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GREENHOUSE GAS EMISSIONS
IN ANIMAL FEED PRODUCTION

DECISION SUPPORT FOR CLIMATE CERTIFICATION

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CONTENTS

1 INTRODUCTION

Feed production is very important for total emissions of greenhouse gases in the life cycle of animal feed. For eggs, chicken and pork, it usually constitutes 60-80% of emissions up to the farm gate, for milk and beef 35-45%. It makes up a relatively smaller proportion for ruminants because methane from feed digestion comprises the dominant fraction of total emissions for milk and beef.

Fossil carbon dioxide (CO_2) and nitrous oxide (dinitrogen oxide, N_2O) are the completely dominant greenhouse gases in animal feed production. CO_2 comes from the use of fossil fuels, particularly diesel in tractors and harvesting machinery, oil in dryers and natural gas in the manufacture of mineral fertiliser nitrogen. In the post-farm stages, CO_2 is emitted in conjunction with various feed processes, with drying being important, and in transport. Nitrous oxide is lost from arable soil when nitrogen is metabolised in the soil, a process known as direct emission. Losses of reactive nitrogen (ammonia and nitrogen leaching from arable soil) from the agricultural system lead indirectly to other ecosystems emitting N_2O, since increased nitrogen deposition leads to increased N_2O emissions (indirect N_2O emissions). In the fertiliser industry, N_2O is emitted when ammonia is oxidised to nitric acid in order to produce nitrogenous fertilisers.

Land use and changes in land use (LULUCF[1]) are regarded as the largest source of greenhouse gases emissions globally in animal feed production. Steinfeld et al. (2006) estimate that global animal production releases just over $7.1 \cdot 10^9$ ton carbon dioxide equivalents[2] per year, which corresponds to approx. 18% of total global emissions. Of these emissions, it is estimated that up to one-third ($\sim 2.4 \cdot 10^9$ ton) can result from forest clearance with the aim of expanding the cultivation of grassland and feed crops in South America. Land use for animal feed production can also be positive for the carbon balance since in these cases the soil acts as a carbon sink, as opposed to being a source of emissions e.g. with deforestation. Permanent, well-managed grassland is the land use in agriculture that has the best potential to function as a carbon sink.

1.1 FOSSIL CARBON DIOXIDE, CO_2

Emissions of fossil CO_2 are completely dependent on the amounts and types of fossil fuels used. Table 1.1 shows emissions data for the fossil fuels most commonly used for heat production and as vehicle fuels. A characteristic of the total climate impact of these fossil fuels (i.e. from extraction from the ground to combustion in a boiler or engine) is that the greenhouse gas emissions are completely dominated by the carbon dioxide emissions arising from end-use of the fuels. This distinguishes them from biofuels, e.g. wood chips, salix, straw, RME (rape methyl ester) and biogas, where combustion can be regarded as carbon dioxide neutral[3] but where processing can produce significant greenhouse gas emissions, particularly if it includes the emissions from cultivation of an energy crop.

In heat production from fossil fuels, coal gives the highest carbon dioxide emissions per unit energy, while natural gas gives the lowest emissions. This is due to differences in the

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[1] LULUCF: Land use, land use changes and forestry according to IPCC nomenclature. That area of climate reporting dealing with uptake and emissions of CO2 from land use (including forestry).

[2] Carbon dioxide equivalents: Conversion to allow the greenhouse effect of different climate gases to be compared. In the present report we used a conversion factor of 1 kg methane (CH4) to 23 kg CO2 and 1 kg nitrous oxide (N2O) to 296 kg CO2.

[3] Assuming that the CO2 is bound in new biomass corresponding to the amount of CO2 released in combustion of the biomass.

chemical composition of these fuels. Choice of fuel is therefore highly significant for carbon dioxide emissions in e.g. drying of feed, one example being dried beet pulp (e.g. Betfor), which in Sweden is dried with natural gas but coal can be used as the energy source in other countries. In addition, the degree of efficiency can differ between different boilers, which means that the fuel requirement can vary between e.g. different drying plants. Using biofuels such as wood chips and straw can lead to very small net emissions of greenhouse gases from fuel combustion, but it increases the significance of greenhouse gas emissions arising during harvesting, transport and possibly growing of the crops (e.g. energy forest). For wood chips from forestry, the estimated greenhouse gas emissions for harvesting and transport make up a few grams of CO_2-equiv per MJ chippings, while the emissions from the entire production chain for energy forest chips (*Salix*) can be around 10 g CO_2-equiv per MJ chips (Uppenberg et al., 2001; Börjesson, 2006).

Diesel is the dominant engine fuel in the feed chain. The greenhouse gas emissions presented for diesel and petrol in Table 1.1 refer to the case without addition of biofuel. However, low inclusion of biofuel in fossil fuels is now increasing as a way of introducing more renewable energy into the transport sector and decreasing its greenhouse gas emissions. In 2007, for example, more than 90% of the petrol used in the transport sector contained 5% ethanol and two-thirds of the diesel contained up to 5% FAME (fatty acid methyl esters). In Sweden low inclusion mainly involves cereal ethanol or Brazilian sugarcane ethanol and FAME in the form of RME (Energimyndigheten, 2008). Although the combustion of these biofuels can be considered to be carbon dioxide neutral, cultivation of the raw materials gives rise to emissions of various greenhouse gases. However, the emissions levels vary greatly depending on the raw materials used, the emissions from land use, the resource demands and efficiency of cultivation, the fuels used in the different processes and the fate of any by-products of fuel processing. The results of life cycle analyses indicate that total greenhouse gas emissions from the production of ethanol can vary between 10-60 g CO_2-equiv/MJ ethanol, with sugarcane ethanol lying at the lower end of this range and cereal or maize ethanol produced using a large proportion of fossil fuels lying at the upper end (Berglund et al., 2008). However, the calculated emissions from cereal ethanol can be low provided that the ethanol factory is powered with biofuel, the by-products (distillers' waste and straw) are utilised well from a climate perspective (e.g. the distillers' waste is used as a feed to replace soyabean) and the cereal is grown efficiently with low total greenhouse gas emissions (Börjesson, 2008). The corresponding figure for RME varies between 30-50 g CO_2-equiv/MJ RME (Börjesson et al., 2008).

Table 1.1 Emissions of CO_2 *in the manufacture and use of fossil fuels from a life cycle perspective*

Fuel	Heat value [1]	Production (g CO_2/MJ_{fuel})	End use (g CO_2/MJ_{fuel})	Total		
				(g CO_2 /MJ_{fuel})	(g CO_2-eq. /MJ_{fuel}) [2]	(kg CO_2/l)
Diesel[3]	35.3 (MJ/l)	8.6	72	81	83	2.8
Petrol[4]	31.4 (MJ/l)	15	73	88	92	2.75
Natural gas[5]	39.7 (MJ/m^3)	5.5	57	62	65	$2.6*10^{-3}$
Heating oil[6]	35.8 (MJ/l)	8.5	74	83	82	2.96
Coal [7]	27.2 (MJ/kg)	6.5	93	99	115	

1) Refers to the lower heat value (Naturvårdsverket, 2007).

2) In production and end use of fuels there can also be emissions of methane and nitrous oxide. Extraction of natural gas and carbon can e.g. give rise to considerable methane emissions. However these emissions can vary widely, e.g. depending on where and how the fuel is extracted, the end use areas and the efficiency of consumption.

3) Emissions from production of diesel according to ELCD (2008) and from end use in lorries according to Concawe et al. (2007). Refers to diesel without inclusion of biofuel (e.g. FAME). Nitrogen oxide emissions can be expected to be higher from a working machine than a lorry, which means that total greenhouse gas emissions from a tractor per unit energy would be higher, ~92 g CO2-equiv/MJ diesel (Naturvårdsverket, 2007; ELCD, 2008)

4) Emissions from production of petrol according to ELCD (2008) and from end use in a private car according to Concawe et al. (2007). Refers to petrol without inclusion of ethanol.
5) Emissions from production of natural gas (incl. pressurisation and transport 1000 km, which is considered to be the European mean) according to Concawe et al. (2007) and end use in the form of stationary combustion according to Naturvårdsverket (2007).
6) Emissions from production of heating oil (light fuel oil) according to ELCD (2008) and from end use in the form of small-scale, stationary combustion according to Naturvårdsverket (2007).
7) Emissions from production of coal according to Concawe et al. (2007) and end use in the form of stationary combustion according to Naturvårdsverket (2007).

1.2 NITROUS OXIDE, N_2O

1.2.1 DIRECT NITROUS OXIDE EMISSIONS

The formation of nitrous oxide in soil occurs through natural processes (known as nitrification and denitrification) in which nitrogen in the form of ammonium and nitrate is transformed in the soil. In these processes there are small losses of N_2O, the magnitude determined in particular by nitrogen availability and soil water content and temperature. Even though only a kilogram or so of N_2O is lost per hectare – which is a small proportion in relation to the major nitrogen flows occurring in agriculture at present – such losses are very significant since nitrous oxide is such a potent greenhouse gas (1 kg is equivalent to ~300 kg CO_2). The water factor appears to be important for the losses (Dobbie & Smith, 2003; Fletchard et al., 2007). When 60-85% of the soil pore system is water-filled, the conditions for N_2O are optimal (provided that readily soluble nitrogen is present in the soil). The fact that nitrous oxide emissions are controlled to such a high degree by climatological factors makes it very difficult to predict the magnitude of these losses from a particular field at a specific nitrogen dose. In European field trials where the same nitrogen dose was applied to the same crop and the N_2O emissions were measured over a number of years, there were great variations in losses between different years owing to variations in rainfall and thus in water content in the field (Flechard et al., 2007).

An example of these variations is shown in Table 1.2 for a study in England where N_2O emissions were measured at 12 experimental sites (Dobbie & Smith, 2003). The highest emissions were recorded on three forage leys in the period June to August, with one of these sites showing very high emissions, in total 27.6 kg N_2O-N/ha. The ley on this experimental site received the highest N dose in the study (427 kg N/ha) and the water content in the soil pore system never fell below 60% during the course of the year.

Table 1.2 Emissions of nitrous oxide from arable land under different crops in England (Dobbie & Smith, 2003)

Crop	Number of sites	Emissions, kg N_2O-N/ha and year, mean	Emission, kg N_2O-N/ha and year, range
Forage ley	9	9.7	1.7-27.6
Winter cereal	2	1.9	0.7-1.2
Potatoes	1	2.4	-

Jungkunst et al. (2006) compiled measurements of N_2O losses from arable land at a large number of measuring sites throughout Germany. In this compilation the nitrogen doses applied varied from 0-400 kg N/ha and the recorded losses varied between 0.04-17.1 kg N_2O-N/ha, see Table 1.3

Table 1.3 Emissions of nitrous oxide from arable land under different uses in Germany (Jungkunst et al., 2006)

Crop	Number of sites	Emissions, kg N_2O-N/ha and year, mean	Emission, kg N_2O-N/ha and year, variation
Unfertilised agricultural land	27	1.27	0.04-3.4

Fertilised grassland	23	1.99	0.3-10
Fertilised arable land (not ley)	79	4.66	0.07-17.1

The EU project GreenGrass measured losses of greenhouse gases from leys and grazing at 10 different research sites in Europe comprising grassland with different intensities of fertilisation and areas of use. Intensively cultivated systems were distinctly greater sources of N_2O emissions than extensively managed grassland, see Table 1.4. High N doses often gave high emissions, but there were also sites where high N doses did not systematically lead to high emissions. In these studies, grazing also appeared to be a factor increasing N_2O emissions, which can indicate the existence of 'hotspots' of N_2O production through continual application of point sources of urine and faeces from the animals and through trampling increasing soil compaction. This effect of grazing was observed in particular on fertilised grassland and was not systematic.

