2 from NTM through Baumann & Tillman (2004) was used to find out the gram CO_2 emitted. The final answer was that 64 kilograms CO_2 is emitted during the whole life cycle of 23 tons of horse manure.

6. Discussion

The fact that fodder cultivation, with about 2 300 kilograms CO_2-eq for a week´s fodder consumption, is the largest contributor to climate change might make you think that there is not much Hippologum can do about it. However businesses that rely on other businesses can chose to make demands or in some cases chose another product or service that fits their needs better. If there was a way for Hippologum to know which farmers who are using the least amount of mineral fertilizer, the most efficient machines for handling and drying maybe this could give some guidances in the choosing of fodder?

How about changing to organic fodder you might ask yourself? Just changing to organically grown fodder would probably not be an option since this crop has a lower yield (Hushållningssällskapet Halland, 2011) and therefore the climate impact might not be reduced, even though no mineral fertilizers are applied on the crop. The emissions per kilogram product might still be high and from a life cycle perspective this makes it hard to recommend a change to organically grown fodder.

Something interesting Hushållningssällskapet Halland (2011) claims is that ley with clover has relatively high yield and according to Flysjö et. al (2008) conventional ley with 25 % clover emits less kilogram CO_2-eq compared to a conventional 100 % grass ley. This study cannot conclude if it would be an idea to change to fodder with a higher clover content, it has to be investigated further. It is also a question about the health of the horses, would eating more clover be healthy for all types of horses?

The result of the small market research on composted manure in Umeå municipality cannot for sure conclude if there is a market for composted horse manure, but it gave a hint that it might have a market since the municipality have asked Forslundagymnasiet for more soil. However many questions remains to answered. For example: How much composted manure per week is mixed with the soil? Can 12 tons of composted manure can be mixed into the soil and is there a need for this amount of soil? And if yes, does Forslundagymnasiet have the capacity to produce this amount, assuming all legal aspects are managed?

The legal aspect of manure which this study investigated showed that the legislation is quite well developed when it comes to organic fertilizers and animal by-products. Especially the EU legislation has a lot to say about how things should be handled. If a company like Dåva DAC would be interested in taking care of some of the weekly tons of horse manure and sell it to consumers the technique studied in this report is recommended. Like mentioned before, the technique is approved by the SBA and complies with the EU legislation on how animal by-products must be hygienized to be allowed on the market. But since the manure market in Umeå municipality was tricky to get a grip on, this report cannot conclude if there actually is a demand for composted horse manure among the Umeå inhabitants.

There is a great amount of uncertainty in the answer on how many kg CO_2-eq that are released during the life cycle of 23 tons of horse manure from Hippologum to refining at Dåva DAC even though Table 2 gives rather exact numbers. 2 291 kg CO_2-eq are therefore rounded up to 2 300 in the report text.

7. Conclusion

According to the screening LCA conducted during this thesis work the greatest impact for 23 tons of horse manure from Hippologum to Dåva DAC is the cultivation of the fodder. The report cannot conclude if there is a manure market in Umeå municipality. Concerning the legal aspects it can be said that the European Union has well developed legislation concerning animal by-products and regulates many aspects of handling and treating of horse manure.

8. Suggestions for future studies

8.1. Scenarios

Different scenarios in the screening LCA would have made it more interesting. For example, one scenario using only organic fodder instead of conventional since the fodder cultivation made the largest contribution to climate change.

A second type of scenario could have been to compare rotary drum composting with different types of windrow composting and include every type of composting technique´s energy and water use. Even though drum composting emits less green house gases it would have been interesting to compare this technique with “ordinary” windrow composting and perhaps force aerated and covered windrow composting. Ordinary windrow compost will use a small amount of energy only when the windrows are turned by a machine, but a rotary drum compost will itself use energy every second. More data added to each technique would hopefully made it possible to compare the techniques in a fair way.

A third scenario could have been where only compacted sawdust was assumed to be used as bedding since SCA claims in a commercial that this product will make the manure less filled with bedding. But on the other hand it takes ten liters of water to use 14 kilograms of this product, so how would including this water use change the environmental impact of the manure composting system? Right now it would be difficult to perform calculations on this third type of scenario since compacted sawdust seems to be quite new to Hippologum, so perhaps the product overall is quite young. Therefore, it might be problematic to estimate how much of the manure actually is bedding. When it comes to common bedding materials, SBA (2013) claims that in worst case up to 90 % of horse manure is bedding, so there is definitively room for improvements in the area of bedding content in the manure.

8.2. Market survey

It would have improved the market research if a market survey had been conducted. A simple questionnaire could have been sent out to businesses selling soil as well as soil producers, for example asking about how much packaged manure they are selling in Umeå.

8.3. Economy

This study does not consider any economical aspects at all, but it would have been interesting and made the study more useful if the economy of rotary drum composting had been included. If the market research had found some trustworthy source on how much an average consumer in Sweden is ready to pay for manure the basic question of "How much manure must be produced in order to reach break-even after investing in a rotary drum composting system?" would have been answered.

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Appendix A

Table A. Data on the yearly tonnes of hay and silage consumed at Hippologum, who is supplying it and the distance between the supplier and Hippologum. Source is Eva Ranered[11].

	Ton/year	*Ton/w*	*Supplier (location)*	*Km to Hippologum*
Fodder				
Oats	6	0,115384615	Fodercentralen (Holmsund)	27
Corn	3	0,057692308	Fodercentralen (Holmsund)	27
Concentrate	18	0,346153846	Lantmännen (Holmsund)	27
Sum	*27*	*0,519230769*		
Basic fodder hay	***Ton/year***	***Ton/w***		
Hay	110	2,115384615	Alltjänst (Vestersmark)	88
Hay	16	0,307692308	Wallgren (Estersmark)	78
Sum hay	*126*	*2,423076923*		
Basic fodder silage	***Ton/year***	***Ton/w***		
Silage	245	4,711538462	Acc foder (Nordmaling)	63
Silage	48	0,923076923	Andreas Martinsson (Degernäs)	16
Sum silage	*293*	*5,634615385*		
Total sum all fodder	*446*	*8,576923077*		*272*

Ton per week have have been calculated for use in Table 1 and Table 3 in the report. The supplier can also be found in this table and also the kilometers from the supplier to Hippologum. This distance was found using Google Maps and it is not known if the transporting vehicle is actually driving the shortest way possible.

Table B. Data on fodder cultivation. Source is Flysjö et. al (2008).

	Grass	*Hay*	*Round bale*	*Grass+Hay*	*Grass+Round bale*
CH4	1,44	0,39	0,708	1,83	2,15
N2O	258,00	0,245	0,0681	258,25	258,07
CO2	57,40	17,2	46,7	74,60	104,10

Data used for calculations can be seen in Table B and the data itself can be found in Flysjö et. al (2008), page 83. The emissions are in gram CO_2-eq/Functional unit. The functional unit in this case was one kilogram of dry matter basic fodder (hay or silage).

11 Eva Ranered, Purchaser at Hippologum, interview at study visit 19th of April 2016.