Table 1.4 Emissions of nitrous oxide from grassland in Europe, 2002-2004 (Fletchard et al., 2007)

Type of grassland	Emissions, mean kg N_2O-N/ha and year	Emission, median kg N_2O-N/ha and year	Emission, range kg N_2O-N/ha and year[1]
Fertilised and grazed	1.77	0.74	0.0-6.4
Fertilised and ungrazed	0.95	0.56	0.0-3.5
Unfertilised and grazed	0.48	0.17	0.0-1.3
Unfertilised and ungrazed	0.32	0.19	-0.4-1.2

1) Negative value means uptake of nitrous oxide in the soil

As is clearly apparent from these examples of measured N_2O emissions in the field, the variations are great. They are particularly dependent on climatic variations affecting soil water content and temperature and variations within fields.

The model used almost exclusively at present to calculate emissions, internationally and in Sweden, is the International Panel on Climate Change guidelines (IPCC, 1997; 2006). This mathematical model only takes account of addition of nitrogen to the soil, yet we know that it is not only N additions that drive the emissions process for N_2O. Soil water content and temperature are two other driving forces that are specifically highlighted in more recent publications. This means that the uncertainty in the calculations is great and that in all probability they do not correspond to reality, but should only be regarded as a rough indicator of how great N_2O emissions can be. At the same time, N addition is one of the controlling factors determining the amount of N_2O that can be lost from agricultural soil and the factor over which the farmer has the greatest control. In the future we will probably have better models that take a number of factors into account in calculation of nitrous oxide emissions from agricultural soil.

1.2.2. INDIRECT NITROUS OXIDE EMISSIONS

Indirect nitrous oxide emissions are the nitrous oxide formed in other ecosystems, but that are caused by nitrogen lost from the agricultural system. This nitrogen originates partly from airborne emissions in the form of ammonia (particularly from animal husbandry) and nitrogen oxides and partly from water-borne emissions via leaching and surface run-off of nitrate. Through denitrification and nitrification parts of this nitrogen are then converted to nitrous oxide in other parts of the ecosystem. However according to current knowledge, indirect nitrous oxide emissions are relatively low in comparison to the direct nitrous oxide emissions that occur from farmland.

1.2.3 PRODUCTION OF MINERAL FERTILISER NITROGEN

Emissions of CO_2 and nitrous oxide occur during the production of nitrogenous fertilisers. The most commonly occurring mineral fertiliser, ammonium nitrate, which consists of equal parts of ammonium- and nitrate-nitrogen, currently releases ~6.8 kg CO_2-equivalents in production (Table 1.5). Calcium nitrate has higher emissions per kg N since all the nitrogen is in nitrate form, but only small amounts of calcium nitrate are used in agriculture today. The majority of the nitrous oxide in the processes can be removed through cleaning techniques and through increasing the efficiency of fossil fuel utilisation, greatly reducing the emissions per kg mineral fertiliser.

Table 1.5 Emissions of greenhouse gases in the production of mineral fertiliser nitrogen

Fertiliser type and manufacturing process	Emissions, kg CO_2-equiv per kg N	Comments
Ammonium nitrate (e.g. N27) (current manufacturing in EU)	6.8	Of which just over 60% of emissions are N_2O (Jensen & Kongshaug 2003)
Calcium nitrate (current manufacturing in EU)	10	Higher emissions per kg N as all N is in nitrate form (Jensen & Kongshaug, 2003)
Ammonium nitrate (best possible technology)	3	F. Brendrup, pers. comm. 2007
Ammonium nitrate (best available technology according to EU IPPC)[4]	4	M. Erlingsson, consultation 2008

Ammonium nitrate is by far the dominant nitrogen fertiliser in Europe. On average for current production in the European fertiliser industry, emissions are reported to be 6.8 kg CO_2-equiv/kg N (Jensen & Kongshaug, 2003), which comprises 2.2 kg CO_2 and 4.6 kg N_2O converted to CO_2-equivalents. Using best possible technology, it is estimated that these emissions could be reduced to 3 kg CO_2-equiv/kg N (1.7 kg CO_2 and 1.3 kg N_2O converted to CO_2-equivalents) (F. Bendrup, pers. comm. 2007). Best possible technology thus gives a great reduction in nitrous oxide emissions but also more efficient use of energy in the process, which leads to lower CO_2-emissions. Completely new fertiliser factories have the potential to decrease emissions to 2.5 kg CO_2-equiv/kg N (F. Brendrup, pers. comm. 2007). Best available technology today, for which economic considerations have also been included, has been defined for an emissions level of 4 kg CO_2-equiv/kg N as ammonium nitrate, see footnote 4.

1.3 CARBON IN THE SOIL

The most frequently used model for calculating changes in carbon stocks in arable soils under Swedish conditions is ICBM (Introductory Carbon Balance Model), which calculates the amount of carbon released or bound by an arable soil during a 30-year period (NV, 2007). The parameter values in the model have been taken from long-term field experiments at SLU and Swedish long-term trials. The ICBM and long-term field experiments in northern Europe have been used to analyse the impact of various cropping practices on soil carbon stocks (Kätterer & Andrén, 1999). The study showed that the potential of individual arable soils to increase or decrease their carbon stocks is largely determined by the cropping history of the soil. If the starting carbon stocks are high (e.g. as a result of repeated manuring or long-lying ley) the soil carbon content will decrease as a result of a change to cultivation of single-season crops. In contrast, on arable land with low starting carbon stocks, e.g. where cereal monoculture and straw removal are part of the cropping system, such a change can lead to increasing carbon stocks. To obtain reliable results from calculations using ICBM, data are required on the organic matter content (starting value) of the arable soil, whether the soil is

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[4] Best available technology according to EU IPCC 'Reference Document on Best Available Techniques (BAT) for the Manufacture of Large Volume Inorganic Chemicals – Ammonia, Acids and Fertilisers' and referring to consultation responses on the first round of criteria for climate certification (Mogens Erlingsson, Yara).

mineral or organic in texture and the geographical location of the soil. The model then calculates various scenarios, e.g. whether straw is ploughed in or manure applied.

The difficulty with quantifying changes in soil carbon stocks in **mineral arable soils** lies in the fact that the changes are often relatively small (a few 100 kg C/ha and year) compared with the total stocks of 40-90 ton C/ha. Even using a model such as ICBM, it can be difficult to make calculations that are sufficiently relevant. In in-value for the soil carbon stocks (starting organic matter content) is important and this can vary within a particular field or, even more so, on a farm. The problems with correctly establishing the original organic matter content in the soil and then verifying and confirming changes in the soil carbon stocks caused by cropping practices make it very difficult to draw up criteria that lead to 'guaranteed' reliable build-up of carbon in arable soil. At the present time, we consider that it is not realistic to develop criteria that can 'reliably' lead to carbon accumulation in mineral soils.

In the case of **organic arable soils** (peat soils) the situation is different. Measurements of gas exchange between soil and the atmosphere in Finland show that carbon losses from cultivated organic soils are 4-6 ton C/ha and year (Maljanen et al., 2007), which agree with the rather rough calculations made in Swedish climate reporting. We consider that emissions of carbon dioxide from the cultivation of organic soils can be quantified with reasonable certainty and could therefore be included as a criterion in a system for climate certification of food. One problem in this case is to clearly and unequivocally define whether a particular soil is an organic soil or a humus-rich mineral soil, as the boundary between organic and mineral soils is very diffuse in practice. The worst crops on organic soil from a climate perspective are row crops, followed by cereals, and the best are long-term leys. However, it should be pointed out that ley cropping on organic soil also gives rise to high emissions – up to 4 t C/ha have been recorded in Finnish studies – compared with leys on mineral soil. So the question of whether organic soils should be permitted in a climate certification system for food is actually also relevant for animal feed crops. This is an overarching issue that must be discussed fully in a climate certification system. If organic soil is to be taken out of production, the question is whether this should be achieved with the help of a certification system, or nationally through e.g. a ban on cropping or very good subsidies for ceasing production on organic soil. The results of Finnish studies emphasise that if organic soils have to be taken out of production to decrease carbon emissions from arable land, a careful study must be made of the measures undertaken to achieve this in order to reduce emissions as much as possible. Passive overgrowth is probably not a suitable measure, as field trials in Finland report considerable carbon losses (~3 t C/ha and year) from organic soils abandoned 20-30 years ago and allowed to become passively overgrown.

A number of international studies have shown that there is considerable carbon sequestration in permanent grassland. Based on these studies, it can be estimated that a reasonable range for carbon sequestration in Swedish **permanent grassland (natural grassland**) is probably between 500 and 1000 kg C/ha and year, although it must be emphasised that the effect is climate-dependent and the carbon decrease is lower in very dry years. It is desirable for natural grassland in Sweden to be used as long as possible, not only in view of carbon sequestration but also of biological diversity. A discussion should be held on whether it is possible to introduce some type of criterion that leads to increased use of natural grassland in a certification system. The problem lies in setting a general requirement that should be applied to the entire country, since the soil type 'natural grassland' occupies a varying proportion of different regions of the country. For example, there is only a small proportion of natural grassland in Norrland, so in that region it would be difficult to fulfil a general requirement on the use of natural grassland. This issue should be discussed further.

2 ANIMAL FEED PRODUCTION, CONVENTIONAL

An LCA database for conventional feedstuffs has recently been compiled at SIK. It includes the environmental impact, defined as resource use and emissions, in animal feed production up to the feed factory for the most commonly occurring conventional feedstuffs in Sweden at present (Flysjö et al., 2008). GWP calculations[5] from the feed database form the basis for this chapter. Indata for Swedish feedstuffs were calculated using current yield levels according to SCB statistics and fertiliser doses were checked against the most recently published fertilisation data (SCB, 2006). Emissions of direct and indirect N_2O emissions were calculated according to the latest guidelines from IPCC (2006). Manufacture of machinery and buildings is not included for the agriculture sector. However, this has little significance for GWP calculations, since emissions other than fossil CO_2 dominate this part of the life cycle (Frischknecht et al., 2007).

Table 2.1 shows an example of how GWP calculations are distributed between different parts of the production chain of 1 kg winter wheat as feed grain.

Table 2.1 Indata for sample calculation, cultivation of winter wheat (in Västra Götaland)

Parameter	Value used
Harvesting, winter wheat, kg/ha	6 000
Seed, kg/ha	220
Diesel for field machinery, l/ha	83
Drying (19 to 14% mc), l/ha	56
Nitrogen dose, mineral fertiliser-N, kg N/ha manure-N, kg N/ha N in crop trash, kg N/ha	125 19 54
Direct emissions, nitrous oxide, kg N_2O-N/ha	2
Indirect emissions, nitrous oxide, kg N_2O-N/ha	0,31
Mineral fertiliser, P, kg/ha K, kg/ha	10 13
Other: lubricating oil, electric dryers, pesticides	Minor amounts, see Flysjö et al. (2008)
Transport to feed factory	150 km by lorry, 90% loading level

Table 2.2 shows how the calculated emissions are distributed between the different stages in the production of feed wheat, per hectare and per kg feed wheat.

Table 2.2 Calculated GWP distributed over different areas of production (crop growing and transport)

	GWP, kg CO_2-equiv/ha	GWP, gram CO_2-equiv/kg wheat*	% distribution GWP/kg wheat
Diesel	286	49	11.2
Oil, drying	175	30	6.8
Production, mineral fertiliser N	858	149	33.5
Production, P & K fertiliser	41	7	1.6
Direct N_2O emissions	921	159	36
Indirect N_2O emissions	143	25	5.6

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[5] GWP=global warming potential, i.e. greenhouse gas emissions converted to CO2-equiv. and presented per kg feed.

Other, crop growing	19	3	0.8
Transport to feed factory	116	20	4.5
Total	2559	443	100

* Seed net-calculated so GWP per kg wheat is calculated as gross yield less seed rate

As shown by Table 2.2, the emissions pattern is dominated by emissions from production of mineral nitrogen fertiliser and direct emissions of N_2O in the field, i.e. production and use of N-fertiliser represented ~70% of total emissions.

2.1 FEED GRAIN

Figure 2.1 shows calculated GWP per kg feed grain, taken as a mean of the current situation. The GWP values are calculated for the three most important types of cereals: winter wheat, oats and barley, divided into the three regions Skåne **(S)**, Västra Götaland **(V)** and Mälardalen including Östergötland **(Ö)**. The sample calculation in Table 2.2 is for winter wheat growing in Västra Götaland.

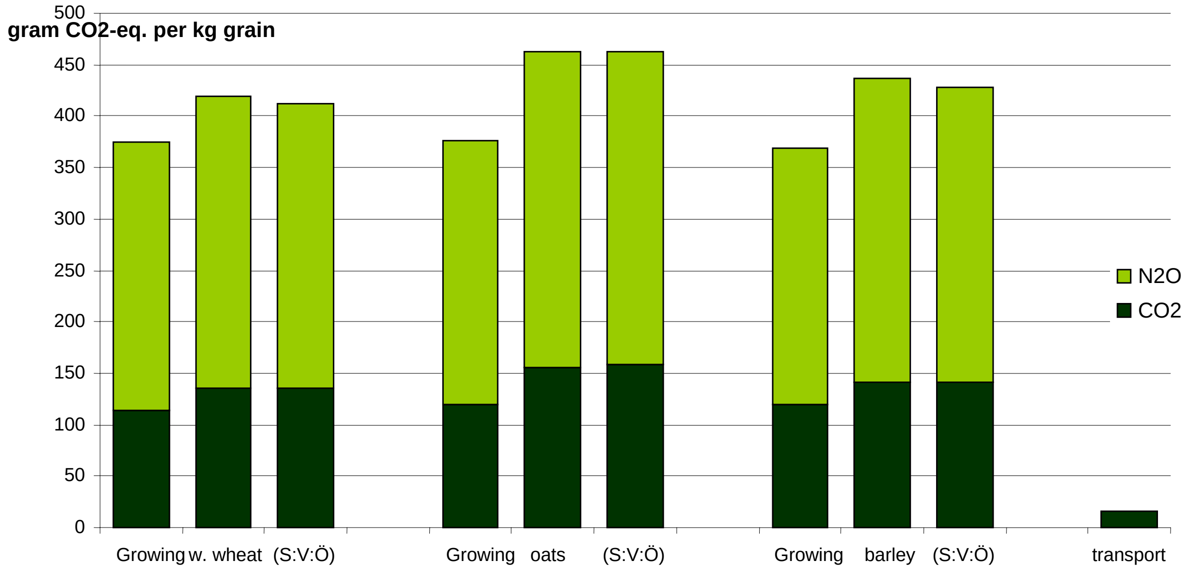

Figure 2.1 GWP values for feed grain (winter wheat, oats and barley) in southern (S), western (V) and eastern (Ö) Sweden

Emissions of greenhouse gases from cereal growing were estimated to be 370-465 g CO_2-equiv/kg (Figure 2.1), with somewhat lower values for winter wheat due to its higher levels of yield compared with oats and barley. Emissions of fossil CO_2 represent just under one-third of total emissions and the fossil CO_2 emissions can be divided between cultivation (diesel and oil for drying), which produces ~50% of emissions, and mineral fertiliser production, which produces ~35%. Emissions of nitrous oxide represent 65-70% of total emissions from crop production and are divided between *i)* emissions in production of mineral fertiliser (35%), *ii)* direct emissions from soil (~55%) and *iii)* indirect N_2O emissions (~10%). Transport of grain to the feed factory (150 km by lorry) gives emissions of ~17 g CO_2-equiv/kg grain, which is equivalent to just under 5% of the entire emissions from production.

Possible change: BAT mineral fertiliser – improving the efficiency of diesel and nitrogen fertiliser use

The sample calculation of GWP emissions per kg wheat in Table 2.2 refers to winter wheat in western Sweden, see Figure 2.1. In the space of a few years, it is reasonable to assume that mineral fertiliser nitrogen produced with Best Available Technology (BAT), corresponding to emissions of around 3 kg CO_2-equiv/kg N (see Table 1.5) will be available on the market. In addition, it is reasonable to assume that there will be more efficient use of diesel and N-fertiliser in crop production (e.g. a move towards eco-driving, strict adherence to recommended N fertiliser doses) and we estimate that it is possible to reduce diesel and nitrogen fertiliser use by 10% without affecting yields. The use of BAT fertiliser and 10% efficiency is estimated to decrease the GWP load per kg feed grain by over 30% compared with the current position, according to Figure 2.1.

2.2 FORAGE – SILAGE AND HAY

In the feed database, forage grown in pure grass leys was compared with forage from mixed leys where the nitrogen requirement differed since the legumes in the mixed leys contributed biological N-fixation. Around half of Swedish leys are fertilised annually with manure and therefore the input of manure is relatively high for these feed products in the database, although equal for grass and mixed leys. Yield of leys in the database is 7 ton DM ha after harvest losses and the average amount of mineral fertiliser used for a three-year ley is 115 kg N/ha in the grass ley and 55 kg N/ha in the mixed ley. For forage, emissions arising from the storage and feeding of silage and hay are also included due to differences between these systems. Round bale silage requires a lot of plastic, while bunker silos require cement in their construction and tower silos require metal.

The predominant emissions of greenhouse gases consist of N_2O in conjunction with growing of the ley (Figure 2.2). Grass leys have higher emissions of N_2O and CO_2, since a greater amount of mineral fertiliser nitrogen has been used. The emissions originate partly from manure production (N_2O and CO_2) and partly from direct emissions from soil (N_2O). For drying or ensiling ley material to hay or silage, respectively, the only emissions are CO_2 in the combustion of fossil fuels. There are very small differences between different silage making systems (round bales, bunker silos, tower silos), while hay has somewhat lower emissions. This is because the energy consumption in hay conservation mainly consists of electricity (hay fan).

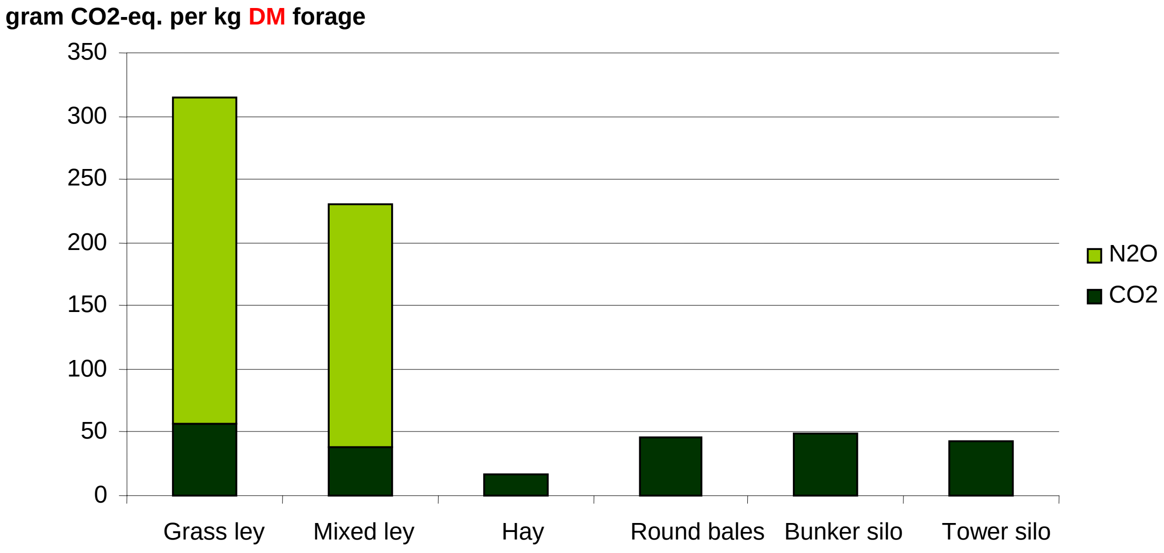

Figure 2.2 Emissions of greenhouse gases in production of one kg forage (dry matter).

To obtain the total emissions of greenhouse gases from one kg forage, the bar for growing (grass or mixed ley) must be added to the bar for conservation method (e.g. bunker silo). One kg DM grass ley in a bunker silo thus gave rise to emissions of almost 370 g CO_2-equiv/kg, while the mixed ley in a bunker silo gave rise to just over 280 g CO_2-equiv/kg. Choosing a mixed ley instead of a grass ley and adjusting the nitrogen dose according to the recommendations on lower nitrogen use in the ley thus means that the estimated emissions of greenhouse gases per kg silage/hay are decreased by 20-25%.

2.3 PEAS/FIELD BEANS

Compared with several other feedstuffs, N_2O represents a small proportion of total emissions of greenhouse gases from peas/field beans. This is because no mineral fertiliser nitrogen is used, which reduces emissions of N_2O (and also CO_2). In addition, the N_2O contribution from the soil is lower since no fertiliser nitrogen is applied. The only nitrogen added to the soil system is that in the nitrogen-rich crop residues that are tilled into the soil after harvest, and international literature shows that losses seldom exceed 1 kg N_2O-N/ha (Rochette & Janzen, 2005).

The feed database shows emissions from the production of field beans in the range 210-240 g CO_2-equiv/kg, see Figure 2.3. The most important improvement measure for this crop is to increase yields, which are low in terms of the feed database but are based on current yield statistics. Yield is set to just over 3 t/ha in eastern and western Sweden and 2.5 t/ha in southern Sweden. In addition, the seed rate is high, 250 kg/ha, so in Skåne only 2.25 t/ha are obtained as an effective feed product. Viewed over a longer time (20 years), very little has happened in terms of yield increases in peas/field beans, but from experience we know that yields of 4-5 t/ha are fully realistic and were not uncommon in the 1980s.

In practical animal feed production, peas/field beans are often co-cropped with cereal and are harvested as a forage. Experience shows high DM yields of these mixtures with little or no inputs of mineral fertiliser. The feed database has no calculations of this cropping option but it is comparable with silage from mixed leys (see Figure 2.2) or silage in organic cropping (see Table 3.3).

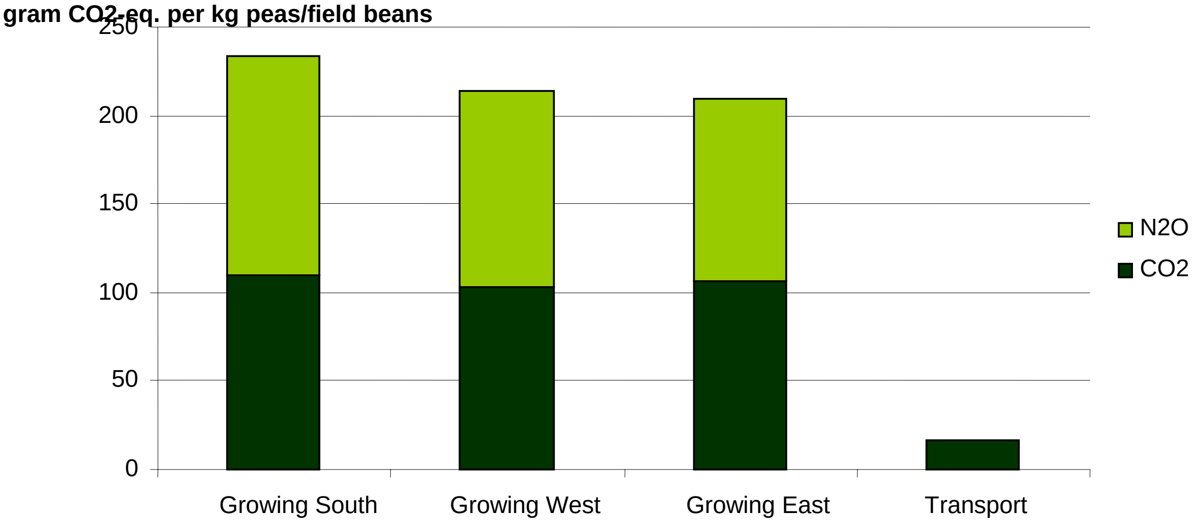

Figure 2.3 Emissions of greenhouse gases in production of one kg peas/field beans.

2.4 RAPESEED PRODUCTS

Calculations for rapeseed products are based on the ‘mean tonne’ of rapeseed in Sweden, which consists to just over half of winter rapeseed and just under half of spring rapeseed. Yield of winter rapeseed varies on average between 3 and 3.3 t/ha depending on where in the country the crop is grown and average yield of spring rapeseed is 2.1 t/ha. The GWP value for one kg rapeseed is around 800 g CO_2-equiv/kg, see Figure 2.4. The high price of rapeseed in recent years has resulted in very little whole (unprocessed) rapeseed being used in animal feed, and instead it is the protein-rich rapeseed meal that is the important feed product.

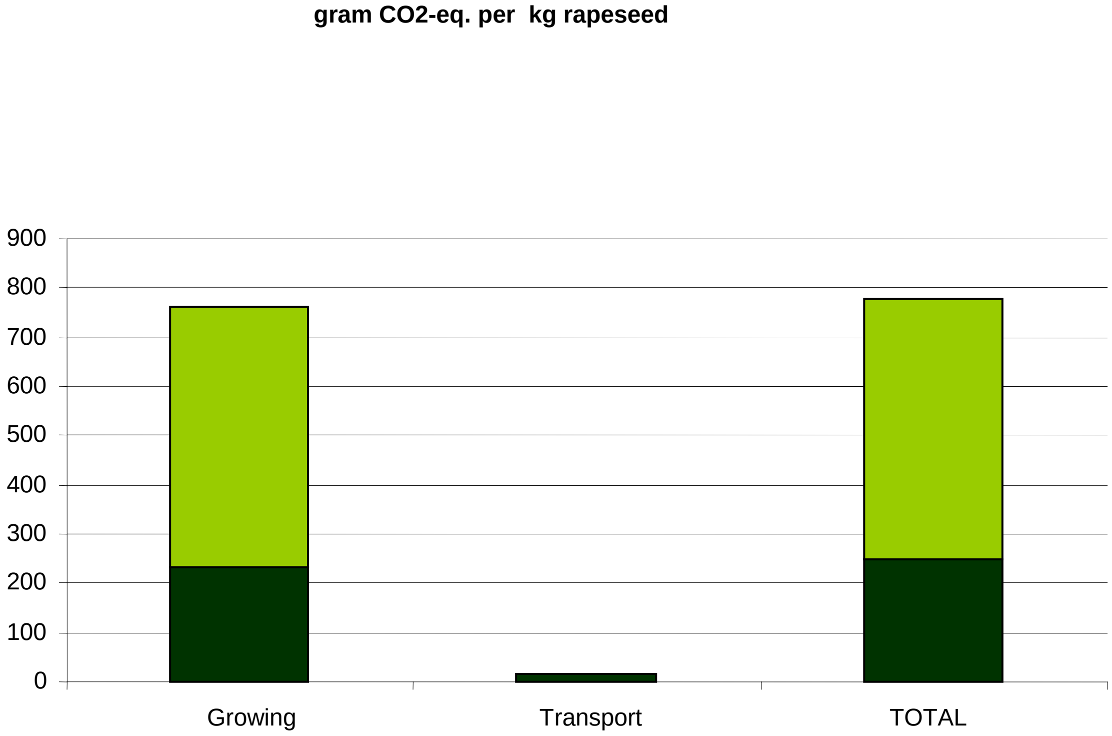

Figure 2.4 Emissions of greenhouse gases in production of one kg whole rapeseed.

The largest volume of rapeseed in Sweden is processed in AAK, Karlshamn, where it is extracted and the oil removed. The protein-rich rapeseed meal is heat-treated and the product ExPro obtained is used almost exclusively in dairy cow feed. Economic allocation has been used to distribute the environmental impact of growing and processing between oil and rapeseed meal, which means that 72% of the impact is allocated to the oil and 28% to the protein feed. As shown by Figure 2.5, emissions of greenhouse gases amount to around 460 g CO_2-equiv/kg rapeseed meal when the raw material is Swedish and when processing and transport are carried out according to the conditions that apply for extraction in AAK today. The emissions from processing are very small (Figure 2.5), since the extraction at AAK mainly uses biofuels as the energy source, together with Swedish average electricity.

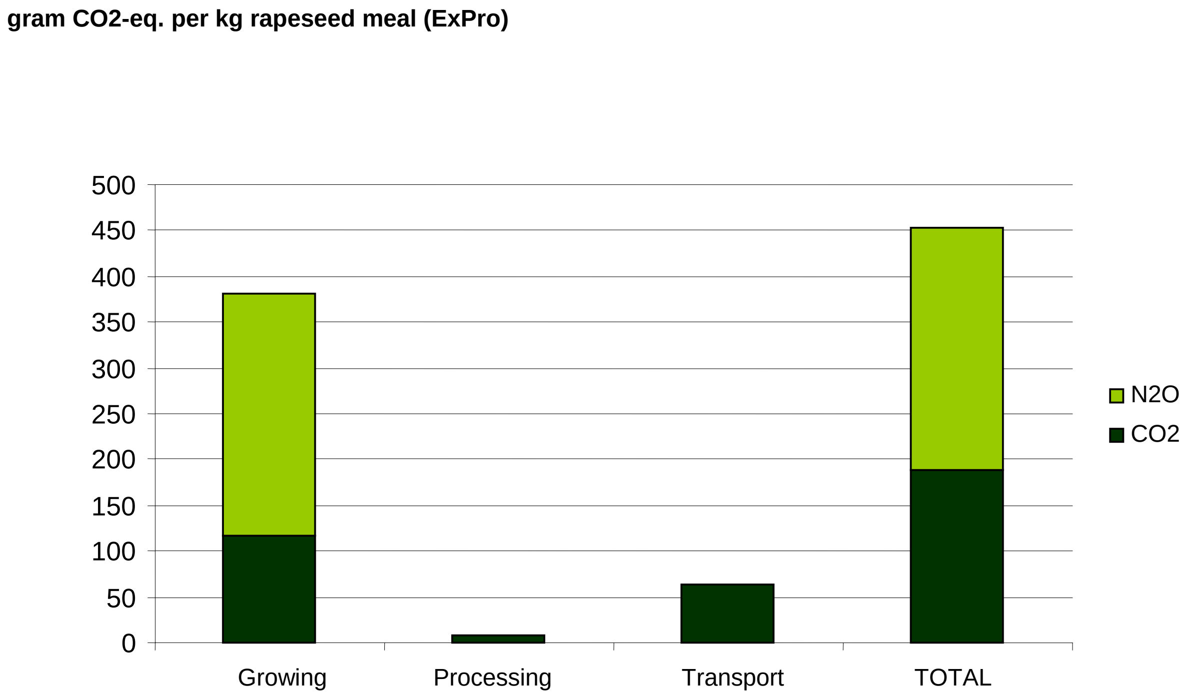

Figure 2.6 Emissions of greenhouse gases in production of one kg ExPro (rapeseed meal)

Much rapeseed meal is imported, since oilseed growing is not sufficiently widespread to meet the protein feed requirement. This rapeseed meal comes from northern Europe, often from Germany. There it has been extracted with hexane, just as in Karlshamn, but not processed with the method developed and used in Karlshamn (patented for ExPro) in order to improve ruminant utilisation of the protein in the rapeseed meal. The imported rapeseed meal is therefore used mainly for monogastric animals that cannot derive any benefit from the ExPro feed's specialist properties developed for ruminants. The database does not contain any calculations for imported rapeseed meal but it is reasonable to assume that growing is relatively similar to that in Sweden and that N_2O from N fertiliser is the dominant contributor. As regards emissions from extraction and transport, these are probably somewhat higher due to the longer distance and as more fossil fuels are probably used in the extraction process on the Continent.

Rapeseed is occasionally cold-pressed in small plants on farms where rapeseed cake is produced as a feed. This method differs from hexane extraction in that the oil recovery is lower and more oil ends up in the feed compound, so it is a more energy- and oil-rich protein feed, but the protein is not as well utilised as that in ExPro for ruminants. When this product is grown as a 'mean tonne' of Swedish rapeseed, its emissions in growing are comparable with those in the database (see Figure 2.5) but emissions from extraction and transport are lower if the rapeseed cake is used locally where it is grown and also processed there. In cold pressing there is no extraction or heat treatment and the energy requirement is met by electricity.

The nitrogen dose is high in rapeseed growing and this has a great impact on the GWP calculations for ExPro. The direct emissions of N_2O from soil caused by nitrogen fertilisation, together with emissions of N_2O and CO_2 in conjunction with nitrogen fertiliser production, represent 65% of total GWP emissions per kg ExPro. If the nitrogen fertiliser only consisted of BAT nitrogen fertiliser, the total emissions from production of ExPro (including feed factory) could be decreased by ~16%.

2.5 SOYABEAN MEAL

Overall, production of soyabean (growing, processing, transport) gives a GWP value of just over 800 g CO_2-equiv/kg soyabean meal, see Figure 2.6. Although transport by ship across the Atlantic is very efficient, the emissions from the transport stage are still relatively great, with transport in Brazil playing a relatively large role (long distances). In the growing stage, the reasons for CO_2 emissions from soil include changes in land use, since soyabean growing leads to degradation of soil humus reserves. Nitrous oxide emissions are relatively small for this protein feed for the same reason as for peas/field beans – the soyabean fixes its own nitrogen and therefore generally requires no mineral fertiliser nitrogen at all.

The GWP calculations for soyabean do not include emissions caused by deforestation to obtain more land for soyabean growing. It is very difficult to calculate these emissions since the uncertainties are many. An important uncertainty factor is the carbon stocks in the original Amazon forest in Brazil, for which the variations are great between different references and in reality, i.e. a hectare of rainforest can have varying amounts of carbon bound in biomass. In addition, land use after deforestation must be monitored for a number of years. After deforestation in the Amazon, the soil can be used for growing field crops or as grazing and the land use can alternate between these. A common phenomenon is for the soil to be abandoned after a few years and forest allowed to grow once again (secondary forest). The soil then becomes a carbon sink again, with carbon being taken up. Finally, the emissions from deforestation have to be distributed over a number of products (field crops for animal feed production and grazing that eventually becomes meat), which are produced on the soil after deforestation and this distribution must be made over a certain period of time. It is therefore very difficult to distribute the emissions from deforestation to the products that are ‘responsible’ for the deforestation and all types of estimates must be regarded as rough figures.

The Ecoinvent database includes a rough estimate of the CO_2 emissions caused by deforestation for cultivation of soyabean in Brazil. When these emissions are added to our GWP calculations for the production of soyabean meal, total emissions increase to around 1.5 kg CO_2-equiv/kg soyabean meal, i.e. by over 0.6 kg CO_2/kg soyabean. Although the uncertainties in this figure must be emphasised once again, it gives an indication of the importance of changes in land use caused by expansion of arable land into the rainforest.

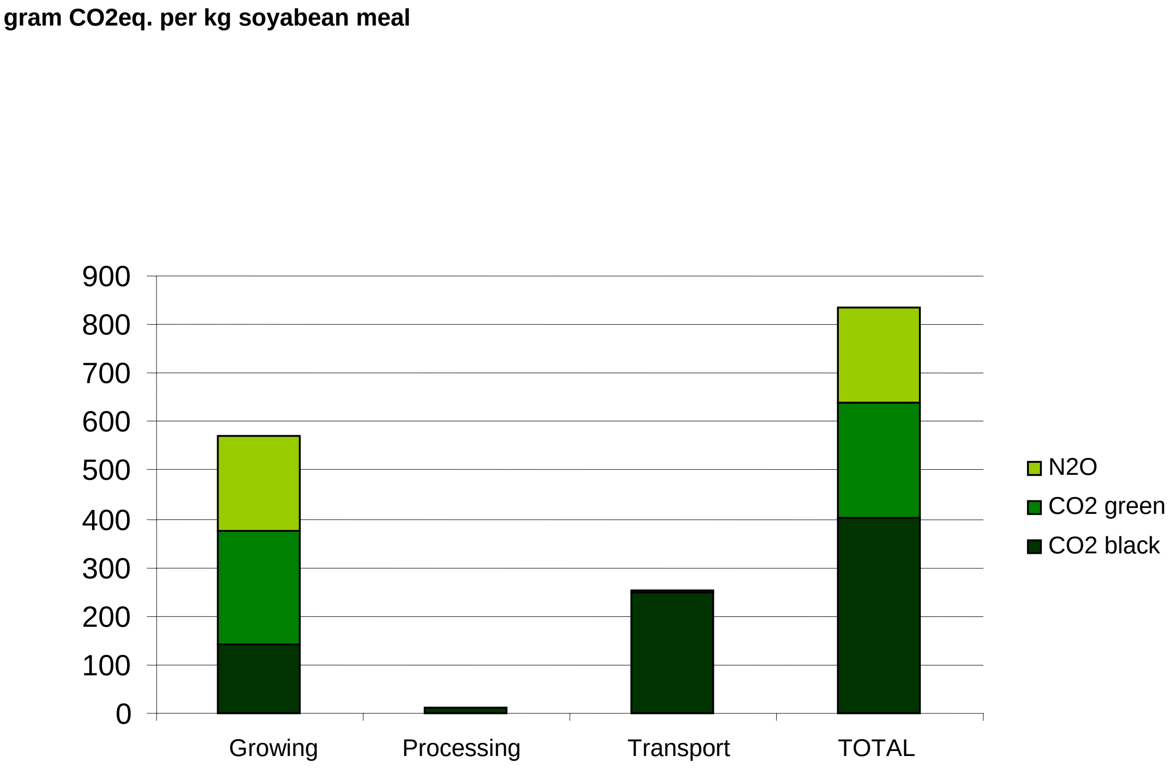

Figure 2.6 Emissions of greenhouse gases in the production of one kg soyabean meal. 'CO$_2$ green' is CO$_2$ from soil after the change in land use and 'CO$_2$ black' is CO$_2$ from fossil fuels.

2.6 BY-PRODUCTS FROM THE SUGAR INDUSTRY

Dried beet pulp (including molassed beet) and molasses are by-products from the sugar industry that are important feedstuffs in Swedish milk production. Around 150 000 tons beet pulp dry matter are consumed by cattle annually and around half of this is imported. Approximately 30% of the dry matter from one hectare sugarbeet becomes feed products.

The profits in sugarbeet growing lie in the sugar and when an economic allocation is made to distribute the environmental impact between sugar and by-products, the majority of the environmental impact is thus placed on the sugar. This means that growing does not comprise the major environmental load of this feed raw material, but rather drying of the beet pulp. GWP calculations in the feed database for Swedish conditions give an estimate of around 550 g CO_2-equiv per kg beet pulp transported to the feed factory. Of this load, emissions in drying make up around 60% of the climate impact of beet pulp, growing 30% and transport 10%, see Figure 2.7. Choice of energy source in the drying process is very important for the GWP value of beet pulp/beet fibre. In Sweden, natural gas is used for drying. If the energy source had been half carbon and oil, the emissions in the processing stage would have been 50% higher compared with Figure 2.6, i.e. total emissions would have been around 675 g CO_2-equiv per kg, provided that the other stages remained relatively similar. The imported beet pulp usually comes from the Baltic region, so transport is relatively short. It is therefore important to emphasise that when discussing the environmental performance of imported beet pulp as regards emissions of greenhouse gases, the transport emissions are relatively unimportant since the beet pulp primarily comes from neighbouring areas (Baltic region). It is the drying process (its efficiency) and choice of energy source that are of absolutely major importance.

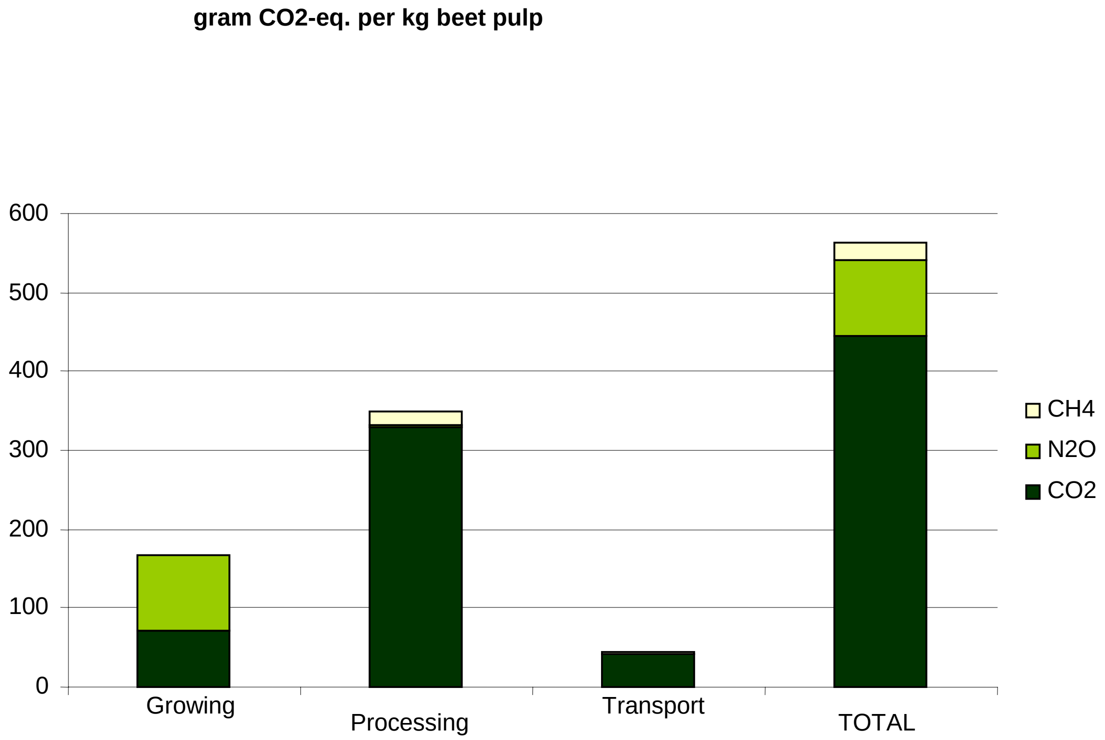

Figure 2.7 Emissions of greenhouse gases in production of one kg beet pulp (Sweden)

HP-Massa is beet pulp that had been ensiled with some molasses (i.e. no drying) and is particularly used in dairy cow diets to partly replace forage (ley). Choosing economic allocation (i.e. most of the environmental load from growing is placed on the product sugar) and assuming that the HP-Massa is transported by lorry 200 km to the farm from Örtofta sugar factory, the GWP value is less than 240 g CO_2-equiv per kg DM. This can be compared with the GWP values for different types of silage (see Figure 2.2). From a climate perspective, HP-Massa is a good forage.

2.7 PALM KERNEL EXPELLER

Palm kernel expeller (PKE) is mainly included in feed for beef animals. PKE is a by-product from the production of palm oil and palm kernel oil. Of the total products from 1 hectare of oil palm, just over 10% of the DM mass consists of PKE but the economic value of this by-product is considerably lower, comprising only ~3% of the income from the oil palm.

The GWP emissions for 1 kg PKE, transported to a feed factory in Sweden, amount to ~800 g CO_2-equiv per kg (see Figure 2.8). In these calculations, it was assumed that 4% of palm cultivation takes place on organic soils, which contributes to the majority of the emissions in the growing stage and represents over one-third of the emissions (approx. 24% N_2O and 10% CO_2) of the chain as a whole. Processing includes removing wastes from the oil factory, which gives rise to emissions of methane, and it is this in particular that contributes to the emissions in the processing stage.

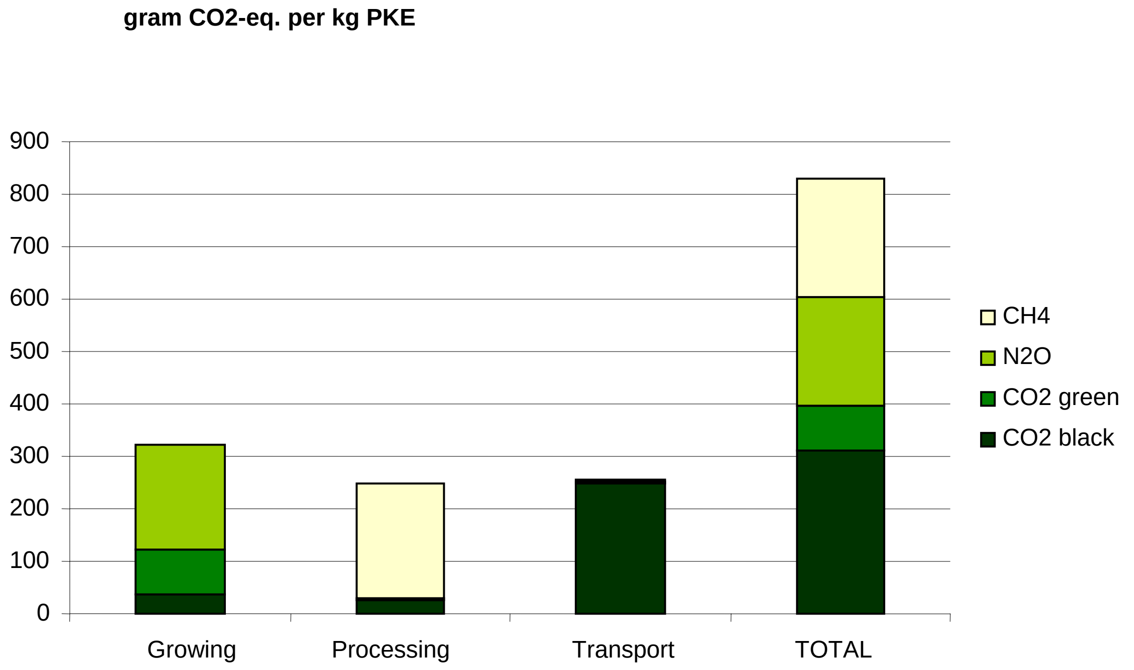

Figure 2.8 Emissions of greenhouse gases in production of one kg palm kernel expeller (PKE). 'CO_2 green' represents net emissions of CO_2 from biological processes and 'CO_2 black' CO_2 from fossil fuels.

The GWP calculations for PKE in Figure 2.8 do not include CO_2 emissions caused by deforestation. As discussed previously for soyabean meal, it is difficult to make such calculations due e.g. to variations in carbon content in biomass in the original vegetation. Rough calculations according to the Ecoinvent database show that if these emissions were included, the load would increase to 1.1 kg CO_2-equiv per kg PKE (including carbon from land under changed use and CO_2 emissions from deforestation). The reason for the increase not being greater is that most of the environmental load in growing is allocated to the palm oil, which gives the greatest economic return in the growing of oil palm.

2.8 OTHER RAW MATERIALS

Other feedstuffs of importance in concentrate today include vegetable oils, distillers' grain (by-product from ethanol production), wheat bran, maize gluten meal, minerals and synthetic amino acids. Table 2.3 shows the GWP values for these raw materials calculated in the SIK LCA feed database with the exception of the estimates for synthetic amino acids, where amino acid data refer to methionine (Strid Eriksson, 2005). Synthetic amino acids have high GWP values per kg product but are included in very small amounts in the feed of monogastric animals. For example, in the feed for laying hens, synthetic amino acids (methionine and lysine) make up around 0.2% of the total product.

It is important to point out that as regards the feed raw materials in Table 2.3, these are used in much lower volumes than forage, grain, soyabean, rapeseed products, beet pulp and palm kernel expeller in current animal feeds in Sweden.

Table 2.3 GWP values for raw materials included in concentrate feed production in small volumes

Product	Gram CO_2-equiv/kg
Vegetable oils	500 – 750
Agrodrank (distillers' grain)	300

Wheat bran	135
Maize gluten meal	1100
Mineral supplement	800
Synthetic amino acids	3 600

3 ANIMAL FEED PRODUCTION, ORGANIC

The SIK LCA feed database only includes conventional feedstuffs. There are insufficient indata on cropping inputs in organic growing, e.g. machine inputs in practical operation. However, there are yield statistics for the most common crops. To make some GWP calculations for organic feedstuffs, we started with two types of crop rotation and with these as a base made estimates of reasonable greenhouse gas emissions in the production of some important feedstuffs using the same methodology as in the conventional feed database. For organic production the entire crop rotation must be studied, since soluble mineral fertiliser is not permitted in this cropping system and instead there is a reliance on manure, N-fixing crops and crop rotation effects, i.e. the following crop can ‘live’ on a good preceding crop. With the help of experienced eco-advisors we compiled two crop rotations, one for a dairy farm in southern Sweden (Table 3.1) and one for a stockless arable farm (Table 3.2), where some of the crops become feed in organic animal production. Using these crop rotations as a base, we calculated reasonable GWP values for some organic feed crops.

Table 3.1 Crop rotation on an organic dairy farm (10 years)

Year	Crop	Manure	Kg N-tot/ha	Yield, t/ha	Yield,% of conventional
1	Cereal & peas + insown (whole crop cereal)	Cattle manure/solid	100	4.5	
2	Ley I	None		5.5	~ 80
3	Ley II	Cattle manure	100	5.5	~ 80
4	Ley III	Cattle manure	100	3	~ 40
5	Winter rapeseed	Cattle manure	100	2	67
6	Spring cereal + insown (whole crop cereal)	Cattle manure/solid	100	5.5	
7	Ley I			5.5	~ 80
8	Ley II	Cattle manure	100	5.5	~ 80
9	Ley III	Cattle manure	100	3.5	50
10	Triticale			3.5	60

In the crop rotation on the organic dairy farm, 60% of the area was in ley, which received 25 t/ha slurry in years 2 and 3. Yields were around 80% of the conventional in years 1 and 2, and 40-50% in year 3. Just as for the conventional ley (see section 2.2) this was a two-cut system, and the same amount of diesel was assumed for both cropping systems. Solid manure was spread in the two insown crops and the effects of this manure were utilised by the first year ley, which also contained clover, so the first year ley was given no manure. Triticale was grown after the ley and had a very good place in the crop rotation so no manure was given to this crop (which ‘lives’ on pre-crop effects). Yields were 60% of conventional yields. Diesel consumption was increased from 70 to 95 l/ha because we included two extra stubble cultivations to control perennial weeds in the crop rotation and two passes with a weed harrow. The winter rapeseed was grown after the ley had been ploughed under and slurry was applied to the growing crop in the spring. Yield was estimated to be two-thirds of the conventional level.

Table 3.2 Crop rotation on an organic arable farm (7 years)

Year	Crop	N applied as Biofer, kg N/ha	N from incorporated green manure	Yield, t/ha	Yield, % of conventional
1	Oats + insown	0	80	3	70
2	Green manure, ploughed in	0			
3	Winter rapeseed	78	80	2	67
4	Winter wheat+insown	96	80	3.8	63
5	Forage ley, one cut removed	0	80	3	50
6	Winter wheat	78	80	3.8	67
7	Field beans	0	0	2	85

The crop rotation on the organic arable farm included two one-year ley crops. In year 2 it was a ‘pure’ green manure crop that was returned to the soil system and for this it was estimated that 300 kg N/ha were ploughed under with crop residues. In year 5 it was one-year forage ley from which one cut was taken, and 100 kg N/ha were assumed to be ploughed under. A total of 400 kg N/ha were thus applied as green manure nitrogen, which were distributed over the five cash crops in the crop rotation. We considered that the field beans should not be allocated a load of this nitrogen since they fix N themselves. The green manure crop in year 2 was not allocated any of this nitrogen either, for here there was no outgoing product to carry the load, so five crops (of seven in the crop rotation) shared the direct N_2O-emissions arising due to incorporation of N-rich crop residues into the soil. Biofer was included as an organic fertiliser and calculation of direct N_2O-emissions was thus based on the N dose applied. Production of Biofer has been estimated to produce emissions of 214 g CO_2/kg (Cederberg et al., 2005). Diesel consumption was increased from 70 to 95 l/ha in cereal because we included two extra stubble cultivations to control perennial weeds in the crop rotation and two passes with a harrow. The GWP calculations for organically grown ley, cereal and rapeseed under these conditions are presented in Table 3.3.

Table 3.3 Estimated emissions of greenhouse gases per kg feedstuff for organic ley, feed grain and rapeseed

	Gram CO_2-equiv/kg
Ley forage (organic dairy farm)	145
Triticale (organic dairy farm)	230
Winter wheat (organic arable farm with green manuring)	440
Winter rapeseed (organic dairy farm)	620
Winter rapeseed (organic arable farm with green manuring)	730

Production of organic ley forage (silage and hay) gave lower emissions than conventional mixed ley and considerably lower emissions than conventional grass ley (see Figure 2.2). This can be explained mainly by the organic ley giving a relatively good level of yield (80%) compared with the conventional ley and no mineral fertiliser being used. The use of nitrogen-fixing legumes in ley cultivation is very important in maintaining yields of this feed crop without the use of soluble nitrogen.

The organic feed grain (triticale/winter wheat) in this sample calculation gave very different GWP values due to the nitrogen and crop rotation strategies used in the two examples. The triticale on the dairy farm was grown after the three-year ley and received its nutrients as pre-crop effects from the ley. All the nitrogen supplied to the ley (manure and N in crop residues) was distributed over the ley crop and was thus included in the GWP values for the ley forage. The yield of triticale was estimated at 60% of the conventional yield, in this example 3.3 t/ha, which is a very reasonable yield for organic triticale in southern Sweden. The GWP value for this feed grain was estimated at 230 g CO_2-equiv/kg, which is ~40% lower than the current conventional yield. Winter wheat grown on the ‘pure’ organic arable farm, where nitrogen supply was based on green manuring and Biofer, did not have as low a GWP value. This was because the winter wheat had received N partly in the form of Biofer and partly via green manuring (distributed over the crop rotation), thereby increasing the risk of N_2O emissions, since relatively large amounts of nitrogen are added to the soil system. Since a large proportion of this nitrogen is organically bound, in contrast to mineral fertiliser where all the N supplied is soluble (ammonium and nitrate form), there is no immediate effect of it and the yield is lower than the conventional (here estimated at ~65% of the conventional yield). However, it should be pointed out that it is not only the nitrogen fertilisation that makes a difference between organic and conventional cereals, since the avoidance of chemical pesticides is very significant for the lower yields in organic winter wheat. The organic winter wheat in the crop rotation with green manuring had a GWP value on the same level as that of current conventional cereal, see Figure 2.1.

The organic winter rapeseed yield was estimated at 2 t/ha, a very realistic level of yield in southern Sweden and approx. 65% of the conventional yield. The estimated GWP values were 620 and 730 g CO_2-equiv/kg rapeseed, which can be compared with just under 800 g CO_2-equiv/kg for conventional rapeseed (see Figure 2.4). As with the feed grain, the higher GWP value for rapeseed in the crop rotation with green manure can be explained by the green manure producing large amounts of organic nitrogen, which risks giving rise to emissions of nitrous oxide from soil without giving a reliable, significant increase in yield.

4 SUGGESTED CRITERIA, CONVENTIONAL FEED

4.1 IN GENERAL FOR OVERALL ANIMAL FEED PRODUCTION ON THE FARM

4.1.1 NITROGEN

On dairy farms there is always considerable animal feed production, as most forage is grown there, and often feed grain. Total greenhouse gas emissions are decreased by good nitrogen use efficiency in crop production, particularly through good manure utilisation (less mineral fertiliser needing to be purchased), which leads to decreased emissions in mineral fertiliser production and decreased direct and indirect N_2O emissions. Nitrogen is so important, not only for the climate issue but also for eutrophication and acidification, that it should be prioritised in criteria work so that some requirement on nitrogen use efficiency in the farm’s animal feed production is introduced.

Proposal: A requirement should be introduced that a nitrogen balance be drawn up annually to measure nitrogen use efficiency in crop production on the farm. A suggested indicator is ‘*input of new*[6] *nitrogen (N) per ton harvested product*’. This indicator must be monitored and a plan for improvement work prepared so that a climate-labelled farm decreases its use of new N per ton harvested product (ley, cereal, rapeseed) in a 10-year perspective. Sigill should produce decision support data to guide the development of this indicator and give reasonable benchmarking values. There should also be an investigation of how far the indicator value can reasonably be broken down – to field level, crop level or, in its simplest form, to all crop production on the farm.

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[6] By ‘new’ nitrogen is meant nitrogen from mineral fertiliser and/or nitrogen fixed in N-fixing crops

4.1.2 ENERGY

Diesel consumption in field machinery is the most important input to consider, but it should be pointed out that emissions of fossil CO_2 constitute a small proportion of the GWP value of feed crops. On dairy farms, a considerable proportion of the diesel is used outside crop production, in different types of work specifically relating to animal production. In addition, very few farmers have such accurate knowledge of their diesel use that they can distinguish between the diesel used in crop production and in animal-related tasks. At the present time no requirement on diesel consumption specifically in crop production is recommended, since it would be extremely difficult to measure and monitor.

Proposal: No specific requirement to be introduced for diesel use in animal feed production, but this to be included instead under an overarching requirement on energy use on the entire farm, see also data support for the entire dairy farm.

4.2 SPECIFIC FOR INDIVIDUAL FEED PRODUCTS

4.2.1 FORAGE

Growing only mixed leys compared with pure grass leys means a decreased use of mineral fertiliser nitrogen per ton forage. Feed trials also show that dairy cows produce more milk on the same feed allocation of white or red clover compared with grass in a pure stand[7]. In addition, the use of fossil energy resources (natural gas) decreases when legumes are used as the nitrogen source instead of mineral fertiliser. The nitrogen fertiliser used should be produced using Best Available Technology (BAT)

Proposal: Grass leys are not permissible. Forage should be grown in mixed leys that include insown legumes to at least 15%. It is important to check that the nitrogen dose is actually lowered according to the fertiliser recommendations that exist for reduced N fertilisation in mixed leys. Here, monitoring of nitrogen use efficiency (see 4.1.1) emerges as an important factor for checking that the fertilisation recommendations are actually followed.

Proposal: The mineral nitrogen fertiliser used in ley production on dairy farms must be manufactured according to BAT.

4.2.2 GRAIN (GROWN ON DAIRY FARMS)

It is critical to monitor nitrogen fertilisation in this crop too. Manure should be used with as minimal losses as possible.

Proposal: Application of manure to cereals in the autumn is not permissible. Manure must be applied in late winter/spring using good techniques (rapid incorporation or band spreading in the growing crop). If manure is used, the mineral nitrogen dose must be carefully adjusted to the N content of the manure (over-optimal N doses are common when both manure and mineral fertiliser are used). Monitoring of nitrogen use efficiency (see 4.1.1) is an important tool in checking that the fertilisation recommendations are actually followed.

Proposal: The mineral nitrogen fertiliser used in cereal production on dairy farms must be manufactured according to BAT.

4.2.3 CEREAL (GENERALLY GROWN, I.E. PURCHASED)

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[7] Legsil project 2001.

Nitrogen fertilisation is central. If there is a requirement that purchased feed grain must be certified, there should be monitoring of N use efficiency in its production.

Proposal: An annual N balance must be prepared and monitored to measure and improve N use efficiency in the growing of certified/climate-labelled feed grain.

Proposal: The mineral nitrogen fertiliser used in climate-labelled/certified feed grain production must be manufactured according to BAT.

4.2.4 RAPESEED PRODUCTS

ExPro and ordinary rapeseed meal are protein feeds that could beneficially be increased in the diet. However, rapeseed growing is currently far too limited to meet requirements, as Svensk Mjölk has estimated that for dairy cows alone, an area of 130 000 ha would be needed to meet the animals' requirements of rapeseed meal (Emanuelson et al., 2006). This is not counting all the other types of animals that would need to consume more rapeseed meal. Increased use of rapeseed meal could decrease imports of soyabean meal, a protein raw material with a relatively high climate load. The rapeseed meal product ExPro, which has a high availability of amino acids for dairy cows, is particularly important in replacing soyabean meal in the diet. For the same milk yield, it is estimated that 1 kg ExPro can replace 0.89 kg soyabean meal (Cederberg & Flysjö, 2008), i.e. the replaceability is high.

From an environmental and climate perspective, it is therefore desirable to increase rapeseed growing, partly in order to replace imported European rapeseed meal but particularly to generally increase Swedish protein animal feed production in order to decrease the requirement for imported soyabean. It is therefore desirable that Sigill farms that do not produce animal feed, but that specialise in cereal production, grow more oilseeds. This would improve the crop rotation on cereal farms, which could decrease the nitrogen requirement per ton cereal, reduce soil tillage and decrease the dependence on chemicals in the long term, while also increasing the supply of domestic protein on an overall level.

Proposal: A requirement for varying crops on cereal-dominated farms in the climate certification system, through cereal being restricted to a maximum of 60% of the crop rotation.

Proposal: The mineral nitrogen fertiliser used in oilseed production must be manufactured according to BAT (from a certain year).

4.2.5 SOYABEAN MEAL

Soyabean meal is the main protein feed internationally and due to increasing global animal production the growing of soyabean crops is increasing strongly in South America. This strong expansion has a number of environmental consequences. A few years ago, the focus was on loss of biological diversity when natural ecosystems were converted to arable land for soyabean growing. In recent years, the focus has increasingly turned to the emissions of carbon dioxide that are the result of ongoing changes in land use, i.e. the carbon bound in above- and below-ground biomass being released during deforestation and cultivation.

The organisation 'Round Table on Responsible Soy Association' (RTRS) is a network that covers the entire soyabean chain from cultivation to trade in Europe, with the aim of drawing up sustainability criteria and labelling of soyabean products. Svensk Mjölk and Lantmännen are members of this organisation. At present, RTRS is working on a proposal for principles and criteria for sustainable soyabean and this is planned to be released during 2009. An important part of this development work is that different actors in the chain (growers, the oil industry, NGOs) are working together for consensus. The draft criteria for sustainable soyabean cultivation contain no requirements on cropping methods to minimise soil erosion and land degradation, protection of natural areas of high biological value or the prioritisation of already cleared and degraded land areas for expansion of soyabean growing. When such criteria are agreed (which will be late 2009 at the earliest) systems for certification and traceability must be established. According to the Lantmännen representative in RTRS, it is realistic for RTRS-certified soyabean to be available on the market by 2012 at the earliest. There appears to be consensus for criteria on sustainable soyabean growing, but there is more uncertainty about how the certification process is to be built up in a trustworthy way (M. Murphy, pers. comm. 2008).

However, there is already sustainability-certified soyabean meal available on the market, e.g. regulated by Campina in the Netherlands and companies in Switzerland. The WWF and COOP in Switzerland have developed the so-called ‘Basel criteria’ for sustainable soyabean production. These regulations have not allowed conversion of natural vegetation to land for soyabean growing since 2004 and also demand that compensation be made for soyabean grown on land deforested in the period 1995-2004.

However, environmental certification of food and feed as a tool to decrease the negative effects of e.g. soyabean production is debatable. There is a great risk of the negative environmental impact being moved somewhere else in the overall production system. If e.g. the European market began to only buy sustainability-certified soyabean, this market could ‘cherry-pick’ and take the soyabean from areas without deforestation, while other export markets with no environmental requirements would buy their soyabean products from anywhere. If the overall demand and the market continued to expand, which would lead to increased cultivation and production, it is by no means certain that the total environmental impact would decrease, despite the environmental certification system. A fundamental problem in this entire complex issue is probably how the world’s remaining ecosystems would deal with the continually increasing demand for more agricultural products that is an effect of increasing population and a higher standard of living.

However, the overall consideration is that if there are customers demanding different production methods than those applied today in soyabean growing, then it is important for this signal to reach the soyabean producers so that at least some can change their ways. A climate certification system should therefore introduce requirements on sustainability certification of soyabean meal. At the same time, it should question the long-term demand for imported soyabean protein, which, directly or indirectly, has severe effects on the environment.

Proposal: The soyabean meal used in animal feed production must be environmentally certified according to some internationally accepted system (Basel criteria or RTRS). Since the system is under development and it will take a certain time to produce certified volumes, the requirement should be introduced over a certain transition period, a proposed 2 years.

4.2.6 PEAS/FIELD BEANS

From a climate perspective pulses are a good protein feed, extended use of which would be beneficial. Svensk Mjölk has estimated that it is possible to increase the use of pulses to dairy cows by up to 140 000 ton dry matter of peas/field beans (Emanuelson et al., 2006). This would require an acreage of 60-65 000 ha (based on net yield of 2.5-2.75 t/ha) for dairy cows alone. To this must be added the pigs and poultry that could well be supplied with considerably more protein peas/field beans to meet their protein requirement than is the case today and thus the imported soyabean requirement could be reduced. Unfortunately there are no data available on the amount of pulses that monogastric animals are able to consume, but the current acreage of around 30 000 ha should be greatly expanded. In addition, there is the problem of low yields in these crops, with scarcely no increase having occurred in the past 25 years.

On an overarching level, stimuli are needed to increase production of pulses in Sweden, partly through increasing the acreage and partly through improving know-how (plant breeding, cropping methods, etc.) in order to increase yields. The changes involving rapid increases in fertiliser that began in 2008 would favour increased growing of peas/field beans since these are low-input crops. It is impossible to predict how the market will change, but if fertiliser prices remain high, this will promote increased growing of pulses. On the whole, this is difficult to incorporate into a criterion for climate certification of animal feed, but it is generally desirable for cultivation of peas/legumes to increase and arable farms are important in this regard. The arguments are the same as for increased oilseed crop production, see 4.2.4. It is desirable for arable farms that do not produce animal feed to grow more peas/field beans. This would improve the crop rotation on cereal farms, which could decrease the nitrogen requirement per ton cereal, reduce soil tillage and decrease the long-term dependence on chemicals, while increasing the supply of domestic protein at an overall level.

Proposal: A requirement for varying crops on cereal-dominated farms in the climate certification system, through cereal being restricted to a maximum of 60% of the crop rotation.

4.2.7 BY-PRODUCTS FROM THE SUGAR INDUSTRY

Drying of beet pulp is the step in the life cycle of molassed beet/beet pulp that dominates its emissions of greenhouse gases. Energy efficiency and fuel replacement are the most important measures needed to decrease the GWP value of these dried beet products. Beet pulp/molassed beet are important products in dairy cow concentrate and contribute to good milk yields. At the present time, we consider that other measures as regards feed products (e.g. improving N use efficiency, more rapeseed products in the diet, certified soyabean) are in more urgent need of introduction in the short term, since they influence the total environmental impact in a positive direction. However, in the long term it is important for the total energy use and CO_2 emissions from the drying of beet pulp to be decreased. The climate certification project should hold ongoing discussions with the feed industry on how this can be achieved and send a signal that it is desirable to have changes in the longer term. In the short term, a measure that can be recommended is increased use of the ensiled molassed beet product HP-Massa relative to dried beet pulp.

Proposal: No requirement for changes in beet pulp/molassed beet to be made at the present time.

4.2.8 PALM KERNEL EXPELLER

The Round Table on Sustainable Palm Oil (RSPO) is working on the development of sustainable palm oil and certification of all stages (see RTRS for soyabean products). For palm oil more progress has been made as criteria were established in 2007 and sustainability-certified palm oil is available on the world market. As for soyabean, these criteria include requirements on fertilisation, cropping methods to avoid land degradation and soil erosion and requirements on where expansion and the establishment of new plantations should take place.

From an economic perspective, PKE comprises a very small proportion of total income in the palm oil chain. This is an important difference from soyabean meal, where the protein feed sector, calculated both as volume and in economic terms, is considerably more important than the soyabean oil. Thus if the aim is to guide developments along a favourable path by demanding environmentally-certified products, it is more important to prioritise the work with soyabean meal ahead of certification of PKE. This is because it is the demand for palm oil that completely controls the development of the entire production chain from oil palm plantation to vegetable oil in the shops, not PKE, which is a small economic proportion of the whole.

However, since the expansion of palm oil production is associated with numerous environmental problems in south-east Asia, it is important to influence developments as much as possible. Therefore, PKE from sustainability-certified palm oil should be prioritised in concentrate feed mixtures that are approved in a climate certification system.

Proposal: The PKE that is used in animal feed production must be environmentally-certified according to RSPO within two years.

4.2.9 OTHER RAW MATERIALS

No criteria are proposed for other raw materials at the present time since they are used in moderate or even small volumes. Synthetic amino acids have a relatively high GWP value per kg product compared with other feedstuffs but are used in very small amounts, e.g. in feed for laying hens only 0.2% of the total feed product is synthetic amino acids (Sonesson et al., 2008).

Proposal: No requirements for changes in other raw materials to be made at the present time.

5 SUGGESTED CRITERIA, ORGANIC FODER

Comparisons of the GWP values of organic and conventional feedstuffs show that the organic feedstuffs currently often have a lower load per kg feedstuffs. However, there are two points to consider if the reverse is not to become a reality and these are: *i)* the levels of yield in organic feed growing and *ii)* the frequency of green manure crops.

Levels of yield

Depending on the feed crop grown, the yields in organic feed production are around 10-50% lower than conventional yields. The least difference occurs with leys, with yields 10-30% lower in organic ley according to statistics (SCB, 2004). The use of symbiotic nitrogen fixation in ley cropping and the almost non-existent need for chemical pesticides means that organic forage production is a very ‘safe’ form of organic cropping. On average, organic forage production at present can generally be said to give feedstuffs with low GWP values.

For organic cereals, yields are reported to be around 30-50% lower than conventional (SCB, 2004). Yields can be halved (or more) in particular circumstances, e.g. in oats due to very severe attack by oat aphid or fritfly. Since chemical treatment is not permitted in organic production, yields can be greatly reduced by severe insect attacks. The CO_2 emissions from diesel and N_2O emissions from fertilisation (e.g. with manure or Biofer) must then be distributed over a considerably smaller yield than would have been the case in a more normal year from a pathogen perspective. A large yield reduction (up to 50%) can therefore lead to significant GWP values per kg cereal.

Organic oilseed crops can also suffer great reductions in yield due to severe attacks by pollen beetle, which occur in individual years. However, winter rapeseed is much less susceptible than spring rapeseed and growing of this rapeseed crop is therefore prioritised in organic production instead of spring rapeseed. Yields are 20-30% lower in organic winter rapeseed compared with conventional (SCB, 2004). At winter rapeseed yields of this level relative to conventional growing, the GWP values in current eco-rapeseed are reasonable, making organic winter rapeseed an important crop in producing protein for organic animal feed production (and organic vegetable oil for the feed industry).

Organic peas and field beans are estimated to have 20-30% lower yields than conventional (SCB, 2004), but if weeds can be handled efficiently in practical growing the differences can be even smaller. In general, yields of pulses (conventional and organic) need to increase to improve profitability and production volumes, but as mentioned previously in this report little has occurred with yield levels in recent decades. Since conventional peas/field beans do not require any mineral fertiliser nitrogen, the differences in GWP value are very small for organic and conventional pulses. Overall, the GWP load is low for legumes that are harvested at maturity (see Figure 2.3), making pulses an important crop in producing protein for organic animal feed production.

How can the importance of ‘good levels of yield’ be incorporated into the criteria for climate certification of organic animal feed production? I have no good answer to this today but the issue is important and should be thoroughly discussed within organic farming. Careful planning of crop rotation, fertilisation, weed control, choice of cultivar. etc. is the foundation for keeping yields at a good level and trying to avoid severe reductions in yield (up to half). I believe that to produce organic feed with reasonable GWP values, it is necessary to maintain reliable, stable levels of yield and avoid extreme yield dips, with yield reductions of over 40% compared with conventional production. The basis for achieving this is the skill of the individual organic grower and this characteristic is very difficult to incorporate into a criterion for climate certification.

Frequency of green manure crops

Green manure crops, e.g. clover and grass grown in mixed leys and then ploughed down into the soil system, are used as nitrogen fertilisers but also as weed controls in the crop rotation. Large amounts of nitrogen can be supplied to the soil, 300 kg N/ha is not impossible, and this nitrogen is difficult to control. In addition, the microorganisms in the soil gain access to large amounts of carbon when the green manure crop is broken down. There is a great risk of significant N_2O emissions from the soil under these conditions, particularly if the soil temperature is high and the soil moisture content is optimal for nitrous oxide formation. In addition, the sample calculations in Tables 3.2 and 3.3 show that with the supply of a large amount of organically bound nitrogen to organic cereal, there is a risk of considerably higher GWP values per kg feed grain. Of a total KRAV-approved area of 140 000 ha in 2000, there were just under 9 000 ha set-aside/green manure (around 6% of the area). It can be pointed out that only a small fraction of the KRAV-approved area acts as a green manure crop and that it is therefore of little significance, but the green manure crop/set-aside area must be carefully considered in relation to the cereal and oilseed area, since it is for these crops that green manure is used, particularly on organic farms without ruminants.

An interesting long-term strategy would be to use green manure ley as a substrate in a biogas process and recover the plant nutrients as biodigestion residues. The nitrogen could then be applied in the form of soluble ammonium (directly plant-available) and the fertiliser could be applied in the growing crop, at the exact time when the crop needs nitrogen. This would most probably increase the nitrogen use efficiency considerably compared with the current situation where nitrogen is applied in organic form in plant biomass and it is very difficult to predict when it will be mineralised and be of benefit to the crop. With the current limited construction of biogas plants, we consider it to be too early to make a criterion for this scenario. However, in the longer term it would be an interesting development and calculations should be made for the entire crop production and energy system in order to evaluate biogas production from ley and the use of biodigestion residues in crop production.

To summarise, there are two factors that are very important in keeping emissions of greenhouse gases in organic animal feed production at a low or acceptable level:

1) Yield levels must not decline excessively (more than ~40-50%) compared with conventional crop production.
2) The supply of nitrogen via green manure crops must not be excessive.

At the present time we are unable to formulate any criteria for these two factors and refer the question further to various interests within organic farming.

5.1 IN GENERAL FOR OVERALL ANIMAL FEED PRODUCTION ON THE FARM

5.1.1 NITROGEN

Proposal: A requirement should be introduced that a nitrogen balance be drawn up annually to measure nitrogen use efficiency in crop production on the farm. A suggested indicator is '*input of new*[8] *nitrogen (N) per ton harvested product*'. This indicator must be monitored and a plan for improvement work drawn up for every individual farm in the climate-certification system in order to increase N use efficiency in a 10-year perspective. Sigill should produce decision support data to guide the development of this indicator and show reasonable benchmarking values. There should also be an investigation of how far the indicator value can reasonably be broken down – to field level, crop level or, in its simplest form, to all crop production on the farm. For organic farms it is important to consider N fixation by the entire crop rotation relative to output of products from the crop rotation.

5.1.2 ENERGY

Diesel consumption in field machinery is the most important input to consider. On dairy farms, a considerable proportion of the diesel is used outside crop production, in different types of work specifically relating to animal production. In addition, very few farmers have such accurate knowledge of their diesel use that they can distinguish between the diesel used in crop production and in animal-related tasks. At the present time no requirement on diesel consumption specifically in crop production is recommended, since it would be extremely difficult to measure and monitor. Instead, diesel use should be controlled in an overarching requirement on energy use on the entire farm.

Proposal: No specific requirement to be introduced for diesel use in animal feed production, but this to be included instead under an overarching requirement on energy use on the entire

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[8] New nitrogen in organic production refers to nitrogen fixed by symbiotic N fixation, i.e. N fixation in legumes, pulses and green manure crops of legumes.

farm, see also data support for the entire dairy farm, see also data support for the entire dairy farm.

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6.1 PERSONAL COMMUNICATIONS

Frank Brendrup, Yara, Hanninghov, October 2007
Michael Murphy, Lantmännen, Stockholm, October 2008